SOHN International SYMPOSIUM

on Advanced Processing of Metals and Materials: Principles, Technologies and Industrial Practice

Incorporating the 4th International Symposium on Sulfide Smelting

August 27-31, 2006
Catamaran Resort
San Diego, California, USA

ADVANCE PROGRAM

Sponsor: TMS
Co-Sponsor: SME

www.tms.org/Sohn2006.html
An Invitation From the Sohn International Symposium Organizers

Join us for this critical symposium on three equally important topics -

Principles • Technologies • Industrial Practice

Benefit from discussions on recent developments in:
- Advanced processing of metals and materials, and industrial application principles
- New and improved technologies related to extraction and processing
- Industrial practice in metals and materials processing

More than 50 sessions presented by authors from 55 countries, covering:
1. Nonferrous High Temperature Extraction and Processing
2. Iron and Steelmaking
3. Aqueous, Electrochemical Processing and Molten Salts
4. Nano, Composite, Refractory and Polymer Materials
5. Recycling, Recovery and Waste Treatment
6. Sulfide Smelting
7. Legal, Management and Environmental Issues

We look forward to your attendance. (See page 95 to register.)

On behalf of the organizing committees,

Chair:
Dr. Florian Kongoli
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Korea Institute of Geosciences and Mineral Resources, Korea

Professor Seshadri Seetharaman
Royal Institute of Technology, Sweden
## About the Symposium

This symposium honors the very distinguished work and lifetime achievements of Professor H.Y. Sohn. He is renowned for his impact in fields such as nonferrous, ferrous and nano-scale materials processing; in many processing routes including pyrometallurgy, hydrometallurgy, chemical vapor synthesis and processing, and recycling; and in several investigating techniques such as experimental measurements, physical modeling and simulation (CFD).

### About Professor Sohn

#### His Research

Professor Sohn has acquired an international reputation for computer modeling and analysis in various metal extraction fields such as flash smelting/flash converting processes as well as the minor element behavior in nonferrous smelting. He has also worked on the analysis of a channel reactor for the continuous production of copper by the countercurrent contacting of slag and matte/metal phases with bottom gas injection through gas-shrouded Savard/Lee injectors. Dr. Sohn has developed a novel solvent extraction process called SOHNEX, which is based on bottom gas injection without mechanical agitation. His latest research involves the chemical vapor synthesis of nano-sized metallic and other inorganic materials, including advanced intermetallic compounds, WC-Co composite powders and metal-hydride hydrogen storage materials.

#### His Career

Dr. Sohn holds the titles of Professor of Metallurgical Engineering and Adjunct Professor of Chemical and Fuels Engineering at the University of Utah, where he has worked for more than 30 years. Professor Sohn has co-authored two monographs, co-edited 16 books and written 315 papers. He has served on the TMS Board of Directors, organized many international symposia, and delivered numerous plenary and keynote lectures. Dr. Sohn has also received several awards, including the James Douglas Gold Medal Award in 2001 for leadership and outstanding contributions in research and education of nonferrous extractive metallurgy, and for work related to the modeling of gas-solid reactors and the development of novel solvent extraction systems.

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- Copper, Nickel, Cobalt Committee
- Materials Characterization Committee
- Process Fundamentals Committee
- Process Modeling, Analysis and Control Committee
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- CSIRO, Australia
- Czech Society for New Materials and Technologies
- Danish Ceramic Society
- Danish Chemical Society
- Danish Metallurgical Society
- Electrochemical Society
- Electrochemical Society of Japan
- Engineering Conferences International
- Eurometaux
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- Federation of European Materials Societies (includes 21 societies)
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- Hellenic Ceramic Society
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- Institute for Nonferrous and Rare Metals
- Institute of Materials Engineering Australasia
- Institute of Materials, Minerals and Mining
- Institute of Metals and Technology
- Institute of Non-Ferrous Metals
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- Swedish Society for Materials Technology
- Swedish Steel Producers Association
- Technologisch Instituut VZW
- The American Ceramic Society
- The Chemical Society of Thailand
- The Finnish Association of Mining and Metallurgical Engineers

Independent Journals and Publishers
- Canadian Mining Journal
- Ferrous Metals Journal
- Industrial Minerals
- Journal of Technical Electronic Materials
- Magnesium Monthly Review
- Materials Engineering News
- Mineral and Metallurgical Processing
- Mineral Processing Journal
- Mining Journal
-Nonferrous Metals Journal
- Ore and Metals Publishing House
- The European Journal of Mineral Processing and Environmental Protection

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- Dr. Florian Kongoli, Chair
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- Professor Ramana G. Reddy, Co-Chair
- University of Alabama
- Telephone (205) 348-4246 / Fax (205) 348-2164
- E-mail reddy@coe.eng.ua.edu
This symposium is organized by an international committee spanning six continents and representing major industrial ferrous and nonferrous companies as well as universities from around the world.

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Mario Sanchez, University of Concepcion, Chile
Michael Sankovitch, La Oroya, Peru
Varadarajan Seshadri, Univ. Federal de Minas Gerais, Brazil
Publication
Symposium papers will be published in separate proceedings, which will be available at the meeting and include an article honoring the lifetime achievements of Professor Sohn. Each member, author, and nonmember attendee will receive a free CD-ROM as part of the registration fee. Additional CDs may be purchased for $130 each plus shipping and handling. A multiple-volume hardcover proceedings book is also available for $250 plus shipping and handling. Purchase additional copies of the proceedings on the registration form.

Final Program
A complete program with abstracts of papers to be presented at the meeting will be available for all registered attendees at the registration desk.

Social Activities
Welcoming Reception
Sunday, August 27 • 6 to 8 p.m.
Beach North Area of the Catamaran Resort

Session Breaks
Morning/Afternoon
Outside the Technical Session Rooms

Symposium Banquet
Monday, August 28 • 6:30 to 9:30 p.m.
Bahia Hotel

Member, author and nonmember attendees may attend for free. Guests and students may purchase tickets at a cost of $65 each. Tickets may be ordered on the registration form; advance purchase is encouraged.

Closing Reception
Wednesday, August 30 • 6 to 8 p.m.
Catamaran Resort

Americans With Disabilities Act
TMS strongly supports the federal Americans with Disabilities Act (ADA) which prohibits discrimination against, and promotes public accessibility for, those with disabilities. In support of, and in compliance with, ADA, we ask those requiring specific equipment or services to indicate their needs on the enclosed housing form or contact TMS Meeting Services in advance.

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Manager, TMS Meeting Services
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Nonmembers who join TMS before registering for the Sohn International Symposium are eligible for a conference rate of only $495.

As your professional partner for career advancement, TMS offers you these benefits:

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For more information, visit www.tms.org or call (800) 759-4TMS.
### Registration

Register in advance for a reduced fee and avoid delays on-site!

#### Advance Registration Fee
- Member or Author: $495
- Nonmember: $595
- Student: $150

Registration fees increase on-site.

#### What Your Registration Fee Includes
- **Member, Author and Nonmember**
  - Technical Sessions
  - Exhibit
  - Welcoming and Closing Receptions
  - Coffee Breaks
  - Symposium Banquet
  - Proceedings on CD-ROM
- **Student**
  - Technical Sessions
  - Exhibit
  - Welcoming and Closing Receptions
  - Coffee Breaks

#### How to Register
Register online at [www.tms.org/Sohn2006.html](http://www.tms.org/Sohn2006.html) or complete the enclosed registration form and mail with full payment in U.S. dollars.

#### Advance Registration Deadline
August 7, 2006

#### On-Site Registration/Advance Registrant Badge Pick-Up
- **Kon Tiki Ballroom Foyer**
  - Sunday, August 27: 3 to 6 p.m.
  - Monday, August 28: 7:30 a.m. to 5 p.m.
  - Tuesday, August 29: 7:30 a.m. to 5 p.m.
  - Wednesday, August 30: 7:30 a.m. to 5 p.m.
  - Thursday, August 31: 7:30 to 10 a.m.

#### Meal Plan
Attendees may purchase a meal plan which consists of a lunch buffet for three days of the symposium at a cost of $40. The buffets will be served on the Catamaran Resort lawn near the beach.

#### Refund Policy
A written request for a refund of the registration fee must be sent to TMS, 184 Thorn Hill Road, Warrendale, PA 15086-7514, USA, postmarked no later than August 7, 2006. A $75 processing fee is charged on all cancellations. No refunds are issued after the deadline date.

#### Questions?
Contact TMS Meeting Services:
- Telephone (800) 759-4TMS or (724) 776-9000, ext. 243;
- E-mail mtgserv@tms.org.

### Accommodations

Make your reservation early to secure your room!

#### Reservation Deadline: July 26, 2006

Sohn International Symposium is being held at the Catamaran Resort in San Diego, California. Due to an overwhelming response in abstract submissions and anticipated attendance, rooms are also available for Sohn Symposium attendees at the Bahia Resort Hotel and the Hyatt Regency Islandia Hotel.

#### Catamaran Resort Hotel
The Catamaran Resort and its surrounding area was originally the summer estate of the Scripps family. This family made their fortune in the late 1800s from the newspaper industry and funded the Scripps Institution of Oceanography, now part of the University of California at Berkeley.

The resort now exhibits typical colonial Hawaiian architecture and imported traditional Pacific Island art. The Catamaran’s rooms and suites have their own balconies or patios, and Mission Bay, the world’s largest aquatic park, is only 100 yards away. The Catamaran has views from the shores of La Jolla to Old Mexico. Sea World, the world-famous San Diego Zoo and the San Diego International Airport are merely minutes away.

Visit [www.catamaranresort.com](http://www.catamaranresort.com) for more information.

#### Bahia Resort Hotel
The sister resort to the Catamaran, the Bahia is located on its own private 14-acre peninsula. Due to its scenic location in the heart of San Diego’s famous Mission Bay, views of the Pacific Ocean can be enjoyed. Patrons will discover tropical gardens, winding walkways, ocean breezes and sandy beaches.

Transportation will be provided via water taxi to and from the Catamaran Resort.

Visit [www.bahiahotel.com](http://www.bahiahotel.com) for more information.

#### For Hotel Parking at the Catamaran or Bahia
Rate: $11 per day, self-parking; $14 per day, valet parking

#### For Reservations at the Catamaran or Bahia
1. Telephone (800) 422-8386
3. Complete the enclosed housing form.

#### Hyatt Regency Islandia Hotel
The Hyatt Regency is in the heart of Mission Bay Park, with seascape views of the marina and Pacific Ocean. It is located six miles from the San Diego International Airport and eight miles from the central business district. Transportation will be provided to and from the Catamaran Resort.

#### For Reservations at the Hyatt
1. Telephone (619) 224-1234
2. Visit [www.hyattregencyislandia.com](http://www.hyattregencyislandia.com)
Visas
Meeting attendees from countries that require a visa to enter the United States are reminded that the process of obtaining a visa may take several months. Attendees should begin the application process early. Visit the U.S. State Department Web site at www.state.gov for visa information.

Transportation
At the airport, cross the airwalks to the shuttle islands for shuttles, taxis, car rentals and hotel shuttles.

Airport Shuttle
Cloud 9 Shuttle
Rate: $12 per person one way
Telephone: (800) 974-8885

Express Shuttle
Rate: $11 per person one way

Taxi
Rate: approximately $25 one way (to/from airport to Catamaran Resort)

Hertz Rent-A-Car
Official Car Rental Company of the Sohn International Symposium
Advance reservations may be made by booking online at www.hertz.com or calling the Hertz reservations line at (800) 654-2240 in the U.S. or (800) 263-0600 in Canada. International customers should contact the nearest Hertz reservation center. Advance reservations are recommended. Travelers must identify themselves as attendees of the Sohn International Symposium and reference CV#02QJ0020 in order to receive the special rates.

Rates are available from Hertz locations in southern California.

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• Weekly rentals are from five-to-seven days. Weekend rentals have a minimum two-day keep, and Thursday pick-up requires a minimum three-day keep.

Tours
To sign up for a tour, complete the Optional Events Reservation Form in this brochure. Tours depart from the Catamaran Resort lobby.

Lifestyle La Jolla
Monday, August 28 • 9 a.m. to 12:30 p.m.
$34 per person
La Jolla is a scenic village located on seven miles of sandy beaches, cliffs and caves. It is a combination of a Mediterranean resort atmosphere and southern California. La Jolla’s Prospect Street is known locally for its upscale boutiques, brimming with designer clothing, jewelry, art and antiques. Cafes and elegant restaurants complement the sunsets over the Pacific Ocean. This seaside town is home to the UCSD-Scripps Institution of Oceanography, Stephen Birch Aquarium & Museum, Torrey Pines State Park, Torrey Pines Golf Course, the San Diego Museum of Contemporary Art and the Tony-Award-winning La Jolla Playhouse.

Coronado Charm
Tuesday, August 29 • 9 a.m. to 1 p.m.
$47 per person
Rich in history and an ocean village atmosphere, Coronado is known as the Crown City. Bordered by the Pacific Ocean, Glorietta Bay and San Diego Bay, this seaside city is linked to the southern California coastline and the city of San Diego by the stately San Diego - Coronado Bridge, and to the south by a narrow strip of land known as the Silver Strand. Guests enjoy Coronado’s architecture and history during a narrated walking tour. The tour begins at the Hotel del Coronado’s clock tower. More than 100 years old, “The Del” sits on a beach along the Pacific Ocean. Guests then visit the home of Wallis Simpson, Duchess of Windsor; the home of Frank Baum, author of the “Wizard of Oz”; and the mansion of sugar magnate John Spreckels. Quaint shops, cafes and galleries are within easy walking distance along Orange Avenue as well as the Coronado Ferry Landing’s boutique stores.

Midway Aircraft Carrier
Wednesday, August 30 • 9 a.m. to 1 p.m.
$47 per person
This United States Naval Aircraft Carrier has been converted into a multi-dimensional, interactive, educational and entertainment destination and is one of the only museums of its kind on the west coast. The Midway’s final tour of duty, after 47 years, is on the south side of Navy Pier in San Diego. She serves as the cornerstone of the revitalized North Embarcadero, the gateway to downtown. The Midway accompanies the Star of India and other historic and visitor attractions along the waterfront. And, perhaps most importantly, she serves as a poignant and compelling tribute to the hundreds of thousands of men and women who have embarked from Navy Pier in service to their country. Guests may come aboard and learn about one of the true icons of the U.S. Navy in the latter half of the 20th century at the Midway Museum!
Corporate Business Opportunities

Reap the benefits of this international audience through exhibition and sponsorship.

Join the exhibition with an audience primed for technologies related to the advanced processing of metals and materials!

- Industrial Practices
- Mineral Processing
- Product Quality and Cleanliness
- Recycling, Waste Treatment, Soil Remediation and Biotechnology
- Solvent Extraction
- Sulfide Smelting
- Waste Processing and Water Treatment

Exhibit Hours
Monday, August 28 ..........9:15 a.m. to 4 p.m.
Tuesday, August 29 ..........8 a.m. to 4 p.m.
Wednesday, August 30 ........8 a.m. to 1 p.m.

Get more details today!
Contact Cindy Wilson, TMS exhibits coordinator:
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Benefits:
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Benefits: Receives gold sponsor benefits
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Benefits: Receives gold sponsor benefits
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Benefits: Receives silver sponsor benefits
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Benefit: Recognition in symposium program

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Please note: all funds are in U.S. dollars.
*Undesignated sponsorships are utilized to offset the cost of proceedings and other symposium expenses.
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*Note: The table above is a sample and may not represent the full schedule.*
2:00 PM Keynote
Sichuan Aostar Smelter in China: Youlai Wang; Yinjian Niu; Dingfeng Qiu; Caifeng Chen; Yong Li; 'Sichuan Aostar Aluminum Company, Ltd.; 'Nonferrous Metals Society of China; 'Beijing General Research Institute of Mining and Metallurgy; 'Guangyang Aluminum Magnesium Design and Research Institute
Sichuan is the richest province for its waterpower source in China. Its technical developable capacity is 120,000MW that accounts for about 27% technical developable capacity in China. It is estimated that the electricity generation installing equipment scale of Sichuan will reach to 35,000MW upon 2010, among this amount, waterpower is 21,000MW; thermal power is 14,000MW kilowatts. Thus it can be seen, Sichuan suits extremely to develop high consume energy industry. Sichuan Aostar Group company has two Aluminum smelters, Guangyang Aostar smelter and Sichuan Aostar smelter. The production of Aostar Group is 240,000 tons in 2004. The construction scale of Sichuan Aostar Aluminum smelter is 250,000 tons per year. The first 168 GY-300KA pre-baked anode cells (130,000 tons/year) were put into production in 2003. This company is the first to use transfer gantry technology in China and realizes the process of emendation the cell cover as well as concentrating to construct the lining of the cell at a distance. This company is also the first to use the EIRICH force mixing and cooling technology in China and first to use the CP Company’s vertical ball mill technology to produce the pre-baked anode in the world. The carbon anode system was completed its 190,000 tons/year productions scales only using one time, which is the technology most advanced and the scale biggest pre-baking anode manufacture in present China. Since Sichuan Aostar 300KA cell has put into production, it runs normally and smoothly, at present the current efficiency is bigger than 94% and the direct current consumes is only 13300KWh/T-Al.

2:25 PM
Cost-Effective Magnesium Oxide Recycling for Economic Viability of Magnesium Hydride Slurry Technology for Hydrogen Storage: Rachel De Luca; Uday Bhanu Pal; Guoshen Ye; Andrew McClaine; 'Boston University; 'Safe Hydrogen
Current methods of hydrogen storage are an impediment to the transition of our energy infrastructure from a hydrocarbon to a hydrogen base. The transportation, handling, and storage costs of hydrogen gas account for a majority of its selling price. Magnesium hydride slurry is a safe, environmentally friendly alternative for hydrogen storage. If this form of storage is to be adopted on a large scale, a cost-effective method for recycling the enormous amounts of magnesium hydride byproduct must be identified. The solid oxide membrane (SOM) process can be used to recycle the magnesium hydride byproduct into magnesium metal, which can be reformed into magnesium hydride and reused for fuel storage. Conventional magnesium extraction/recycling technologies require a great deal of energy and create byproducts that are harmful to the environment and human health. The SOM process poses none of these detrimental effects and requires less energy and feed preparation. The economic viability of a facility that utilizes the solid oxide membrane process for the direct reduction of magnesium must be examined in more detail if industry is to consider it. Cost analysis data related to the commercial viability of a scale-up will be compared to two standard industrial processes: current magnesium production techniques including electrolytic and metallo-thermic processes. We have shown in our cost comparison that the SOM process is cheaper than these traditional techniques and that it is also comparable to aluminum’s Hall-Héroult process in cost but with none of the environmentally harmful byproducts.

2:50 PM Keynote
An Attempt at Direct Ingot Making of Titanium by the Electro-Winning from Molten Salt with DC-ESR Unit: Masahiro Kawakami; Masayuki Orihaka; Takahiro Kawabata; Toshihde Takenaka; Seiji Yokoyama; 'Toyohashi University of Technology
In order to make titanium ingot directly from molten salt, the metal pool was tried to form and used as the cathode. The electro-slag remelting (ESR) unit was used for the purpose. The unit is composed of water cooled copper mold and the DC power source of 2000A and 100V. The graphite electrode was used for anode and the base plate was used for cathode. The re-melted slag of CaO-CaF2 was melted in the mold with the addition of TiO2. The following reactions are expected to occur: Ti4+ + 4e = Ti at cathode 2O2- + 4e = 2O + 2H2O. During the process, large amount of molten salt splashed out from the mold, showing the CO evolution at anode. The metal deposit was obtained but in the form of block and piled up on the base plate. The metal pool was not obtained perfectly because of shortage of heat supply. The cathodic current efficiency was 60% at maximum. The metal deposit contained much impurity. In order to reduce the impurity and increase the current efficiency, the twin-cell structure was tried successfully. The results will be given in the symposium.

3:15 PM
Review on the Part of HVOF Thermal Spray Coating in Protection to Corrosion: Hazoor Singh Siddhu; Buta Singh Siddhu; Satya Prakash; ' Yaduindra College of Engineering; 'GZS College of Engineering and Technology; 'Indian Institute of Technology
Materials degradation due to corrosion is the major problem in power generation equipment, gas turbine, fluidized bed combustion, industrial waste incinerators etc. Some super alloys have been developed, but they are unable to have different properties to meet the demand of today’s industry. Therefore, a composite system of a base material providing the necessary mechanical strength with a protective surface layer different in structure and/ or chemical composition can be an optimum choice in combining material properties. Thermal spray coating of the components before they put into
service by suitable surfacing alloy and with suitable coating method can increase the life of these components several fold. Choice of right coating method and alloy for a particular application is extremely important to get the desired service life. In the paper the corrosion of some materials and the role of HVOF thermal spray coatings to counteract the same have been reviewed, with an aim to understand the phenomena and along with various application.

3:40 PM Break

3:55 PM A Dynamic Control Model for a Submerged Arc Furnace for P-Production: Markus Reuter; University of Melbourne
This paper discusses a dynamic process model that links CFD into the control structure of 60MW submerged arc furnaces for P production. The model combines plant measurements, data reconciliation, dynamic modelling and CFD modelling to predict P-production and slag quality from tap-to-tap. All models have been calibrated by plant measurements, dig-outs, thermocouples placed a strategic places within refractory after relining etc.

4:20 PM Keynote
The Role of Scaling, Similarity, and Dimensional Analysis in the Modeling of Metals Processing: Patricio F. Mendez; Colorado School of Mines
The prediction of performance of metallurgical processes, and also the design of new processes involve unique challenges. Metal processing operations are typically governed by many more physical principles, and have a higher degree of coupling than other manufacturing techniques. For example, arc welding of metals involves heat transfer, fluid flow, and electromagnetism for both the molten metal and the plasma arc. These phenomena are tightly intertwined in each region, and also across regions, coupling through a free surface that involves evaporation, capillary, and thermocapillary effects. While scaling, similarity, and dimensional analysis have been known for a long time, they have not been applied to metals processing with the same consistency they have been applied to other areas such as chemical engineering. This talk will address the potential reasons why these powerful techniques are not currently more widespread in the modeling of metals processes, will review current state of the art in their application, and suggest paths to overcome obstacles to their full implementation.

4:45 PM Computational Modeling of a CVD Reactor to Produce Diamond Films: Miguel Olivas-Martinez; Manuel Perez-Tello; Rafael Enrique Cabanillas-Lopez; University of Sonora
A two-dimensional computational model for the hot filament chemical vapor deposition (HFCVD) process to produce diamond films is presented. The model incorporates the transport of momentum, energy, and mass inside the reaction chamber of a HFCVD reactor. The gas-phase transport equations were coupled to the kinetic expressions representing the catalytic dissociation of the molecular hydrogen at the filament surface and the deposition rate of the diamond film on the substrate. The computational model was solved numerically by means of a commercial software. The model predictions showed good agreement with the experimental data reported in the literature in terms of both temperature and methyl concentration profiles along the filament-substrate center distance. Examples of the potential applications of the present formulation for the design and further optimization of the HFCVD reactor are discussed.

5:10 PM Keynote
Computational Fluid Dynamics Simulation of High Temperature Raw Materials Processing: Yongxiang Yang; Bo Zhou; Jim Post; Emile Scheepers; Markus A. Reuter; Delft University of Technology; Corus Research; Melbourne University
High temperature processing of raw materials in metals production and recycling often involves complex multi-phase fluid flow and heterogeneous chemical reactions at various scales. Good understanding the process physics and chemistry is crucial for process operation and process development. The traditional scale-up process through laboratory scale – pilot scale – commercial scale route has been more and more complemented and partially replaced by full-scale process simulation. Computational fluid dynamics (CFD) has become a very useful simulation tool in process research and development. At the same time industrial applications challenge the CFD development with its complex transport phenomena, often in large-scale reactors with small-scale physics and chemistry. The current paper discusses the applications of CFD to a number of high temperature metallurgical and materials processing applications. The research was carried out by using commercial CFD codes as the framework, and the emphasis was given to the special efforts for the development and implementations of sub-models of process-dependent physical and chemical characteristics. To illustrate the application of CFD simulation to high temperature raw materials processing and coupling of sub-models to general CFD code, five examples are given: (1) melting of aluminum scrap in a rotary furnace for recycling, (2) molten iron flow in a heterogeneous coke-bed of a blast furnace hearth, (3) gas flow and heat/mass transfer in a submerge electric arc furnace for phosphorus production, (4) high temperature incineration of hazardous waste in rotary kiln, and (5) transient heating of metals in heat treatment furnaces.

5:35 PM Invited Model-Based Electroslag Remelting Control for Simultaneous, Consistent and Responsive Melt Rate and Immersion Depth Control: David K. Melgaard; Joseph J. Beaman; Gregory Shelmidine; Sandia National Laboratories; University of Texas
Electroslag Remelting (ESR) furnaces are used to produce high quality specialty alloy ingots. Ingot quality can be directly correlated to variances in melt rate and immersion depth. Conventional ESR furnaces control these quantities using two independent control loops using current for melt rate and ram drive for immersion depth. However it is well known that they are highly coupled, i.e. changing the current to account for melt rate deviations changes the voltage depth relationship and vice versa. In addition the noise in measurements of the ESR process can be considerable, forcing conventional controllers to use damped responses. A new model-based controller has been developed to embody the coupling and improve responsiveness by using estimates from a reduced-order linear ESR model and the typical process measurements to control melt rate and immersion depth simultaneously. Kalman filtering is used to optimally combine the model estimates of nine process states and the measurements of voltage, current, position and mass to estimate the instantaneous melt rate and immersion depth. Several ESR melts under steady state and transient conditions were conducted to evaluate the performance of the new controller. This paper will discuss the design of the new ESR model and controller and will present experimental results demonstrating its improved control and responsiveness.

International Symposium on Sulfide Smelting: Sulfur and Gas Handling

2:00 PM Keynote
Elemental Sulphur Fixation in Smelting Gas: Is it Feasible?: Takahiko Okura; Nippon Mining R&T
Sulphur, with its multiple oxidation states, play critical roles in many processes, ranging from regulating enzymes in plants, to acidifying aquatic systems, and to affecting the global climate. Most of non-ferrous smelters have been contributing to reduce atmospheric emissions of sulfur dioxide to acceptable levels, converting it to sulphuric acid and/or gypsum. However, some amount of SO2 gas is still emitted from isolated smelters. Furthermore, sulphuric acid is competing with involuntary elemental sulphur in the market. This situation puts the non-ferrous metallurgical industries to develop a new sulphur fixation process. This paper briefly describes the new technologies for fixation, followed by the novel proposal to convert SO2 gas to elemental sulphur using organic materials. Finally, the feasibility will be presented technologically and economically.
For the treatment of huge amounts of the sulfur which is from the earth by both natural and man-made activities, a harmonized sulfur cycle was presented. The man-made sulfur cycle which includes sulfur circulation from oil, coal and ore was analyzed in detail based on the recent world sulfur trend. Then the man-made cycle was compared with the natural sulfur evolution such as volcano. Finally, the harmony in both natural and man-made sulfur cycles was discussed.

Evaluation of Recent Advances in the Design and Operation of Metallurgical Sulfuric Acid Plants: Leonard J. Friedman; Acid Engineering and Consulting Inc

In the last fifteen to twenty years there have been many changes in equipment design and operation of metallurgical sulfuric acid plants. Some advances are in the state of the art, some marginal, and some better left alone. Some of these alternate designs include: designs to meet low stack SO2 emission requirements (100 PPMV), low ignition catalyst, alloy towers, pump tanks and converters, fiber reinforced plastic quench towers, plastic electrostatic precipitators, heat exchangers inside/outside converters, and acid heat recovery systems. This paper reviews each of the design alternatives and evaluates the advantages and disadvantages of each, as well as their effect on the acid plant operation and reliability. The aim of the paper is provide a greater understanding of the design alternatives available to operating companies for new plants or for modifications to existing plants, and to encourage a more thorough evaluation of proposed designs to reduce metallurgical sulfuric acid plant capital cost, reduce maintenance costs and increase operating reliability.

New Types of Sulfur and Non-Conventional Methods for Its Use: O. G. Yeremin; V. A. Tanayants; Valery M. Paresky; Gintsvetnet; Inter-S, Astrakhan

The Joint Venture “Inter-S” jointly with the Gintsvetnet Institute have developed a technology for manufacture of sulfoconcrete and sulfoasphalt. The sulfoconcrete manufacturing technology comprises preliminary production of modified sulfur, which is blended in liquid form at a temperature of 120°C with an inert material preheated to the same temperature. The process of sulfur modification is based on a chemical reaction of liquid sulfur with organic modifying agents, i.e. organic compounds preventing a decrease in the volume of sulfur in the process of its solidification. The developed sulfur modification process ensures a possibility for production of sulfoconcrete with strength properties exceeding by a factor of 1.5 to 2 the respective values of regular concrete. The second promising area for the use of sulfur is partial substitution of modified sulfur for more expensive bitumen. The sulfoasphalt manufacturing process comprises preliminary production of a sulfur and bitumen mixture with a sulfur content of 30% to 40%, which is then blended with inert materials using conventional techniques. Sulfoasphalt manufactured at a full-scale plant meets all requirements set to its strength properties for road paving.

Production of Elemental Sulfur from Metallurgical Gases by Direct High- and Low-Temperature Catalytic SO2 Reduction: Andrey V. Tarasov; O. G. Yeremin; Gintsvetnet

Technology has been developed for production of elemental sulfur from off-gas from autogenous smelting processes based on reduction of sulfur dioxide with natural gas with subsequent treatment of reduced gas containing hydrogen sulfide by the Klaus method. This technology has been applied on a commercial scale at the copper smelter of the Norilsk Mining and Metallurgical Complex for treatment of off-gas from the Vanyukov smelting process (PV). A specific feature of the proposed technology is preliminary wet treatment of gas, which is then sent to reduction in a pressurized hollow cyclone-type reactor. This technique permits production of high-grade sulfur with 99.85% purity. The design capacity of the sulfur manufacturing plant is 80,000 tpy. In the course of further improvement of the technology a catalytic version of the process has been developed based on the use of a catalyst at the reduction stage, which permits a decrease in the natural gas requirement by 25% to 30%.

Production of Elemental Sulphur From SO2: Mahin Rameshni; S. Santo; WorleyParsons

WorleyParsons innovative SO2 reduction process efficiently recovers sulphur from SO2 streams. Effluent gases from ore roasters and smelters and coal-fired power plants can be treated to reduce sulphur emissions. This exciting new process is an innovative combination of well-established processes of reaction of CH4 and sulphur vapor to produce CS2, followed by catalytic hydrolysis of CS2 to H2S and Claus reaction of H2S and SO2 to sulphur. Key advantages are lower fuel consumption, reduced emissions, better product sulphur quality and better operational stability.

Evaluation of the Effectiveness of a Gas Purging System in a Copper Anode Furnace: Klaus Gamweger; RHI

There are different reasons for purging a metal bath. The operations are varied, for example the purging gas can be used as a reactive gas being part of the metallurgical process or as an inert gas using the rising gas bubbles for agitation only. The different purposes for agitation, chemical and thermal homogenisation or a preferential movement of the slag to the slag skimming door have to be considered. It depends on the furnace type and its dimensions as well as the process characteristics what the focus is on. For an optimised arrangement of numbers and position of all single plugs in the furnace, mathematical modelling - the CFD Computational Fluid Dynamics method - is used. This paper shows how the operation of purging plugs can influence the metallurgical process of an anode furnace by the example of Jinchuan Copper in China. The potentials for savings in energy consumption as well as in time for oxidation and reduction are presented.
Technical Program

5:35 PM
Thermal Reduction of Vaniukov Furnace Sulfurous Oxygen-Bearing Off-Gas by Methane: O. I. Platonov; Gipronickel Institute JS

Method of high-temperature reduction of oxygen-bearng sulfurous gas has been developed at Copper Plant (CP) of MMC Norilsk Nickel’s Polar Division with the aim of producing elemental sulfur from Vaniukov furnace off-gas. Non-explosive reduction technology of oxygen-bearing sulfurous gas by methane utilized at Copper Plant has been designed to separate the processes of heating and sulfur dioxide reduction based on different kinetic of the reactions oxygen fixing and SO₂ reduction. First, natural gas promptly reacts with oxygen contained in the process gas to heat a gas mixture up to the temperature of sulfur dioxide reduction (~1200°C). Then isothermal reduction takes place within ~ 1 sec. Combustion chamber (pre-chamber) design developed based on the above principles is presented. The pre-chamber design is not directly associated with that of reduction reactor, so it may become a component of any reactor. Practical experience of the two reduction reactors operation at CP since 1996 proves high efficiency of the developed reduction process. The volume efficiency rises dramatically thanks to the fact that both fuel and reducing agent are fed into the reactor volume in the form of high-speed turbulent jets providing an intensive mixing of the reacting gases (at Re~10²). On condition of equal internal volume of the reactors, the developed process offers higher efficiency of reagent interaction resulting in sulfur conversion exceeding 90%, as compared to the equilibrium one.

2:00 PM Keynote
Influence of New Technologies on Company Mergers, Acquisitions, and Joint Ventures, Antitrust and Competition Laws and Court Decisions: Migen Dibra; Quebec Court of Appeal

Antitrust and competition laws are designed to protect the free markets and promote competition in order to assure a dynamic and efficient economy and to provide competitive prices for quality products and services. They apply to mergers and acquisitions as well as to joint ventures especially among competitor companies who possess market power and these include collaborations on research and development. If it is determined that these actions are likely to substantially prevent or lessen competition the courts might dissolve, stop, alternate them, etc. Two new factors affect this process today: The role of new technologies and the markets globalization. They both have a considerable effect on the way these laws are interpreted by the courts and on their eventual amendments in order to reflect the new reality. A new applied technology may change the factors that determine how anticompetitive a merger or acquisition between competitors may be and may also serve as a basis for amending the antitrust and competition laws. In this paper, a review of the recent mergers and acquisitions of various companies has been carried out along with an analysis of the current antitrust and competition laws in the view of their capacity to handle the new reality. Some related court decisions in USA, Canada and EU are examined and several examples are given in order to illustrate the influence of new technologies on interpreting the existing laws and on their amendment possibilities. Suggestions are given on criteria of interpretations and amendments.

2:25 PM
Mining the Value from Your Intellectual Property Portfolio - The Strategic Role of Intellectual Property in Your Operations: Jonathan A. Paul; Tech Law Group, P.C.

The most profitable companies in the world recognize that a huge competitive and financial power lies in their intangible assets. The competition to be in command of raw materials and markets is now waged more and more over the exclusive rights to new technology and ideas. The value gained from mining the innovation in your organization and protecting your intellectual property can be enormous. This paper will address the following topics: 1) understanding the connection between your competitive position and intellectual property, 2) determining the value of your current portfolio and strengthening protection, 3) converting knowledge into assets and adding value to the operation, and 4) litigation strategies to enforce your position and achieve your business objectives. The presentation is designed for company executives and government managers who need to know how to identify and address core intellectual property issues that arise in the minerals, metals and materials extraction and processing industries.

2:50 PM
Patent Protection Strategies: Mark W. Sajewycz; Gowling Lafleur Henderson LLP

Creating technology, securing patent rights, and managing a patent portfolio are time-sensitive and dynamic activities. Agreements should be in place with technology partners (employees, contractors, joint venture partners), prior to embarking on research and development projects, so as to mitigate future disputes over patent rights. Technology partners should be educated on patent law basics so as to be mindful of patent law triggering events. Accurate records must be maintained to capture information relevant for preparation and filing of patent applications, including subject matter, names of inventors, and invention date. Developed inventions should be evaluated for whether to file for patent protection, delay patenting until technology is further developed, maintain trade secrecy, or effect deliberate public disclosure. Once decision is made to file for patent protection, time is of the essence, and application for patent protection should be filed as soon as possible, as many countries award patents on a “first-to-file” basis. Decisions on where to file are made having regard to potential competitive advantages versus cost considerations, and can be delayed by taking advantage of priority rights recognized in patent legislation of most countries. Once patents are granted, competitors must be policed for potential patent infringement, and legal action may be necessary to prevent patent infringement.

3:15 PM
The Arbitration Process: Thomas C. Frost; Shustal, Jalil & Heller

In this time of market globalization, many industrial companies are including detailed arbitration clauses in their international contracts, in order to avoid the potential costs, delays, and uncertainties of litigation in foreign courts. Arbitration is less expensive and more flexible, procedurally, than court proceedings, and arbitral awards enjoy much greater international recognition than judgments of national courts. More than 134 countries have signed the 1958 United Nations Convention on the Recognition and Enforcement of Foreign Arbitral Awards, known as the “New York Convention”, which facilitates the enforcement of arbitral awards internationally. There are several other similar arbitration conventions that provide for the enforcement of cross-border arbitral awards. Additionally, arbitral awards are not subject to appeal, whereas judgments of national courts are routinely subjected to a lengthy appeals process, and there are very few viable bases to challenge arbitral awards. This discussion will review key considerations in drafting arbitration clauses, including choice of law and choice of forum considerations; issues surrounding the selection of arbitrators; the discovery process; presentation of evidence; and enforcement of arbitral awards.

3:40 PM Break

3:55 PM
Transborder Legal Issues Concerning Intellectual Property Procurement, Protection and Enforcement: David M. Beckwith; John A. Hankins; McDermott Will & Emery LLP

Increased globalization and outsourcing manufacturing complicate the procurement and enforcement of intellectual property rights on a worldwide basis. Recent legislative and case law developments in the United States highlight the importance of a multinational intellectual property strategy. IP lawyers David Beckwith and John Hankins will discuss planning and pitfalls in this rapidly changing trans-border environment. Topics to be
discussed include harmonization with international patent laws, protecting your technology and market space with a comprehensive approach to IP, and patent enforcement issues relating to import/export of products and components in the United States.

4:20 PM
A patent is a right granted by the government to exclude others from making, using, selling, offering to sell, or importing a claimed invention. Once the right is granted, the patentee may use the U.S. Federal Courts to enforce that right. Reading a patent from a litigation perspective is quite different than reading it from a technical perspective. The Judge’s interpretation of the claims will affect their scope, and likely the ultimate outcome of a patent case. Additionally, the patent right can be challenged. If done successfully, the patent can be rendered invalid or unenforceable. The likelihood of success, and well as the achievement of other litigation goals is often influenced by the forum where the litigation is initiated. Finally, patent litigation costs are significant, and will weigh heavily in the decision to file (or fight) a patent lawsuit.

New, Improved and Existing Technologies: Aqueous Processing I: Leaching and Biotechnology

Monday PM  Room: Boardroom West  Location: Catamaran Resort Hotel  August 28, 2006

2:00 PM Keynote
Pressure Leaching of Sulfdized Chalcopyrite in Sulfuric Acid-Oxygen Media; Rafael D. Padilla1; Daniel Vega; Maria Cristina Ruiz; 1University of Concepcion
The recovery of copper from chalcopyrite concentrates by leaching is difficult due to the slow dissolution kinetics of this mineral in most leaching media. However, recovery of copper from sulfidized chalcopyrite (a mixture of CuS and FeS2) by leaching is faster and could be selective depending on the leaching media. In this paper, the result of an investigation on the H2SO4-O2 pressure leaching of sulfidized chalcopyrite is presented. The variables considered in the study were stirring speed, concentration of sulfuric acid, temperature, and partial pressure of oxygen. The experimental data indicated that stirring speed over 500 rpm and sulfuric acid concentration over 0.1 M had very little effect on the leaching rate. An increase in temperature from 90 to 100°C increased both copper and iron dissolution; however, further increase to 120°C affected negatively the copper dissolution. Oxygen partial pressure was found to be the main variable that controls the copper/iron selectivity of the leaching. An increase in oxygen partial pressure increased significantly the rate of copper dissolution but deteriorated the copper/iron selectivity. The analysis for sulfur of the leaching solid residues indicated that most of the copper sulfide sulfur in the sulfidized concentrate oxidized to elemental sulfur.

2:25 PM Invited
Agglomeration of Copper Heap Leaching Feed Using Acid-Resistant Binders; Kimberly A. Lewandowski1; Jeff Gurler1; Timothy C. Eische; S Komar Kawatra1; 1Michigan Technological University
The benefits of agglomeration are well-known in gold heap leaching operations, which can be effectively agglomerated using binders such as Portland cement due to the alkaline leaching solutions used. However, agglomeration has not been very effective in the heap leaching of copper ores, because these ores require an acidic leaching solution. In order to gain the benefits of agglomeration in copper heap leaching, an economical, acid-resistant binder is needed. The two issues that needed to be addressed were: 1) Lack of effective methods for evaluating binder acid resistance before performing expensive, time-consuming, full-scale heap leaching tests, and 2) The vast majority of known binders react poorly to acid conditions, and so a basis was needed for determining which binders are most likely to be acid-resistant. In this paper, the development of two new tests for evaluating binder acid resistance in the laboratory are described. The “soak test” as a rapid means for comparing large numbers of binders, and the “percolation test” measures several different parameters to determine how a binder is likely to perform in heap leaching. Using these tests, a broad spectrum of binders were examined. Soak testing determined that the most acid-resistant binders were nonionic polymers. Five of these binders were further evaluated using percolation testing. Results of percolation tests are presented, and the reasons for the differences in binder performance are discussed.

2:50 PM
Extraction and Recovery of Base and Precious Metals Using the Activox® Process; Chris Palmer1; Gary D. Johnson1; 1Western Minerals Technology
The Activox® process is a hydrometallurgical process owned and developed by Western Minerals Technology Pty Ltd (WMT) for the oxidative leaching of base and precious metal sulfide concentrates. The Activox® process incorporates ultra-fine grinding to a P80 of ~10μm to activate the minerals, followed by a leach at 105°C and 1900kPa oxygen pressure to oxidise the sulfide matrix. Base metals are then recovered from solution while gold and platinum group elements can be recovered from the leach residue by cyanidation. In July 2004, WMT commissioned a Hydrometallurgical Demonstration Plant (HDP) at LionOne’s Tati Nickel Mine in Botswana. The HDP has a name plate capacity of 310kg/hr nickel concentrate and involves WMT’s patented Activox® leach, solid/liquid separation, iron removal, solvent extraction and electrowinning to produce LME nickel and copper cathode and a cobalt carbonate intermediate. The HDP recovers up to 98% nickel, 89% cobalt and 85% copper from base and precious metal sulfide concentrates from Tati, Nkomi and BCL operations. The encouraging results have led to the completion of three independent Definitive Feasibility Studies for the construction of commercial Activox® metal plants. Early development work for the Activox® process focused on the oxidation of refractory sulfide gold ores in which the gold is entrained in sulfide minerals such as pyrite, chalcopyrite, pyrrhotite and arsenopyrite. Encouraging bench scale results combine with process and engineering lessons learned from the Tati HDP operation and place Activox® in a convincing position to exploit refractory gold assets.

3:15 PM
Recovery of Cobalt and Lithium from Leaching Solution of Spent Lithium Ion Battery by Solvent Extraction; Jeong-Soo Sohn; Chu-Yong Cheng1; 1Korea Institute of Geoscience and Mineral Resources; 1CSIRO Minerals
In recycling of spent lithium ion battery, the sulfuric acid leaching solution containing some metal ions such as Co, Ni, Li, Al, Fe and Cu would be produced from crushed spent lithium ion battery. Electrowinning is a general process for the pure cobalt metal. But nowadays there are some nickel ions in the leaching solution because some cobalt could be replaced by nickel in the cathodic material such as lithium cobalt oxide. In order to get the pure cobalt metal, those impurities should be removed before electrowinning. In this paper, a process flow sheet has been proposed for recovering cobalt and lithium from spent lithium ion battery leaching solution using synergistic solvent extraction with the lonquest 801/Acorga M5640 system or D2EHPA/ Acorga M5640 system in the first SX circuit and Cyanex 272 in the second SX circuit. In the first SX circuit of this process, almost all iron, aluminium and copper would be extracted and any co-extracted Co, Ni, and Li would be scrubbed into the raffinate. In the second SX circuit, Co and Ni could be separated from Li by Cyanex 272 at pH 7.5 and scrubbing. Pure nickel solution will be obtained by selectively stripping the loaded organic solution at pH 6-6.5. Scrubbing of organic solution with cobalt solution will remove co-extracted nickel. Stripping the loaded organic solution at pH <3 will give a pure cobalt solution.

www.tms.org/Sohn2006.html
In the processing of copper concentrates by the conventional smelting-converting technology, complying with the increasingly severity of environmental legislation in some countries has become difficult, mainly due to severe fugitive emissions of gases produced during the batch PS (Picec-Smith) converting step. In this work, the results of an investigation on the pressure leaching with sulfuric acid and oxygen of white metal (produced in a Teniente Converter reactor) are discussed. The study was carried out at laboratory scale and the main variables studied were temperature, concentration of sulfuric acid and partial pressure of oxygen. The experimental results indicated that most of the sulfur in the white metal was oxidized to sulfate in the whole range of temperature studied (105°C to 150°C). The concentrations of sulfuric acid over 0.05M and oxygen partial pressure over 6 atm had little effect on the dissolution of copper from the white metal. On the other hand, temperature had the most significant effect on the copper dissolution; below 130°C, copper dissolution was incomplete after 5 hours of leaching while at 150°C the dissolution was complete in 90 minutes and 10 atm of partial pressure of oxygen.

The leaching experiment used by bacteria on the low grade sulfide copper ore which is difficult to leach were carried out. Some leaching bacteria were isolated and domesticated. The bacteria have good physiological and leaching activity, and are adapted to leaching ore. The effective domesticated method was put forward. Some technique parameters, such as ore acidification, potential controlling leaching method, ore granularity, leaching acidity, leaching liquid quantity and acid consumption were obtained by column experiment and leaching ore in situ under the ore well. It could leach 30.62% of copper in the low-grade sulfide copper ore within 24 weeks by column leaching method, and the bioleaching rate of copper is 22.83% months by leaching in situ under the ore well. The results laid the foundations for improving the resource utilize ratio.

The present work deals with a study of mechanical activation of processing of Egyptian monazite by its simultaneous ball-milling and pressure leaching, to improve the recovery of thorium and lanthanides from monazite. Experiments of ball-milling and alkaline leaching of monazite concentrate were carried out in stainless steel ball-mills of cylindrical shape under different conditions. The ball-mills were heated and mechanically rotated in an electric furnace by means of roll mechanism. The effective rotation speed was fixed at 130 rpm in all tests. The charge of steel balls of different diameters was taken as 45% of the mill volume. Monazite was charged in ball–mill without preliminary grinding. It is found that high rate of monazite leaching by ball-milling method is reached at lower temperature, shorter time and lower expense of alkali than in autoclaves. The results obtained show that complete extraction of thorium and lanthanides from monazite (99.8%) by this method is attained at 140°C within 2 hours. It is concluded that processing of monazite by its simultaneous ball–milling and leaching is mechanically activated and accelerated as a result of the grinding action of steel balls that caused the continuous removal of the hydroxide product from reacting particle surfaces. This leads to the exposing of fresh and activated monazite particle surfaces to alkaline leach solution and consequently the acceleration of the reaction of monazite processing. The ball-milling method shows many advantages such as: no preliminary grinding of initial ore and grinding and leaching are combined together in one process.
has been virtually terminated, the proportion of lead used for rolled and stamped products has decreased substantially, the use of lead for manufacture of lead-acid batteries has been growing and reached 76.7% of the overall world production of this metal. This has taken place against the background of more stringent environmental norms and environmental legislation. This is due to the lack of an alternative for lead in manufacture of local power sources. A solution to the problem of meeting the industrial demand for lead with simultaneous reduction in the primary lead production is in recycling. A large amount of batteries manufactured worldwide and their short life cycle, as well as the positive economics and a possibility to comply with the environmental requirements encourage the development of secondary lead production. Currently, over 60% of the world demand for lead is met due to recycling. The current situation with collection, transportation, storage and processing of spent lead-acid batteries has been analyzed in this paper. Examples are given to illustrate technological and equipment solutions and trends for improvement of secondary lead production discussed.

2:25 PM
Recupyl Process for Recycling Lithium Ion Battery from Mobile Phones: Farouk Tedjar; 1Recupyl SA
Among the actual rechargeable systems, Lithium ion batteries have highest voltage and gravimetric energy density. Since their introduction 15 years before, this battery become today the most largely adopted for portable electronic devices. The composition of those batteries imposes a particular consideration of their end of life management due to the environment impact and valuable source of materials. In order to comply with these two parameters, the new Recupyl process was oriented to room temperature and pressure technology. This way avoids any greenhouse gases, acid rain potential gases and other emission and present an important CO2 credit in comparison with thermal processes.

2:50 PM
Recycling of Spent Li/MnO2 Batteries: Jitka Jandova; Jan Kundas; 1Prague Institute of Chemical Technology
Consumption of lithium primary batteries, namely Li/MnO2, batteries, is constantly expanding at a very fast rate. Disposal of spent lithium batteries may soon become a serious problem because these batteries are processed only in a few plants in the world using low-temperature process. During the last ten years a great number of research works concerning recycling of lithium-containing batteries have been published, but only few works are focused on processing Li/MnO2 batteries. The aim of this study was to propose and verify on a laboratory scale a simple processing of spent Li/MnO2 batteries in order to recover Li2CO3. This process is based on roasting Li/MnO2 batteries in a vacuum furnace, leaching of calcined electrode material in distilled water and controlled crystallization of pure Li2CO3. Experiments performed was focused on the determination of optimum roasting and leaching conditions, under which practically all lithium contained in the electrode material is transformed to Li2CO3 and dissolved in water solutions. Finally, a dependence between the degree of water evaporation from Li2CO3 solutions processed and the purity of the crystallized Li2CO3 was established to obtain pure Li2CO3 at simultaneous achieving its maximum yield.

3:15 PM
Recycling of Spent Ni-Cd Batteries by Physical-Chemical Processing: Carlos Alberto Nogueira1; Fernanda Margarido2; 1INETI; 2Instituto Superior Técnico
Spent Ni-Cd batteries contain in the electrode materials heavy metals like Ni, Cd and Co, which must be recycled due to environmental problems. Pyrometallurgy is normally used for recycling these end-of-life products. But alternative processes by hydrometallurgy, integrating also physical operations, can be used. Hydrometallurgy seems to be useful, because metals can be efficiently recuperated in chemical forms with commercial value. The economical viability of this recycling process can be improved increasing the treatment capacity, through the application to different types of residues with similar characteristics like Ni-MH and domestic batteries, or other residues containing Ni/Co, like sludges, dusts or spent catalysts. Spent Ni-Cd batteries were first physically processed using shredding and wet sieving operations. Best results were achieved using an output of 6 mm in the shredder and 1.7 mm in the separation by wet sieving, resulting a fine fraction with 70% of electrode material recovered which also contains 6% of the initial scrap. The acid leaching of the obtained material in the previous operation was studied, being the parameters like: temperature, H2SO4 concentration and the liquid/solid ratio (L/S) optimized. The values attributed to the factors which concerned the best results obtained on the leaching process were mainly influenced by Ni recovery. In opposition, Co and Cd were easily leached in a wide range of conditions. To attain an overall recovery, with minimum costs, of the three metals, the values of T=100°C, [H2SO4]=2.3-2.7 M and L/S=8-10 L/kg were considered the most appropriate.

3:40 PM Break

3:55 PM
Study and Development of the Physical Treatment of Spent Batteries in an Integrated Recycling Process: Fernanda Margarido1; Carlos Alberto Nogueira1; 1Instituto Superior Técnico; 2INETI
Recycling of metals contained in the electrode materials of batteries, was studied considering an integrated recycling process constituted by physical and chemical operations. The physical treatment included the shredding of the spent batteries, followed by a wet sieving operation of the fragmented material. The physical behavior of Ni-Cd and Zn-Mn based (alkaline and saline) system batteries were studied and compared. In that sense, shredding operation was performed testing three sieves with different apertures. For Ni-Cd batteries the contamination of electrode material with the scrap after the shredding operation was lesser using the 10 mm sieve, while different behavior was observed for the Zn-Mn batteries, where similar result was obtained with the 6 mm sieve. This difference can be explained by the composition of the case materials and the internal physical constitution of the electrodes. The wet sieving studies carried out allowed optimizing the separation of the electrode fine fractions from the scrap materials through the analysis of selectivity Cd/Fe or Zn/Fe. For Ni-Cd batteries, maximum selectivity was achieved at granulometry of 1.4 mm, while for alkaline and saline systems best selectivity were obtained at 2.8 mm and 5.6 mm, respectively. This process allowed the recovery of about 75% of electrodes with less than 5% of scrap as contaminant. This physical step can be considered as a pre-treatment of this type of waste material envisaging its valorization by chemical treatment, as improves the concentration of the elements of interest and decreasing the iron content.

4:20 PM
Utilization of Mn-Zn System Batteries: Tinatin Lezhava1; R. Agladze2; 1Bakuriani Technological Institute; 2Institute of Inorganic Chemistry and Electrochemistry
Recycling technology of spent Mn-Zn system batteries has been worked out and tested in laboratory and large laboratory scale (Georgian Patent #2003 3011). Compared to the analogies existing in the world, the utilization method is characterized by compactness of the technological scheme, simplicity, cheapness and what is most important the process runs at a room temperature (instead of 400-800°C). The proposed technological scheme includes the following basic operations: Breakage of the elements, hydro-vibrated treatment of broken up mass, electrolysis by using of alkali electrolyte. This method enables extracting at 200-220kg of zinc in or powder form 300-350kg of manganese concentrate and 130kg iron in the form of scrap, from each ton of the broken up elements. The products obtained from the reprocessing of the worked out elements can be used: 1) zinc – for metallurgical aims, in powder metallurgy, as reagent in chemical production and even in production of elements as one of the current produced materials, 2) manganese concentrate – for metallurgical aims, further treatment of this metal will cause the obtaining of metallic manganese of high purity, manganese sulfate, potassium permanganate and manganese dioxide and 3) scrap iron – in metallurgy.

4:45 PM
Comparison of Primary and Secondary Magnesium Alloys: Helmut Seebacher1; Helmut Anrekowitz2; 1University of Leoben; 2University of Graz
Almost 90% of the total magnesium production in the world is used for aluminium alloying, high pressure die casting and steel desulphurisation. Over the last 10 years the demand for magnesium and magnesium alloys
has grown at an average rate of 3.5% per year. It is expected that in the next 5 to 10 years the magnesium markets for structural applications will grow significantly. Besides new applications for die casting alloys there exist also good opportunities for an increased usage of wrought magnesium alloys. From this follows, that different processes are needed for the recycling of scrap from the different kinds of applications of magnesium alloys; Processing the scrap into cast alloys allows higher degrees of contamination. Recycling in the form of wrought alloys on the other hand requires a dilution with pure materials, the extraction of which requires a lot of energy. Therefore, it is useful to produce secondary magnesium alloys. but for an further usage it is necessary to determine the strength properties and the corrosion behaviour of these secondary alloys. Another valuable point is the cost reduction of the alloying elements. The Christian-Doppler-Laboratory for Secondary Metallurgy of Non-Ferrous Metals investigates the methods for an ecological and economical recycling process of magnesium alloys.

5:10 PM

Efficient Processing and Utilization of Precious Metals Scrap: V. A. Bryukvin; N. N. Vinetskaya; A. M. Levin; T. A. Makarenkova; Valery M. Pataisky; Gintsvetmet; 'Russian Academy of Sciences

At present, two classic approaches are used worldwide and in Russia for processing of electronic scrap, i.e. single-stage process using aqua regia dissolution and double-stage nitric acid and aqua regia dissolution. A hydroelectrochemical technology has been proposed and experimentally proven for processing metallic gold and silver-containing concentrates on the basis of copper and copper alloys obtained as a result of preliminary physico-mechanical upgrading of electronic scrap. The proposed technology is based on hydroelectrochemical leaching of scrap using reversible electric current and diluted nitric acid solutions, containing complexing agents, permitting complete separation of gold from the nonferrous matrix without involving gold in the process, and dissolving copper, zinc, lead and tin virtually without any emission of nitrose gases. The gold recovery into gold bullion of at least 99.9% purity by weight is 98.2%. The technology permits simultaneous recovery of up to 65% to 80% silver and up to 85% to 95% palladium. The developed technology with respect to its physico-chemical basic principles is unique both for the Russian and foreign practice and provides a firm basis for establishing an integrated environmentally safe waste-less operation for processing of military and general electronic scrap.

5:35 PM

Information Methods of Non-Ferrous Scrap Sorting: V. Bredykhin; O. Shevelyev; E. Kazban; V. Kostjuk; V. Kushnerov; Donetsk Physics and Technology Institute of the NAS of Ukraine; 'Technocrop Ltd.; Donsplav Ltd.; Gintsvetmet; Technical University

The efficiency of scrap processing depends firstly on reliability of information about its chemical composition. The paper presents the results of the investigation and development regarding solid copper alloy scrap in the range of lump size 40–300 mm. Nowadays the sorting of lump scrap is done by two methods: 1. Sorting according to metals and alloys is done at places of scrap generation, and further till metallurgical processing each lot has its “certificate”; 2. Hand sorting of scrap is done according to the marks on solid items in special shops using proximate analyzers or manually by experienced workers. This sorting process is labor - consuming low efficient and involves mistakes. The informational method is a promising trend in the copper scrap sorting. The method is direct, i.e. as a result of sorting the chemical composition of each scrap lump or main elements is determined, and assured data of qualitative and quantitative composition are received.

Thermo and Physicochemical Principles: Aqueous Processing: Leaching and Flotation

Monday PM
August 28, 2006
Room: Boardroom East
Location: Catamaran Resort Hotel

2:00 PM Keynote
Computational Modelling of Heap Leaching Processes: Mark Cross

2:25 PM
Acidic Leaching of Turkish Lateritic Nickel Ore: Fatma Arslan

2:50 PM
Gold Extraction from a Low Grade Ore Using the System of Metal-Ammonium-Chloride-Ammonia: Shao-Hua Ju; Mo-Tang Tang; Sheng-Hai Yang

Although nowadays gold extraction methods are very abundant, none of them is satisfying, especially, in the field of heap leaching of low grade
gold ore. The traditional heap leaching with cyanide plays an inglorious role of badly environmental pollution. In this paper, a bran-new and innoxious method of gold extraction system, metal-ammonium-chloride-ammonia (MACA), was proposed, and was also analyzed both thermodynamically and practically. In thermodynamic aspect, according to the principles of simultaneous chemical equilibrium and electronic charge neutrality, the thermodynamics of MACA system was studied by using the exponential computation method and through MATLAB programming, and the solid figure of its potential - e(NH4Cl) - e(NH4OH) was drawn. The results show that, when the concentration of ammonia is higher than 0.6 mol/L, \( \Delta G^\circ = 0.5 \) is only about -0.2 V. Thus using air, oxygen or hypochlorite as oxidant, Au can be leached out. In practical aspect, using hypochlorite as oxidant, the leaching results of a cuprous gold ore showed that the extraction of gold can reach to 80% in this system. The preliminary results of reduction of the rich solution with copper and zinc powders showed that with deoxygenizing, the reduction effects were relatively good. These new findings and results have established a theoretical and practical base for developing a new process for heap leaching of low grade gold ores in this system.

3:15 PM
The Leaching Kinetics of Phase-Transformed Chalcopyrite with Sulfate Processes of Copper from Sulfide Minerals: Félix José Sieros Velarde¹; Paulino Rodolfo Zegarra Panca¹; Ángela F. Danil de Namor²; Ángela F. Danil de Namor; Universidad Nacional de San Agustín; University of Surrey

Electrochemical aspects on leaching and electrowinning processes of copper (II) from sulfide minerals have been evaluated. The thermodynamics of oxygen leaching of covellite in concentrated alkaline tartaric solutions has shown that the extraction of copper from its ore is only feasible by a complex formation process in which the tartrate ion plays an important role as the complexing agent within the overall redox reaction. See the following Scheme 1. 

\[ [Cu(OH)2C4H4O6]^{2-} + 2 OH^- \rightarrow Cu(OH)_2 + C4H4O6^{2-} + H_2O \] 

In order to examine the adaptability and kinetics for leaching different kinds of gold ores before and after leaching were studied in virtue of modern analytic techniques, e.g., XRD, SEM, and so on. The results indicate that alkaline thiourea solution can be used to leaching gold ore, for \( \# \) oxidized gold concentrate removed arsenie by microbe pretreatment the leaching rate of gold is up to 82.68%, such conclusion overthrows the parlance reported that pH value must be less than 1.78, or gold can not dissolve in thiourea solution. Chemical components and phase are in connection with gold leaching rate, different gold ores are fit for different leaching system, and alkaline thiourea solution are suitable for the pretreated oxidized gold ores with low content of sulfur and in which the main phase was SiO2, phase almost not change before and after leaching basically. Generally speaking, leaching in alkaline thiourea solution, surfaces of gold ores with glass change greatly to ones with coarseness, distinct trace and holes of corrosion. Particle size decrease and specific surface area increase of gold ores after leaching in alkaline thiourea solution with high stability except 5# gold concentrate of Zhongyuan gold smelter.

3:45 PM
The Leaching of Metal Nickel in Copper Sulfate Solutions at the Presence of Oxygen and Chloride-Ion: M. I. Kalashnikova¹; L. V. Volkov²; J. M. Shneerson³; E. G. Saltykova; Gispromnickel Institute

The leaching of metal nickel in copper sulfate solutions is investigated. It is established, that irrespective of presence or absence of chloride-ion and oxidizer (oxygen) in system process can be divided into three stages, characterizing by restoration and oxidation of metals with formation of metal copper and cuprite and differing in the speeds of sedimentation of copper and transition of nickel into solution. At the initial stage of process along with allocation of metal copper it is besiegled cuprite, that results in excess of speed of sedimentation of copper in comparison with dissolution of nickel. At the second stage speed of transition of nickel into solution falls practically to zero, and sedimentation of copper proceeds on reaction of interaction of metal copper with copper sulfate solutions with cuprite formation. During the final period speed of transition of nickel into solution exceeds speed of sedimentation of copper due to course of reaction of restoration of cuprite up to metal. Influence of an ion of chloride and oxidizer on formation of various phases is revealed. It is established, that presence of an oxidizer results in increase in a share of cuprite in a deposit. With increase of the maintenance of chloride-ion speed of metal copper allocation essentially grows even at presence of an oxidizer in system. On the basis of the data of X-ray analysis it is shown, that increase of extraction of nickel at its oxidizing leaching by copper sulfate solutions at the presence of chloride-ion speaks sharp increase.

5:10 PM
Evaluation of Lead-Zinc Flotation Tailings: Fatma Arslan¹; Y. Aykaç²; K. T. Perek³; G. Oral¹; Istanbul Technical University

Aladag (Kayseri-Turkey) lead-zinc sulfide-oxide ores contain 10.17% Pb, 10.98 %Zn, 164 g/t Cd and 57 g/t Ag. During the laboratory scale flotation tests of these ores, it was found that almost all zinc was remined in the tailings that contain 11.4% Zn, 1.35%Pb, 198.3 g/t Cd, and 22.3%Fe. Three different methods were studied such as basic (NaOH) leaching, roasting+acidic (H2SO4) leaching and direct acidic leaching for recovering metals that these tailings contain. In the basic leaching tests, effects of solid/liquid ratio, amount of reagent (NaOH), and leaching time on zinc and lead dissolution efficiencies were studied where temperature and stirring speed were kept constant at 95±5°C and 400 rpm, respectively. In the roasting followed by acidic leaching tests, effects of roasting temperature, leaching temperature, solid/liquid ratio, acid concentration, and leaching time on metal dissolution efficiencies were investigated. In the direct acidic leaching experiments, leaching temperature and acid concentrations were the parameters tested. Results of these methods were compared and discussed in terms of metal dissolution efficiencies and reagent consumption. Dissolution mechanism was also discussed in relation to the mineralogy of ore. As a
result of direct acidic leaching which gave the best results, zinc with 87%, cadmium with 81% and iron with 8.58% efficiencies were dissolved at the optimum leaching conditions while Pb remained in the leach residues. The leach liquors contained 9.0 g/L Zn, 16.1 mg/L Cd, and 1.91 g/L and the acid consumption was 422.3 kg/ton of tailings. These results were combined with the flotation results of the Pb-Zn ore and a process flowsheet for the treatment of the Pb-Zn ore is proposed which partially started to be constructed in an industrial scale.

5:35 PM
Lead Carbonate Colloid Flotation Using Sparged Flotation Cells under Continuous Conditions: F. J. Tavares; R. Escudero; Metallurgical Research Institute

The colloid flotation of lead carbonate precipitates in aqueous medium is studied at a pH of 7. The flotation system consisted of five sparged flotation cells in a serial array. The flotation system was operated under controlled conditions of superficial air velocity, superficial liquid velocity, frother concentration, and collector concentration. The measured variables were gas hold-up, bubble size, superficial bubble surface flux, and lead recovery (reported to the concentrate). The experimental data show that it is possible to separate as much as 97% (w/w) lead from the aqueous media when the superficial gas velocity is 1 cm/s and the superficial liquid velocity is 0.19 cm/s.

Thermo and Physicochemical Principles: Iron Making: Alternative Routes, Blast Furnace Coke and Coal

Monday PM
August 28, 2006
Room: Russeau Suite
Location: Catamaran Resort Hotel

2:00 PM Keynote
Gas-Solid Reaction Will Help Solid-Solid Reaction — Novel Iron Ore Agglomerate Bearing Semi-Coal-Char: Tateo Unui; Hirokazu Konishi; Noriyoshi Iwoue; Osaka University

In the course of carbonization of coal under a rising temperature condition, volatile matter is released. The kind and amount of volatile matter released depend on the kind of coal. Components of volatile matter are tar, hydrocarbons (CH₄, C₂H₆, C₃H₈, C₄H₁₀), CO, CO₂, and H₂, which are released in this order as a function of carbonization temperature. When the carbonization of coal under a rising temperature condition is interrupted at a certain temperature, say Tₑ, semi-coal-char with residual volatile matter is obtained. If some optimum interruption-temperature is chosen, small but most suitable amount of volatile matter, namely H₂, is retained. We propose novel iron ore agglomerate bearing such semi-coal-char with some strength. While simple iron ore agglomerate bearing coal char will start the reduction reaction as solid-solid reaction at somewhat higher temperature, the proposed one will start the reduction reaction as gas-solid reaction at somewhat lower temperature but higher than Tₑ. Samples of semi-coal-char and novel iron ore agglomerate bearing such semi-coal-char have been prepared and evaluated.

2:25 PM
The Kinetics of Hydrogen Reduction of Fine Iron Oxide Particles: Moo Eob Choi; Hong Yong Sohn; Gilsoo Han; University of Utah

The reduction of iron oxide particles by hydrogen is one of the most widely investigated gas-solid reactions. The search for new methods for producing iron by the direct reduction of iron oxide has resulted in a large number of exhaustive studies of the various aspects of this reaction. However, previous studies have largely been done with either pellets or lump ores. Little has been published on the hydrogen reduction of very fine particles of less than 37 µm (-400 mesh). The kinetics of hydrogen reduction of fine iron oxide particles were investigated to determine the feasibility of producing iron by a suspension reduction technology that uses hydrogen as the reducing agent. The experiments were done with samples of various particle sizes less than 37 µm (-400 mesh) at different temperatures and hydrogen and water vapor concentrations.

2:50 PM
A Laboratory Study of the Reduction of Iron Oxides by Hydrogen: Damien Wagner; Olivier Devisme; Fabrice Patisson; Denis Ablitzer; ‘School of Mines of Nancy

To reduce the emission of greenhouse gases by the steel industry, particularly for ironmaking, the production of DRI (Direct Reduced Iron) using hydrogen as the reducing gas instead of carbon monoxide is being considered. In this context, the reduction of pure hematite by hydrogen was studied at the laboratory scale, varying the experimental conditions and observing the rate and the course of the reaction. All the reduction experiments were performed in a thermobalance and supplementary characterization methods were used like scanning and transmission electron microscopy, X-ray diffraction, and Mössbauer spectrometry. The influence of rising temperature in the range 550-900°C is to accelerate the reaction; no slowing down was observed, contrary to some literature conclusions. A series of experiments consisted in interrupting the runs before complete conversion, thus enabling the characterization of partially reduced samples. Interpretation confirms the occurrence of three successive and rather separate reduction steps, through magnetite and wustite to iron, and illustrates a clear structural evolution of the samples. Finally, the influence of the sample type was revealed comparing a regular powder, a nanopowder and a sintered sample. The regular powder proved to be the most reactive despite its larger grain size, due to a more porous final structure.

3:15 PM Invited
Unsteady State Heat Transfer Analysis of Lower Part of Blast Furnace with Liquid Flow: Buneshu Nishimura; Masaki Naito; Morimasa Ichida; Shimokawa Matsumaki; Nippon Steel Corporation

Stable operation of the blast furnace needs adequate control of the lower part. To clarify the behavior of the lower part of the blast furnace with accurate consideration of the property of slag and its flow characteristic, a new mathematical model has been developed. Using this model, the effects of the change of operational conditions on the behavior of the lower part of the blast furnace were studied. Further, means to control of the lower part of the blast furnace, especially effective means to maintain adequate temperature, were discussed. And desirable slag property and composition, especially the upper limit of FeO concentration dripping from the bottom of the cohesive zone to avoid a decrease in temperature of the lower part of the blast furnace was quantitatively estimated.

3:40 PM Break

3:55 PM Invited
Advances and Understandings of Phenomena in Blast Furnace Hearth: Pinakin Chaubal; Chenn Qian Zhou; Mittal Steel Company; Purdue University Calumet

The blast furnace is a key component in an integrated steel mill. Since most current furnaces have reached their productivity limit, efforts to increase productivity and lower the cost must depend on the infusion of advanced technologies. One major driver for the technological development of blast furnaces is extension of their campaign life. A longer campaign life can significantly lower costs and increase productivity, because less blast furnace downtime would be needed for repairs and refractory relining. It is widely recognized that the main limitation for a long campaign life is the hearth wear, which is significantly affected by the hot metal velocity and temperature distributions and refractory temperatures. Because of the difficulty in making measurements inside the hearth, a new approach to gain fundamental understanding of the detailed physical and chemical processes in the hearth should be developed. In the last three years, a partnership has been established between the US steel industry and universities to develop an advanced computational fluid dynamics (CFD) model specifically for the blast furnace hearth. The 3-D CFD model is being utilized (1) to understand the phenomena in the hearth, (2) to understand the impact of changes in the internal conditions of the hearth on wear patterns; and (3) to design a monitoring/controlling system for prolonging campaign life. In this paper,
the results will be reviewed.

4:25 PM
The Boudouard Reactivity Influenced by the Properties of Cokes and Experimental Conditions; Jakub Kuczorowski; Tor Lindstad; 1Norwegian University of Science and Technology

In the production of Mn-alloys, the Boudouard reaction significantly influences the mass and energy balance. The endothermic nature of this reaction requires more energy for the process, while the direct consumption of carbon is reflected in the greater demand for carbonaceous raw materials. Therefore, it is desirable to eliminate or suppress the reaction. The kinetics of the Boudouard reaction are a function of many factors, of which coke properties and the conditions around the particles (i.e., temperature, gas composition) seem to be the most important. In the present study properties of selected single source and commercial metallurgical cokes are compared with reactivity results. The single source cokes represent a single coal that has been carbonized in a laboratory scale furnace. The commercial cokes are products of carbonization of coal blends under industrial conditions. The coke properties include proximate, ultimate and ash analysis. Also, coke petrography with carbon forms is included. The reactivity tests were performed on different particle sizes at various temperatures, gas compositions and gas flow rates. The experimental parameters were chosen to simulate conditions present in an industrial furnace. The results show that highly graphitized structure of cokes, minimal surface area and a low concentration of ash retard the reactivity. Of the other kinetics factors, the temperature and the gas composition have the greatest impact on the reactivity.

4:50 PM
Catalytic Effect of Some Inorganic Materials on the Gasification Reaction of Carbonaceous Materials; Masahiro Kawakami1; Yu Takashima2; Haruki Kambu3; Tatsuya Iwabuchi4; Toshiohide Takakano5; Seiji Yokoyama5; 1Toyohashi University of Technology

In the fast furnace, the reduction of iron oxide and gasification of coke occur simultaneously. It is well accepted that the gasification reaction controls the simultaneous reaction. Therefore, it is important to develop highly reactive carbonaceous materials. It is also known that the reaction is accelerated catalytically with the addition of some materials. In the present work, the catalytic effect of iron, nickel and some other materials was examined. The pulverized sample of coke, graphite and some kind of wood charcoal was reacted with pure CO2 in a thermo-gravimetric balance. From the weight change, the reaction rate was obtained. In some experiments, the amount of adsorbed CO2 was estimated with transient kinetic technique. Some amount of iron, nickel and CaO powder was added to the carbonaceous materials. At 1023K, the reaction rate of graphite increased four times with the addition of 10%CaO. The catalytic effect decreased with the increase in temperature. The catalytic effect of iron and nickel were also obtained at lower temperature but not at high temperature of 1373K. The mechanism of acceleration will be discussed.

5:15 PM
Application of Artificial Neural Network in Modeling Study of Coal Washing Circuits; Vijay Kumar Kalyani; Pallavika1; 1CMRI

In recent years, artificial neural network (ANNs) have been found to be an attractive tool for steady-state/dynamic process modeling, and model based control in situations where the development of phenomenological or the empirical models just given either becomes impractical or cumbersome. ANN technology is well suited to solving problems in the mineral industry, and is expected to have a significant impact in many technological areas. Coal beneficiation plants are often very complex in nature with a number of alternative flow sheets are possible for the same type of coal. Computer simulation is a very useful tool to study the different flowsheets and the combination of the flowsheet parameters. Such simulation study can be useful to predict the performance of the beneficiation plant when it is still on the drawing board. At the stage of experimentation, simulation can greatly help in substantially reducing the number of experiments necessary to arrive at the optimum flowsheet. In the present paper, a three layer feed forward artificial neural network (ANN) model, trained using the error back propagation algorithm, has been established to simulate the washing unit of coal beneficiation plant. The network model validates the experimentally observed trends. The optimal model parameters in terms of network weights have been estimated and can be used for computing parameters of the process over wide-ranging experimental conditions.

5:40 PM
Experimental Effect of Sulfur Removal in Coal with Fungus; Dewen He; Wen-Ying Jiang; Liyuan Chai; 1Central South University

The influence of coal desulfurization by fungus was experimentally studied. The present results suggest that fungus can effectively remove inorganic and organic sulfur in coal, and main influence factors of desulfurization by fungus of pH value, temperature, coal slurry concentration and coal granularity are studied by orthodox experiment and the optimal experimental conditions are as following: pH value 6, temperature 45°C, coal slurry concentration 10% and coal granularity 100 µm. Under above conditions, fungus can remove up to 44.96% total sulfur and 54.87% inorganic sulfur within two days, and their desulfurization rates will be increase along with time. Compared to sulfolobas, desulfurization by fungus is steady and more effective, and has advantage of high speed.

Thermo and Physicochemical Principles: Nano and Composite Materials I

Monday PM  Room: Russeau West
August 28, 2006  Location: Catamaran Resort Hotel

2:00 PM  Keynote
Non-Catalytic Growth of ZnO Nanostructures: Growth Mechanism, Structural and Optical Properties, and Applications; Soon-Bong Hahn; Ahmad Unmar; Hyun-Wook Ra; 1Chonbuk National University

Different shapes of ZnO nanostructures such as nanowires, nanotowars, nanostars, nanoflowers, nanocomb, sea-urchin like nanowires, nano/micro spheres and cages, etc have been synthesized without the use of any metal catalyst or additives on various substrates such as Si(100), Si(111), ZnO/Si(100), and steel alloy substrates. The nanostuctures of ZnO were quite dependent on kind of substrate and growth technique as well as the process variables such as temperature, concentrations of oxygen and zinc, pretreatment, and growth time. A cyclic feeding chemical vapor deposition (CFCVD) produced nanoneedles, nanostars and nanoflowers on Si substrates depending on growth condition, but thermal evaporation technique resulted in formation of nanowires, nanotowars, nanotubes etc. The structural and optical properties of ZnO nanostructures were examined using XRD, TEM, selected area electron diffraction (SAED), Ramman, and photoluminescence (PL). The high resolution TEM microscopy and SAED patterns showed that the grown ZnO nanostructures are single crystalline and grew along the [0001] direction. Appearance of sharp, strong and dominant E2 mode in Raman spectra, for all the cases of ZnO nanostructures, indicated that the grown ZnO nanostructures have good crystal quality with the hexagonal wurzite phase. All the structures except micro spheres and cages exhibited a strong and sharp UV emission at 380 nm with very less or no structural defects. Based on observations, growth mechanisms of ZnO nanostructures were proposed and discussed in detail, depending on substrate and growth process. Possible application areas of the ZnO nanostructures were also proposed, especially for optical devices and biosensors.

2:25 PM
Liquid Phase Migration between Two Aggregates of Solid Particles Intermixed with a Liquid; Peng Fan; Zhigang Zak Fang; O. Eso; H. Y. Sohn; 1University of Utah

A liquid intermixed within aggregates of solid particles tends to migrate towards a region composed of smaller particles and/or lower volume fraction of the liquid phase. The liquid migration in these systems occurs in a solid-liquid two-phase system. This phenomenon is similar to, but should not
be treated as, a process induced by the capillary force which causes the 
imbibition of liquid into porous media. The capillary force is defined as 
the interaction among three-phase (solid, liquid and gas) interfaces. The liquid 
migration in a two phase system can be attributed to the driving force for 
the system to decrease its total interfacial energy. The thermodynamics 
and kinetics of this phenomenon is of great practical importance for many 
industrial processes, one of which is the liquid phase sintering of functionally 
graded composite materials. A recently published method for manufacturing 
functionally graded WC-Co composites involves creating a carbon gradient 
in the green state prior to liquid phase sintering. During the liquid phase 
sintering, the liquid phase volume fraction (i.e., the Co phase) at different 
locations within the material changes with time and forms a gradient. This 
paper describes a numerical simulation of the kinetic process of the formation 
of cobalt gradient during the liquid phase sintering, taking into account both 
liquid phase migration and diffusion.

2:50 PM 
Processing of Al Alloy-AIN Metal Matrix Composites: Vinod Kumar 
Namlakonda¹; Ramana G. Reddy²; ¹University of Alabama 
In situ synthesis of discontinuously reinforced Al alloy metal matrix 
composites was investigated. Aluminum alloy (A356: Al-7mol%Si) was 
reinforced with dispersed AIN particles. AIN particles were synthesized 
via chemical in situ reaction in the Al melt by NH₃ gas. Thermodynamic 
feasibility of AIN in A356 alloy was investigated using Gibbs energy 
minimization theory. Thermodynamic modeling was carried out to determine 
the equilibrium composition of various phases formed on adding NH₃ to 
Al alloy melts in the temperature range 1173-1473K. Experiments were carried 
out in Lindberg furnace to form AIN in the molten A356 alloy at 1473K. 
Reinforcement in composites was varied from 5 to 35wt%. The products were 
characterized using SEM, XRD and optical microscope. Effect of processing 
parameters such as time and flow rate of NH₃ gas on the composition of AIN 
formed in the composites was investigated.

3:15 PM 
Silicon Carbide Composite DPF: Yanxia Ann Lu; ¹Corning Incorporated 
Porous silicon carbide (SiC) has been the top selection for diesel particular 
filters (DPFs) since 2000 because of its high thermal diffusivity and strong 
body, which help it to survive in the harsh environment of a diesel exhaust 
system. However, the process to produce SiC DPFs is a costly one. The work 
presented herein describes more cost effective composite materials for this 
application, namely Si-SiC and Si₃N₄-SiC. Both composites have shown 
excellent filtration efficiency, low back pressure and outstanding survivability 
of regeneration at high soot loadings. Since the composites are batched from 
silicon metal, they can be prepared by a low temperature process that is 
possible in the production of pure SiC PDFs. In fact, fabrication of SiC 
composites simply involves reactions between nitrogen gas and silicon metal, 
or silicon metal bonded with SiC, and as such uses a much less costly 
process when compared to the one employed to make SiC. In addition, 
the pore structure of the composites can easily be tuned by selecting raw 
materials and changing the ratio of two components. A typical pore structure 
consists of well connected pores with a median pore size of 5-20 µm and 
a porosity of 40-55%. This talk will describe the exothermic behavior as well 
as the mechanical and thermal properties of SiC composites in comparison to 
those of SiC filters. It will also show the superior thermal shock resistance of 
Si₃N₄ bonded SiC which is due to the unique combination of these phases 
that lowers the thermal expansion and elastic modulus relative to pure SiC.

3:40 PM Break

3:55 PM Keynote

Effects of Some Anions on Crystalline of ZnS and CdS Nanoparticles: 
Li Qihou¹; Bi Danan¹; Liu Zhizhong¹; Zhang Duomo¹; ¹Central South 
University 
During the preparation of ultrafine particles with hydrochemical methods, 
the growth of particles is a certain physical and chemical process, and 
their structures and morphologies are closely related to the symmetry of 
crystal structure, the mutual force among structural units, crystalline lattice 
 imperfection and their growth environments. So the study on the structure 
and morphology control of ultrafine particles is not only concerned with 
the inherent crystal habits, but with the effect of physical and chemical 
conditions in the solution associated with crystalgrowing. In this study, ZnS 
and CdS nanoparticles were prepared by a homogenous precipitation method, 
and the effects of Sulfate ion, nitric ion and chloride ion on their crystalline 
were investigated individually. It was found that under the experimental 
conditions, anions have no influence on the crystalline of ZnS, but different 
crystalline CdS ultrafine particles were produced in different anion systems, 
where the blende-type CdS was obtained from natrate or sulphate solution, 
and wurzite-type CdS was obtained from chloride solution. It was ascribed 
to the coordination of Cl⁻ and Cd²⁺, which altered the supersaturation of the 
solution, the existing growth units and their connecting patterns.

4:20 PM 
Transport Phenomena in Nanomechanical Systems for Molecular 
Manufacturing: David R. Forrest; ¹Naval Surface Warfare Center 
In 1981, K. E. Drexler proposed using massively parallel nanomechanical 
systems to manufacture large atomically exact structures. As in macroscopic 
mechanical systems, they would contain components that serve traditional 
functions such as trusses for support, gears to transmit power, bearings for 
low-friction support of rotating surfaces, motors to supply torque, pipes and 
conveyor belts for material transport, and channels for coolant. Many of these 
components would only contain a few thousand atoms. Specific designs for 
these devices became available in the early 1990s, and a few working devices 
appeared in laboratories by the early 2000s. As advances continue, a thorough 
understanding of the operative transport phenomena will guide the intelligent 
design and construction of nanomechanical structures, devices, and systems. 
The familiar equations of continuum mechanics are generally inadequate to 
describe the flow of heat and mass in the proposed nanosystems. Boundary 
conditions often need to be described in terms of potential surfaces. Surfaces 
are not geometrically smooth, but periodic according to the locations of 
atomic nuclei. Friction occurs not due to the plastic deformation of asperities 
on mating surfaces, but to phenomena such as thermoelastic damping and 
phonon viscosity when atoms slide past each other. Electrostatic forces 
dominate over gravitational forces by orders of magnitude; there is no role 
here for natural convection. Structural components, no matter how stiff and 
strong, are in constant motion due to the thermal noise in the system. The 
fluids are described in terms of individual molecules in constant motion.

4:45 PM 
Effect of Surface State of Nano Al Powders on the Mechanical Properties 
of Nanostructured Al Composites Fabricated by Magnetic Pulse 
Compaction: Whung Whoe Kim¹; Geunhee Lee¹; Chang Kyu Rheé²; ²Korea 
Atomic Energy Research Institute 
A nanostructured metals have an extraordinary mechanical, thermal 
and electrical properties owing to very high volume fraction of interface as a 
defective and open structure. Usually the nanostructured metals have been 
fabricated by either severe deformation of micro-structured bulk metals 
(Top down) or compaction of nano metallic powders (Bottom up). In this 
study, to investigate the effect of surface state of nano Al powders on the 
mechanical properties of nanostructured Al compacts, three kinds of nano Al 
powders, e.g., the oxygen-passivated, organic-coated, and hexane-conserved 
nano Al powders, which were prepared by pulsed wire evaporation (PWE) 
method, of 80–120 nm in diameter were compacted by magnetic pulse 
compaction (MPC) method. All of powders were degassed and preheated 
in the temperature ranges of 20 to 400°C in vacuum before compaction. A 
main advantage of the magnetic pulse compaction, as one of the dynamic 
compaction method, is the ability to reach higher relative density of compacts 
of metallic nano powders owing to sufficiently high pressure and adiabatic 
heating in a very short time of an order of micro-second. In our experiments, 
the compaction pressure of 1.6 GPa was applied as a pulse within 300µsec 
in duration time. These conditions had seemed to be sufficient for both 
compacting and sintering of nano Al powders without any grain growth. After 
compaction, each compacts was annealed at 400°C for 1 hour and cooled in 
furnace. The compacts showed the nanostructure of little grain growth.
Wear of Dense Metal Matrix Composites

6:00 PM Invited
Wear of Dense Metal Matrix Composites: Pranav Deshpande; Ray Y. Lin; ‘University of Cincinnati

The wear behavior of metal matrix composites differs from that of the monolithic metallic counterparts. This has arisen from the nature of the composite materials having multiple constituents in the structure and differential degrees of wear exist among them. It was observed that under moderate heat treatment is a single-phase olivine LiFePO₄ with particle size of about 300nm. A carbon-coated olivine LiFePO₄/C was also prepared by adding conductive carbon, such as glucose, activated carbon and acetylene black, into the precursor solution. The existence of carbon increases the electronic conductivity of LiFePO₄/C composite, and consequently, leads to high rechargeable capacity. The carbon coated material with carbon amount of 7.64%wt obtained from glucose has the first discharge capacity of 150.3mAh/g at a 0.1C rate and 129.3mAh/g at a 1.0C rate, respectively. After cycled for 50 times, the capacity retention rate is 95.13% at a 1.0C rate in the voltage range between 2.5 to 4.3 V vs. Li.

5:35 PM
Study of Corrosion Resistance of Nano Composite Coating on Sintering Nd-Fe-B Permanent Magnet: WeiHong Xie; Baizheng Chen; ‘Central South University

After being pre-treated, composite electro-deposits of semi-brighten nickel-nano SiO₂ with bright nickel or with amorphous Ni-P alloy, and composite electro-deposits of Zinc were prepared on Nd-Fe-B magnetic material. The effect of cathodic current densities, nano-SiO₂ concentration, stirring strength and surfactants on the corrosion resistance of electro-deposits were studied. Also surface appearance and structure of the composite coatings were analyzed by SEM. The present investigation shows that the corrosion resistance of composite electro-deposits of semi-brighten nickel-nano SiO₂ with bright nickel was high. The solution system of semi-brighten nickel-nano SiO₂ with bright nickel was stable and its electro-deposits also had an excellent corrosion resistance, composite electro-deposits of Zinc not only had good corrosion resistance, but also had a low cost, so it was a good electro-deposits for medium or low-class Nd-Fe-B magnetic material.

2:00 PM Keynote
Gas-Solid Reactions: Towards New Frontiers: Seshadri Seetharaman; Ricardo Morales Estrella; Ioannis Arvanitidis; ‘Royal Institute of Technology; ‘UMSNH; ‘Sandvik Mining and Construction

Reactions between solids and gas phase have many interesting theoretical aspects as well as technological applications. The present group had carried out experimental investigations as well as theoretical studies of a number of gas-solid reactions over the past decade and was able to derive interesting results. Studies of the decomposition of alkaline earth carbonates were carried out by thermogravimetric analyses. The experiments were carried out using thin powder beds as well as iso-statically pressed compacts with thermocouples embedded in the same. The investigations revealed the complexity of the reactions and the impact of the heat- and mass transfer aspects on the reaction kinetics. In the case of BaCO₃, the kinetics of decomposition was complicated by the formation of a liquid phase. In the case of SrCO₃, the reaction kinetics could be simulated by theoretical modeling. Gas-solid reactions were also employed as a versatile process tool towards the production of alloys and intermetallics involving transition elements by hydrogen reduction of complex oxides involving transition metals. Thin powder beds were employed to examine the micro-kinetcs, while fluidized bed technique was utilized to produce bulk alloys. Preliminary correlations could be drawn between the thermodynamic stabilities of the oxides and the activation energies of chemical reduction steps. Adjusting the process parameters, products at nano-scale could be produced. The structural, mechanical and thermal properties were investigated in the case of these products. The potentialities of this method as a green route to produce industrially important alloys and intermetallics with unique properties are demonstrated.

2:25 PM
Kinetic Studies on the Soda-Ash Roasting of Titaniferous Ores for the Extraction of TiO₂: Abhishek Lahiri; Animesh Jha; ‘University of Leeds

Titanium dioxide is extracted from titaniferous ores by chloride and sulfate processes. These processes produce wastes in form of iron chloride, iron sulfate and rare earth oxides gangue, each of which has to go through a further treatment before it can be disposed safely, which may be expensive. The shortage of high-grade ores is also making the two conventional processes less efficient. In view of the above mentioned problems, an alternate beneficiational process of roasting titaniferous ores with soda ash is discussed. The advantage of this process is that, there is no production of wastes. The impurities present in the ore can be selectively separated after the roasting process. The roasting of titaniferous ores with soda ash was carried out between temperatures of 873K and1173K for several hours. The roasting process resulted in the formation of complex alkali compounds and various sodium titanate compounds, depending on the Na₂CO₃ to ore ratio. The phases formed after roasting were characterized using the X-ray powder diffraction (XRD), X-ray florescence (XRF) and scanning electron microscopy (SEM) techniques. The phase equilibria in the Na-Ti-O system were evaluated and compared with the phases obtained after the roasting process. The effects of temperature and the proportion of sodium carbonate on titaniferous ores are also discussed. From the experimental data, the kinetics and phase analysis data were analysed to ascertain the mechanism of overall reaction and the rate-limiting steps.

2:00 PM Invited
Thermo and Physicochemical Principles: Non-Ferrous Processing: Kinetics
Monday PM Room: Russeau East August 28, 2006 Location: Catamaran Resort Hotel

2:00 PM Keynote
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A new kinetic modelling technique has been applied to study the rate of MnO reduction from slags by dissolved carbon in liquid iron. Based on a consideration of the fundamental reaction kinetics, a general differential equation for the slag reduction process has been formulated, which then is solved analytically for certain special cases. By re-writing the solutions in a dimensionless form the poorly known kinetic constants are eliminated, which makes model both flexible and applicable to a wide range of experimental conditions. For example, changes in process parameters such as temperature, metal composition, slag composition, gas composition can readily be captured along with variations in the crucible geometry. Based on a comparison with a series of experimental reduction curves being reported in the literature, it is concluded that the predictive power of the model is surprisingly good, yielding outputs that are both reliable and physically reasonable. An attractive feature of the model is that it provides an alternative way of calculating the activation energies from experimental reductions curves. For example, it suggests that the activation energy for the reduction of MnO by dissolved carbon in liquid iron is 154 kJ/mol, which is different with the previously reported activation energies. The model also suggests that the crucible geometry, which affects both slag volume and resulting slag/metal interfacial area, has a significant influence on the overall reduction kinetics. This design parameter is a key to further optimisation of the process on an industrial scale.

**3:15 PM Keynote**

Using Sohn’s Law of Additive Reaction Times for Modeling a Multiparticle Reactor: The Case of the Moving Bed Furnace Converting Uranium Trioxide into Tetrafluoride: Fabrice Patisson; Bernard Dussoubs; Jean Jourde; Denis Abitader; ‘School of Mines of Nancy; Comurhex

One of the major issues with multiparticle reactors is to handle their multiscale aspect. For modeling, it usually comes to coupling a reactor model (describing the phenomena at the macroscopic scale) with a so-called grain model (simulating the behavior of a single grain or a particle). An interesting approach proposed by H.Y. Sohn (1978) is to use the law of additive reaction times in order to calculate, approximately but analytically, the reaction rate of a particle in the reactor model. Its great advantage, compared to a numerical grain model, is to drastically reduce the computation time, particularly in the case of complex reactor models. This is the approach we retained for modeling the moving bed furnace, a counter-current gas-solid reactor used in the nuclear fuel-making route for producing uranium tetrafluoride from uranium trioxide. The numerical model we developed is 2-dimensional, steady-state and based on the finite volume method. It describes solid and gas flow, convective, conductive and radiative heat transfers, and six chemical reactions involved in the process. The law of additive reaction times is used to calculate analytically the rate of the three principal gas-solid reactions at every discrete point in the reactor. We have demonstrated the validity of this approach by comparing its results with those calculated from a numerical grain model. Also detailed in the paper are the main results of the moving bed furnace model itself and the possibilities of optimizing the process revealed by the calculations.

**3:40 PM Break**

**3:55 PM Keynote**

Physicochemical Criteria on the Mechanism of Gas-Solid Reactions Used in Extractive Metallurgy: Ana E. Bohé; Daniel M. Pasquevich; ‘Centro Atómico Bariloche/ Consejo Nacional de Investigaciones Científicas y Técnicas/Universidad Nacional del Comahue; ‘Centro Atómico Bariloche/ Consejo Nacional de Investigaciones Científicas y Técnicas

 Nowadays, gas-solid processes are widely used in the industry. The chlorination and carbochlorination of metallic compounds are some of this kind of non catalitic heterogeneous reactions. In particular those related with extractive metallurgy of refractory elements (Zr, Ti, Nb, Ta, RE, etc). The development of materials to be used in reactors at elevated temperatures and with high corrosion performance, enhance the application of this kind of processes. Although they are currently carried out in the production of many commodities, the mechanism of most of them are yet not well understood. The present work is a deep discussion on the most important aspects to take into account for determining the mechanism of gas-solid reaction, and those criteria fulfill in this analysis were applied to chlorination and carbochlorination examples. The microstructural characteristic of solids, the mass and heat transfer phenomenon, the adsorption and desorption of gaseous species on active surface, surface diffusion processes and chemical elementary steps, which are the main contributions to the mechanism of these reactions were analysed. Furthermore, the effect of them on the reactivity of solids and the control step of the reactions were determined. The application of catalitic mathematical models to this kind of reaction and the modification for the better interpretation of experimental results is also undertaken. The most appropriate experimental procedures for following these reactions and the microstructural characterization techniques needed to be use in each case, there limits and applicability are also indicated.

**4:20 PM Invited**

Modelling of Gas-Solid and Solid-Solid Reaction Kinetics: Du Sichen; Seshadri Seetharaman; ‘KTH

A number of metallurgical processes are based on gas-solid and solid-solid reactions. Gas-solid reactions often involve the chemical reaction step as well as the different diffusion steps for the reactants and products. Heat transfer is an important phenomenon in these reactions, where exothermic or endothermic reactions can lead to significant temperature changes at the reaction site. Solid-solid reactions are somewhat similar and can often be a part of the gas-solid reactions, where the solid product can react with the solid reactant. Both gas-solid as well as solid-solid reactions involve further complications like sintering, swelling, melting or cracking. In a number of cases of solid-solid reactions, it is necessary to design tailored experiments in order to evaluate the diffusion coefficients. In such cases, it is necessary to develop suitable models to describe the reaction results. The present paper presents the modeling of gas-solid reactions in the case of the decomposition of CaCO₃, describing the reaction kinetics on the basis of heat-transfer concepts which could be compared with thermogravimetric results. In the case of solid-solid reactions, the present paper describes the model developed for describing solid-solid reactions from dynamic X-ray diffraction technique, developed by the present team. The model has been successful in explaining the solid solution formation in the case of the system NiO-MgO as well as the formation of spinel from MgO and Al₂O₃.

**4:45 PM**

Oxidation of Molybdenite by Water Vapor: Edgar R. Blanco; Hong Yong Sohn; Gilsoo Han; Kliment Y. Hakobyan; ‘University of Utah; ‘Navro LTD

A thermodynamic and experimental investigation to develop a new process for converting molybdenite concentrate to molybdenum dioxide by a water-vapor oxidation process was carried out. In addition, the behavior of thorium and selenium in molybdenum concentrate during the process was investigated. The kinetics of the reaction were determined by measuring the weight change of a sample with time in water vapor at temperatures between 900-1000°C. The results were analyzed by a Shrinking Unreacted Core model under chemical reaction control, which showed an activation energy value of 84.1 kJ/mol. To determine the behavior of thorium and selenium, their concentrations in the molybdenum sulfide and the product molybdenum dioxide were measured by the use of ICP. While most thorium remained with the molybdenum dioxide after the water vapor oxidation, almost all selenium volatilized. These results agree with thermodynamic analysis.

**5:10 PM Keynote**

Oxidation Removal Behavior of Boron and Local Nonequilibrium Reaction Field in Purification Process of Molten Silicon by Applying Flux Injection Technique: Mitsuru Tanahashi; Masamichi Sano; Chikabumi Yamauchi; Kunihiko Takeda; ‘Nagoya University

Oxidation removal behavior of boron from molten silicon by the CaO-CaF₂ flux powder injection was investigated from a viewpoint of process dynamics. This boron removal method is one of the nonequilibrium processes with oxygen gas injection, which is finished before the overall reaction system approaches the equilibrium state, with highly basic flux based on the
high oxygen partial pressure locally established at the flux-O$_2$-Si interface. By applying this method, the boron concentration in the metallurgical-grade silicon (MG-Si) can be reduced to single-ppm-ordered level. In this study, the local nonequilibrium reaction field of boron oxidation at the interface was focused upon, and the effects of the kinetic energy of the flux particles injected into the silicon melt and the flux-O$_2$-Si reaction area on the boron removal behavior were discussed. From the results obtained, it was clarified that the kinetic energy of the flux particles is determined by the injection conditions, such as the flow rate of the oxygen carrier gas and the size of the flux particle, and that the boron removal rate is affected by this kinetic energy. At relatively higher oxygen gas flow rates, the injected flux particles have so high kinetic energy that they can break through the bubble formed at the exit of the injection nozzle, which resulted in the formation of a new reaction field of boron removal. On the other hand, at relatively lower gas flow rates, the formation of the reaction field is limited, resulting in the reduction of the boron removal rate.

5:35 PM
Effects of Mass Transfer in Evaporation Process of Alloy Components in Vacuum Processes: Agnieszka Fornalczyk$^1$, Leszek Blacha$^1$; Silesian University of Technology

Since a several year time there is noted an increasing importance of the metallurgical vacuum technology. This refers mainly to the extrafurnace steel treatment processes, melting of steel and special alloys in the induction and arc vacuum furnaces, as well as refining processes of nonferrous metals. In the presented work, there is discussed a phenomenon of evaporation of volatile components of metal bath under reduced pressure with description of kinetics of this process. Presented are the possibilities for evaluation of the values of mass transfer coefficients in the liquid and gaseous phase. Basing on results of own research on removal rate of impurities from liquid copper (bismuth, lead) in vacuum refining process, determined is the thickness of hypothetical boundary layer in gas phase. This allowed to formulate a general kinetic equation defining the evaporation rate of gaseous components from metal bath. The values of overall mass transfer coefficients determined from this equation were compared with experimental results by other authors working on the evaporation effect of liquid components of metal alloys.
Therefore, in order to maintain the copper loss in slag within the proper level, by the diminution of coke charge with higher matte grade operation (67% expansion, because the reduction effect for the settler will come to be smaller settling time due to high concentrate charge rate and high matte grade in the such as the installation of the computer guided system and the improvement Tamano Type Flash Smelting Furnace (T-FSF). The coke combustion technology since the start-up in 1972. Its technology has developed in the operation without a slag cleaning furnace (SCF) by our own coke combustion Tamano Smelter of Hibi Kyodo Smelting Co., Ltd. has been continued Kyodo Smelting Furuta Operation Change by the Introduction of Slag Cleaning Furnace 8:50 AM Invited; Masaru Takebayashi; Keisuke Yamamoto; Sumitomo Metal Mining Company, Ltd. Sumitomo Metal Mining decided to expand cathode copper production capacity of Toyo Smelter and Refinery to cope with the recent copper demand growth in Asia, and to survive by reducing cost. The expansion plan is promoted to increase electrolytic refined copper production capacity from 270,000 metric tons in 2001 to 450,000 metric tons in 2007. The major changes in smelting section are introduction of the rotary steam dryer, renewal of the feeding system for flash furnace, improvement of the concentrate burner, modification of the flash furnace cooling materials, renewal of the slag cleaning furnace, modification of the flash furnace waste heat boiler, installation of a new converter furnace, enlargement of two anode furnaces. In addition, the gas cleaning system was upgraded and the second acid plant was installed. In the refinery section, the existing tank houses have been operated at high current density of 300A/m² using the conventional starting sheet cathode technology and moreover a new tank house utilizing the permanent cathode technology was constructed. Although the copper production capacity has been increased, SO2 emission has been kept the lowest in the world through consideration of influence on the environment by expansion project. 8:50 AM Invited; Philip S. Arthur; Xstrata Technology The ISASMELT process is a submerged lance smelting technology operating in smelters in Australia, the USA, Belgium, India, Germany, Malaysia and China. Further plants are under construction in Peru and Zambia. Initially developed at Mount Isa Mines, Australia, the technology is marketed by Xstrata Technology. Yunnan Copper Corporation (YCC) commissioned the first copper ISASMELT furnace in China in 2002. The plant quickly ramped up to design capacity and the first campaign lasted over 2 years. Now into the second campaign, the furnace is exceeding the original design capacity and YCC has won numerous awards for its contribution to reducing emissions and energy consumption. YCC and Xstrata put great effort into managing the design, construction and commissioning of the smelter. Xstrata’s technology was combined with YCC’s novel management approach. This effort has been repaid in terms of the outstanding performance of the plant since startup. This paper updates the reader on the first few years’ operation of the YCC ISASMELT plant and discusses the way in which the technology was transferred, leading to fast ramp up and, as a result, enhanced profitability for the operators. 10:20 AM Invited; Ross McClelland; Ross Andrews; Brian R. Baldock; ‘Austral Ltd; ‘Hindustan Zinc Ltd Hindustan Zinc Limited (HZL), a Vedanta Resources group company, is one of India’s leading base metal producers. HZL activities range from exploration, mining and ore processing to smelting and refining of lead, zinc, cadmium, cobalt, copper and precious metals. It is also an important producer of sulphuric acid. As part of its recent expansion program for the Chanderia complex, HZL installed a new Ausmelt lead smelter of 60,000 MT per annum capacity. The Ausmelt furnace at HZL was designed to produce crude lead bullion and a zinc rich fume in a three stage batch operation smelting local concentrates, and revert materials from within the existing Chanderia complex. This paper discusses the commissioning and initial operations of the Ausmelt furnace at Hindustan Zinc.
Technical Program

10:45 AM Invited
Expansion of Gresik Copper Smelter and Refinery: Mineo Hayashi; Nozomu Hasegawa; Budi P. Handogo; Anthony Prayoga; PT Smelting Gresik plant, PT Smelting, is the first and only one copper smelter and refinery in Indonesia, with the original design capacity of 200,000 tpy of LME grade A cathode production, by treating copper concentrates mainly coming from Grasberg mine in Papua, Indonesia. The smelter employing the Mitsubishi process was put into operation at the end of 1998, then the refinery capacity was expanded up to 259,000 tpy in April 2004 in order to meet with soaring demand of copper cathode in South East Asian market. In addition, the construction work for the second refinery expansion project to have additional 12,000 tpy capacity, in total 271,000 tpy, was already started, and it is scheduled to be completed in July 2006. This paper describes the chronology of the expansion and future operational strategy of Gresik plant.

11:10 AM Invited
The Slag Cleaning Technologies for One-Stage Flash Smelting of KGHM Polska Miedź Concentrates: Jozef Czernecki; Zbigniew Smieszek; Zdzislaw Miezczkowski; Norbert Kubace; Jerzy Dobrzanski; Janusz Siaszko; Leszek Byszynski; Institute of Non-Ferrous Metals; ‘KGHM Polska Miedz’ S.A.
Chalcocite-bornite concentrates of KGHM contain, similarly to chalcocryptite concentrates, 20-30% Cu but several times less iron (2-7 wt.%), and sulphur (9-12 wt.%). Another useful characteristic of KGHM concentrates is the presence of organic carbon (5.5-8.5 wt.%) in them, which serves as fuel in the flash smelting process. The main contaminants of the concentrates are lead (1.3-2.5 wt.%) and arsenic (0.05-0.4 wt.) which require appropriate technological treatment in order to remove them from the copper product. Chalcocite-bornite concentrates are processed in KGHM by two different processes: a flash smelting process (Glogow 2 Smelter); a shaft smelting process (Glogow 1 Smelter, Legnica Smelter). The shaft smelting process used in the Glogow 1 Smelter and in the Legnica Smelter has higher production costs than the flash smelting process of HM Glogow 2. Additionally, the shaft smelting process employs several concurrently running installations (six dryers, seven briquetting lines, six shaft furnaces, nine converters), the operation of which, including maintenance, requires significant financial expenditure. Therefore, the Company is currently considering the substitution of the shaft furnace process in the Glogow 1 Smelter and in the Legnica Smelter by the one stage flash smelting process located in the Glogow Smelter, with output equaling the copper production capacity of both smelters, i.e. 320,000 – 350,000 t/a.
There are two technological options being considered which differ from each other in their manner of flash slag cleaning.

11:35 AM Invited
SPCC’s 1,200,000 tpa ISASMELT Copper Smelter: Phil Partington; Henry Walqui; Carlos Noriega; Xstrata Technology; Southern Peru Copper Corporation
Southern Peru Copper Corporation (SPCC) are modernizing the Ilo copper smelter. A single ISASMELT furnace will start smelting 1,200,000 tonnes per year of concentrate during 2006. The existing Peirce Smith converters are being upgraded for converting the matte to blister copper. Two new anode furnaces and a twin anode casting wheel are being installed, along with a new acid plant and oxygen plant. The modernization project will ensure that the smelter satisfies new environmental regulations due in January 2007. One of the reasons for choosing ISASMELT technology was its ability to surpass legal specifications requiring collection of 92% of sulphur in offgas. Prior to making a selection, SPCC analysed all modern copper smelting technologies over a number of years. A combination of factors led to ISASMELT being the preferred technology. The fact that the process can be installed for a relatively low capital cost was a key advantage. Its ease of operation and flexibility as demonstrated in plants running in Australia, USA, India, and China, was also important. In addition, the technology package provided all ingredients that SPCC believed were necessary for successful implementation, including an extensive training program in the Mount Isa copper smelter, and access to operations experience made over more than ten years of operation at a similar scale to the plant at Ilo. This paper summarises the background to the modernization project, describes the main design features of the new copper smelter and summarises progress on the smelter construction as of early 2006.

Legal, Management, and Environmental Issues: Business Management

Tuesday AM
Room: Kon Tiki Ballroom
Location: Catalamar Resort Hotel

8:00 AM Keynote
Norddeutsche Affinerie AG: Europe’s Leading Copper Producer: Peter Willbrandt; Norddeutsche Affinerie AG
Norddeutsche Affinerie’s routes date back to the 18th century. NA was established in 1866 as a joint stock corporation. NA’s core business covers the production of copper cathodes from primary and secondary raw materials and the processing of them into wire rod and shapes. Part of the shapes are processed into pre-rolled strip and shaped wires within the Group. With some 3,200 well qualified and highly motivated employees, the NA Group produces some 560,000 tonnes of copper cathodes, 370,000 tonnes of wire rod, 230,000 tonnes of shapes, 130,000 tonnes of pre-rolled strip as well as 70,000 tonnes of strips and shaped wires annually. NA's product range is complemented primarily by precious metals, selenium, sulphuric acid, lead and nickel sulphate. The paper will give an insight into the performance of NA and its business units with regard to production, environmental and health protection and occupational safety.

8:25 AM Invited
The Managing System: How to Get Your Dreams to Work: David A. Willbrandt; Strategic Asset Management Inc.
Many times, we as Maintenance professionals have been involved in changes to processes or systems. Often we relied on seat of the pants knowledge to determine whether or not we were successful. More often than not, once our attention has been turned to other endeavors, the initiative has floundered. This paper will describe those measures that can be most effectively used to track and manage the success of implementing an improved Work Management System. However, not only will the paper discuss traditional work indicators, it will also explain how to establish the behaviors in the workplace that will ultimately ensure successful implementation. Combined with the discussion on indicators will be a discussion on how to tie them to bottom line results and display them in the form of a scorecard. Actual results will be discussed.

8:50 AM
The Optimax Program - The Optimal Relationship for Owner/Clients to Procure Industrial Services: Neil Smith; Laura Taylor; Auburn Industrial Services Ltd
Mineral processing plants typically procure a range of industrial services from contractors. Their satisfaction and value received is directly affected by how the services are procured, rationalized and delivered. Traditional purchasing strategies often focus on price rather than on optimizing the service relationship between supplier and customer. The nature of this relationship may have the greatest potential to reduce costs and enhance production. It has been documented that a service involves simultaneous production and consumption. A high degree of customer involvement is often necessary for a successful outcome and the expectations and attitudes of the customer can positively or negatively affect delivery of the service. This indicates that the customer can enhance or diminish their own satisfaction and value received and the supplier cannot act alone for best results. The Optimax Program for industrial services is a service delivery framework whereby a customer and supplier work together to raise the efficiency of the service exchange. The Optimax Program is intended to help the customer optimize costs and maximize production by connecting the customer and supplier through shared information and objectives. This paper will review traditional procurement strategies for services and identify their pros and cons. In addition, the paper
will outline the Optimax Program and highlight its features. Some actual case studies will be used to illustrate the successful results of the program.

9:15 AM Keynote
Development Plan for the Codelco-Chile’s Smelter and Refinery Business: Pedro Morales; Roberto Mac-Kay; Hector Recalvi; Codelco-Chile

Current Codelco’s smelter and refinery (Smelt and Ref’s) business has growing complexities, concentrates with lower copper grades, higher impurities contents, and strong environmental restrictions which have led to refocus the Codelco business, not only by considering the isolated developments for each of the Codello’s Smelt and Ref complexes but in an integrated corporate scheme which takes advantages of the economy of scale, optimizes the synergies, and includes new technologies for higher productivity and lower operational costs. Accordingly, for the 2008-2012 period, Codelco has prepared a Development Plan integrated to the Smelt & Ref’s business units that improves its single potentialities, includes the last advances achieved by the Teniente Converter and Continuous Converting Technologies, and includes the concept of decoupling the smelting process from the converting process with a higher operational flexibility and better control of its contaminants. Thus processing the white metal generated in the Teniente Converter unit of the smelter A into the smelter B has comparative advantages. These changes in the business concept increases the overall smelting capacity by processing only white metal as a final product through a very marginal investment, eliminating the total or partial white metal conversion into blister copper and by using the available gas capture-treating capacity and the available acid plants.

9:40 AM Break

9:55 AM
Short Term Forecast of Metal Prices: Commercial Application for Operation on Forwards and Optimization the Hedging: Boris Arlyuk; Alumconsolt Ltd

The system of short term forecast of metal prices at LME is based on correlation between prices within the quarter forward and at the first place by economic parameters at the West, determining the consumption of metals. Such economic parameters are presented by data of indexes of Western World industrial production (WW IP), official data of IP and Dow Jones indexes at USA. For price forecast within the quarter forward (one day ahead, 3 day -65 days MA forward prices) are significant the changes of actual prices (official and close) at the past and the parameters of daily trade at LME at the past (futures turnover, open interest, LME stocks). It is developed subsystem of price forecast within the quarter forward based on analytical approach determining the relations between the participants of the market. It gives the opportunity to reduce the number of empirical coefficients at the model and receive good accuracy of forecast the MA prices and its direction at the past. The cycle times between knowledge generation and innovation are often neglected in the traditional capital expenditures and building of new plants. The paper reviews several implementations in which they have started with new ways of using operational information management. Initiatives to assist in the implementation of mine to product strategies, metallurgical mass balances, solvent extraction composition statistical process control, methods to minimize organic losses, reduce variable costs and to improve metal extraction are presented.

10:20 AM Keynote
Systematic Approach to Rod Mill Technology Upgrade Decisions at Gerdau Ameristeel Beaumont: Bhaskar Yalamanchili; ‘North Star Steel Texas Inc

Gerdau Ameristeel Beaumont presents its systematic approach for upgrade decisions that has developed over 30 years of ongoing capital projects for quality and cost improvements. This system serves to identify product needs, select process improvement strategies, justify them, and assist multi-department communications and decision-making. This is illustrated with Beaumont mills’ last Stelmor upgrade and leads to a discussion of the need to consider Life Cycles of both products and technologies as we move to answer the challenges of the future.

10:45 AM
An Alternative Approach to Completing Furnace Rebuild Projects: Mike Santaluce; Neil Smith; Sandy McKinty; Auburn Furnace Services Inc.

Smelting furnace rebuild projects often require a significant capital expenditure and an extended smelter outage. Increasingly, smelter operators are searching for methods and initiatives to shorten overall furnace rebuild outage schedules and contain costs. This paper discusses a “Partnership Model” for completing furnace rebuilds; a project driven approach which Auburn has developed in response to the need for shorter schedules and manageable costs. The Partnership Model for completing furnace rebuild projects is based on assembling the key project team members at the start of the project life cycle: the owner/client manager, the project/construction manager and the design engineering team. This is in contrast to the traditional EPCM method in which the client first hires the design engineering firm. As engineering nears completion, materials are procured and the construction manager/constructors are hired after a tendering process. In the Partnership Model, all of the key project participants are assembled at the start of the design phase and have input into the overall project planning. This paper will discuss the Partnership Model and the project driven approach for furnace rebuild projects. It will discuss the project management discipline and the importance of modern day project management theory and best practices in the context of the Partnership Model. The paper will identify the merits and challenges of the model and study the use of similar approaches that have succeeded in other industries. The paper will conclude with a case study on the application of the Partnership Model to a furnace rebuild project.

11:10 AM Keynote
Innovations in Performance Management of Integrated Hydrometallurgical Plants: Osvaldo A. Bascur; Roberto Linares; OSIsoft, Inc.

Several new hydrometallurgical plants have been built in the past years. They have implemented new processes to treat new type of ores. New technologies have been used to improve metallurgical performance from the start. The cycle times between knowledge generation and innovation are often neglected in the traditional capital expenditures and building of new plants. The paper reviews several implementations in which they have started with new ways of using operational information management. Initiatives to assist in the implementation of mine to product strategies, metallurgical mass balances, solvent extraction composition statistical process control, methods to minimize organic losses, reduce variable costs and to improve metal extraction are presented.

11:35 AM Invited
Education and Research in the COE on Nature-Guided Materials Processing: Ken-Ichi Miyazawa; Shigeo Asai; Nagoya University

Our Nature COE was selected in 2002 as one of the 21st Century COE (center of excellence) in fields of chemistry and materials science and supported by Japanese Ministry of Education, Culture, Sports, Science and Technology. In the Nature COE, under collaboration with researchers in four departments relating to the fields of chemistry and materials science in the university, a new field of material research is being developed through learning the laws of nature, namely, methods of attaining “appearance of the maximum function under the minimum substance and energy consumption”, which the nature and living organisms have acquired through their evolution in long period. In the presentation, the education and research in the Nature COE will be discussed. This COE is opened for the outside of the university through an “Open-Cluster Program”, which is originated for promoting researches by 23 groups consisting of young researchers in and out of the university and also for fostering them, together with such educational programs for Ph.D. students as research incentive and overseas training programs. Through conducting these programs, world-highest intelligent fruits and a gathering of young minds for leading new fields will be expected.

12:00 PM Invited
Macromanagement of Metallurgical Industries: N. Lohja; Z. Lleshi; O. Gliozheni; Polytechnic University of Tirana; General Directorate of Mines; University of Tirana

Macro management of metallurgical industries becomes an important issue in certain situations especially when some government owned metallurgical
industries are on the verge or have stopped being feasible. In these cases a
government lead macro management is decisive in order to steer them to a
profitable path. This process is not necessary an easy one and incorporates
many unknowns and various alternatives. In this paper the macromanagement
of the metallurgical industries in Albania will be described as a particular case
and various published data will be analyzed. As a country with many mineral
resources, the exploration, research, exploitation and processing work of
mineral ores before 1990 constituted an important activity of its economy,
especially in the exportation of various products of this industry. Since 1990
this activity slowed down considerably for various reasons and this prompted
the necessity of a government lead macromanagement. This process aims
improving and renewing the technologies in the metallurgical industry in
order to transform it in to a feasible branch of economy. This goal is being
implemented among others through the transformation of the ownership from
a state-owned property to local or foreign private administrators. Priority is
given to the raising of the processing range of the traditional minerals such as
chromium, copper, nickel-iron etc. Some recommendations are also given.

This paper will present a description of the development and commissioning
of the world’s most efficient process for manufacturing high purity zinc
bromide. The method for making zinc bromide from metallic zinc and
bromine comprises contacting zinc with bromine dissolved in a reaction
solvent containing a metal halide salt. During the practice of this method, the
reaction temperature is maintained at less than 60°C. The reaction solvent
preferably comprises an alkali, alkaline earth or transition metal halide and
the halide salt preferably comprises a chloride or a bromide. One preferred
method includes the step of recirculating the zinc bromide product stream
back to the reaction vessel. The reaction vessel can comprise either a one
stage or a multiple stage reactor. The resulting product stream comprises
a high density zinc bromide solution. The process is so novel that it was

9:15 AM
New Process for Extracting Cadmium by the Ammonium-Ammonia
System: Liu Wei; He Jing; Tang Mo Tang; ‘Central South University
A new process for extracting cadmium from the electric precipitation dust
was studied. Leaching the dirt with NH3-H2O-(NH4)2SO4 system has got a
good result, the best leaching condition was: the ratio of liquid to solid=2.5,
[NH3]/[NH4+] = 3.5, total concentration of ammonium and ammonia >2.0 M/
L, leaching time: 1.5h, temperature: 35°C. Under this condition the leaching
rate of cadmium reached 90.99%; When the total concentration of Zinc and
Cadmium was up to 45g/L and the solution put static more than 17h, the most
troublesome impurity Lead could deposit automatically from the solution
without adding any reagent, the final concentration of Lead was 0.0047g/l,
the removal rate was up to 99%; The metallic Cadmium was prepared by
electro-winning, the best condition of electro-winning was: current density:
750A/m², total concentration of Cd²+ and Zn²+~25g/L, and the metal contains
Cadmium 99%, the current efficiency was about 82%, the energy consumption
for per ton cadmium is about 548kWh, the main impurities of the metal was Copper and Zinc, it could be got rid of in the pyrometallurgical
refining step.

9:40 AM Break

9:55 AM
Optimization of the Critical Steps of the Altair Hydrochloride Pigment
Process: Dirk Verhulst; Bruce Sabacky; Bob Wang; Jeffrey Lang; Douglas
K. Ellsworth; ‘Altair Nanomaterials Inc
The Altair Hydrochloride Pigment Process is a new “third route”, besides
the established high-temperature chloride process and the older sulfate
process, to manufacture TiO₂ pigment from ilmenite ore. It has been tested
at a scale of 5 t/day feed. The ore concentrate is digested in high-acid, high
total chloride solution (+/- 39% Cl). Titanium and iron both go into solution.
Iron is separated as FeCl₃, crystals after reduction and cooling. Titanium is
transferred by solvent extraction into a purified, high-Ti stream. It is spray-
hydrolyzed to produce a TiO₂ hydrate and further calcined with additives
into high-quality pigment. HCl solutions generated by pyrohydrolysis and
spray hydrolysis are treated by pressure-swing distillation to regenerate
HCl gas for re-injection into the digestion reactor. All chloride streams are
recycled. Recent work has concentrated on optimization, particularly in 3
areas: 1) solvent extraction: a new organic mixture, including a new diluent,
makes it possible to work at room temperature, to avoid TiO₂ hydrolysis
problems and to improve phase disengagement and impurity separation, 2)
pigment finishing: a systematic study of the parameters involved, followed
by long runs in the best conditions confirm pigment quality, 3) flow sheet
optimization: innovative modifications of the conditions of spray hydrolysis
and pyrohydrolysis, combined with re-routing of streams achieve significant
energy savings.

10:20 AM
Precipitation of Hematite from Ferrous Sulfate Solutions: Effect of
Variables on the Quality of the Precipitates: Maria Cristina Ruiz; Julio
Zapata; Rafael D. Padilla; ‘University of Concepcion
The removal of iron from the leaching circuits is a common problem in the
hydrometallurgical processing of non ferrous metals. Among the currently
available processes, hematite precipitation is the most recommendable from

New, Improved and Existing Technologies: Aqueous Processing II

Tuesday AM
August 29, 2006
Room: Boardroom West
Location: Catamaran Resort Hotel

8:00 AM Invited
On-Line Free Acidity Measurement in Hydrometallurgical Process
Solutions up to 250°C: A New Industrial Sensor: Ming Huang; Vladimirov
G. Papangelakis; ‘University of Toronto
An electrodeless conductivity-based sensor for on-line measurement of
free acid was recently developed at the University of Toronto. Because the
sensor does not have metal parts, its operation is corrosion-free. It has been
tested against literature data and compared to measurements made using a
previously developed contact-type conductivity cell, with an average
difference less than 1%. Several H2SO4 – MSO4 (M: Mg, Ni, Co, Mn)
solutions were also measured from 15 to 250°C at the equilibrium vapour
pressure and up to 50 g/L free H2SO4 and 1.4 mol/L total dissolved metal.
Consequently, a semi-empirical model has been developed to account for the
contribution to conductivity of metal sulphates and chlorides. This model
and sensor were further tested on-line during a pilot plant campaign of a new
hydrometallurgical process. The average difference between the measure
acid concentration from this sensor system and the one from titration was
less than 5%, which provides an excellent tool for quick and accurate free
acid measurements on line.

8:25 AM
Extraction and Recovery of Indium and Germanium from Primary and
Secondary Hydrometallurgical Streams Using Molecular Recognition
Technology (MRT): Ron Bruening; John Dale; Neil Izatt; Steven Izatt;
’IBC Advanced Technologies, Inc.
The use of Molecular Recognition Technology (MRT), a selective
separations technology using specifically designed ligands, has been
established as an effective process for removal of metal ions found in many
hydrometallurgical, chemical, and wastewater streams. The MRT process
has been proven to be highly efficient and effective for indium extraction
and recovery from zinc acid leach, electrolyte, chemical process and waste
streams. A high percentage of the Indium is recovered in a solid product
format. MRT has also proven effective for germanium extraction and
recovery from similar feed streams. This paper provides the indium and
germanium metal recovery flowsheets and analytical results of the metal load
and recovery steps.

8:50 AM
Highly Efficient Method of Manufacturing Zinc Bromide: Weyman
Dunaway; ‘TETRA Technologies, Inc.
Technical Program

10:45 AM
Precursor Synthesis of Fibrous and Porous Cobalt Powder by Coordination Precipitation Process: Chengyong Dong1; Chuanfu Zhang2; Jing Zhan3; ‘Central South University

Generally, cobalt powders used in cemented carbide, catalyst and battery manufacture are often spherical, and little study on the preparation of fibrous cobalt powders is carried out. Now, the fibrous precursor can be obtained by coordination precipitation process, using oxalate, cobalt chloride and ammonia. XRD pattern of precursor precipitated at pH=9.0 is different from that of $\text{Co}_2\text{CO}_3\cdot\text{H}_2\text{O}$ precipitated at pH=1.0 and indicates that the precursor powders are one type of cobalt complex. Based on the analytical results of E-pH and IR, it is concluded that the composition of the precursor is $[\text{Co}((\text{NH}_3)_x\text{H}_2\text{O})\text{CO}_3\cdot\text{H}_2\text{O}]_x$ (x=1.2). The SEM analysis shows that the initial Co2+ concentration, pH value and temperature influence the morphologies of the precursor powders. By using proper surfactant, the dispersion of the precursor powders would be improved. At last, the final product-fibrous cobalt powders which are about 0.3~0.5µm in size and 20~40 in aspect ratio were produced by thermal decomposition at 400~500 °C in the weak reducing atmosphere. With the escape of gas in the thermal decomposition process, such as NH3, CO, CO2, the porous cobalt powders were obtained.

11:10 AM
The Separation of Precious Metals from Base Metals in Gold-Antimony Alloy by Selective Chlorination Leaching by Controlling Potential: Tianzu Yang1; Wei-Feng Liu2; Ming-Xi Jiang3; ‘Central South University

In this work, a new hydrometallurgical method of the extraction of precious metals from the antimony-gold alloy — selective chlorination by controlling potential, has been investigated to substitute the previous pyrometallurgical method which has been unable to operate normally due to the increasing of the contents of base metals such as copper, lead and nickel etc. in the gold-antimony alloy. The experimental results show that the recovery of the metals such as gold, lead and antimony etc. increase and the production costs lower when the gold-antimony alloy is treated by the new method. The experiment results of selective chlorination leaching by controlling potential indicate that copper and nickel containing in the gold-antimony alloy can not be removed by the oxidation of hydrogen peroxide in sulfuric acid system, but in hydrochloric acid system the base metals such as copper, nickel and antimony can be oxidized completely and enter into the solution. The effects of the concentration of hydrochloric acid, the concentration of sulfuric acid, the liquid-solid ratio, leaching temperature, leaching time and oxidation potential in hydrochloric acid system on the leaching efficiencies of the base metals have been investigated. Under the following operation conditions: hydrochloric acid concentration [HCl]=4.0mol/L, sulfuric acid concentration [H2SO4]=1.2mol/L, liquid-solid ratio L:S=7:5, leaching temperature 80°, leaching time 2h, the oxidation potential 400±20mV, the leaching efficiencies of copper, nickel and antimony are over 99%. The leaching efficiency of silver and gold are 20% and 0.01% respectively.

11:35 AM
Isolation of Mineral Specific Extracellular Protein from Paenibacillus Polymyxa and its Application in Complex Sulphide Mineral Processing: Partha Patra1; ‘Indian Institute of Science

Extracellular bacterial protein (EBP) from Paenibacillus polymyxa was isolated. Adsorption of bacterial cells of Paenibacillus polymyxa as well as EBP onto pyrite, galena and sphalerite was studied. Both bacterial cells and EBP was found to have different adsorption density for different minerals. Protein from mineral surfaces were extracted and examined through SDS PAGE electrophoresis. Specific group of protein was found to be adsorbing, specific to respective minerals. EBP was fractionated through FPLC. Adsorption studies were carried out with each fractions. Difference in adsorption density was observed for individual minerals. Flocculation and flotation experiment were carried out with these mineral specific EBP. Pyrite was selectively removed from ternary mixture of galena and sphalerite through flocculation and flotation using pyrite specific EBP. Mineral specific EBP was found to selectively separate remove pyrite from the complex sulphide mixture. Zetapotential studies were carried out to examine the surface chemical changes of the minerals on interaction with EBP. Hydrophobicity of the minerals were carried out on interaction with bacterial cells as well as mineral specific EBP.

New, Improved and Existing Technologies: Iron Making

Tuesday AM
August 29, 2006
Location: Catamaran Resort Hotel

8:00 AM Keynote
Dust and Nanoparticulate Issues in Pyrometallurgical Operations: S. K. Kawatra1; ‘Michigan Technological University

A growing concern for pyrometallurgical operations is the generation of airborne particulates. These particulates can be generated by combustion processes, or by materials handling. Regulation of these particles by the EPA has become progressively more stringent, first for particulates finer than 10 micrometers (PM_{10}), which are particles fine enough to be inhaled into the lungs. Then, restrictions were introduced on emissions of particles finer than 2.5 micrometers (PM_{2.5}), which are fine enough to become embedded in lung tissues. The next stage of regulations is likely to be “nanoparticulates,” particles finer than 100 nanometers, which are in a size range where their absorption into the lungs is enhanced. While all of the health effects due to nanoparticulates have not yet been determined, there have been enough studies to indicate that there is a problem, and restrictions on nanoparticulate emissions are only a matter of time. In this paper, it will be demonstrated that dry handling, comminution, and combustion sources represent a significant concern for both PM and nanoparticulate emissions.

In regards to dry handling, the effects of utilizing effective dust suppressants on PM and nanoparticulate emissions will be explored.

8:25 AM Invited
Coke Strength and Tuyere Velocity: Morimasa Ichida1; T enhanced Nishimura2; Shinroku Matsuzaki3; ‘Nippon Steel Corporation

One of the most important points of the blast furnace stability operation is the condition with a high-productivity and high-rate pulverized coal injection is to expand the race way and to reduce the dead man area. The descent area expands and the center gas flow is maintained by reducing the above-mentioned dead man area. Then, the cold and hot experiments of race way furnace in which the tuyere velocity and coke strength were changed was executed and fine ratio generated from coke in raceway was measured. The equivalent relation between coke strength and the tuyere velocity concerning fine generation of coke in the race way was led based on the above-mentioned fine ratio and the idea of coke strength when the tuyere...
velocity rose was examined.

8:50 AM
Process, Quality and Management Control in the Operation of a Direct Reduced Iron Plant: Barbara Franco1; Alessandro Martinis1; Andrea Tavano; Alim Ullah2; 1Danieli & C; 2Nemur

In order to produce Direct Reduced Iron (DRI) at minimum cost and that meets quality requirements, various forms of control are necessary. In process control, the operators have to control the key process variables like gas composition, reduction temperature, etc., within the specified limits. Statistical Process Control (SPC) techniques can be used to assure that the quality requirements are maintained. One of the key features of SPC is that it separates the variations in quality because of natural causes from those resulting from assignable causes. Whereas the shift operators have to take corrective actions for assignable-cause variations, management intervention is necessary for reducing natural-cause variations. A properly designed and implemented accounting system can be a very useful tool for management to verify if standards are met and, if not, the reasons for deviations. The paper will discuss the key process variables and their effects on productivity and/or quality of the DRI produced. SPC techniques for monitoring the quality of DRI through measurements of metallization or equivalent metallization will be included in the paper. Finally, the paper will describe the implementation of a suggested standard system for analyses of variations, for example, in the consumption of raw material and energy, when they occur.

9:15 AM
Properties of Pig Iron Nuggets Produced Directly from Iron Ore Concentrate: Basak Ananmeric1; S. Komar Kowatra2; 1Michigan Technological University

The TIiK3 process is being developed by Kobe Steel as an alternative to the traditional blast furnace process. The pig iron nugget process utilizes coal instead of coke and self reducing and fluxing dried green balls instead of indurated pellets and sinters. The advantages of this approach are (i) the environmental emissions caused by coke production are eliminated, since coke is not needed for the process; and (ii) the elimination of the pellet induration (heat hardening) step of conventional iron production results in a considerable saving of energy. Pig iron nuggets were produced characterized to compare them with blast furnace pig iron. Pig iron nuggets were analyzed using density measurements, optical metallography, electron microscopy with local chemical analysis, bulk chemical analysis and microhardness measurements to determine chemical composition, degree of metallization, apparent density, and microstructure. It was determined that pig iron nuggets had high apparent density (6.7 – 7 g/cm³); were highly metallized, with a slag free structure; had a high iron content (95 – 97 %); and exhibited microstructures similar to white cast iron, which is essentially the same as pig iron from a blast furnace. This indicates that the pig iron nuggets are a competitive alternative to blast furnace pig iron.

9:40 AM Break

9:55 AM Keynote
Experimental Analysis for Thermally Non-Equilibrium State under Microwave Irradiations: A Greener Process for Steel Making: Motoyasu Sato; Akihiro Matsubara; Sadatsugu Takayama; Osamu Motojima; Kazuhiro Nagata; Kotoro Ishizaki; Tetsuro Hayashi; Dinesh Agrawal; Rustum Roy; 1National Institute for Fusion Science; 2Tokyo Institute of Technology; 3Research Institute of Industrial Products Gifu Prefectural Government; 4Pennsylvania State University

Highly pure pig iron can be produced from the 50–100 micron meter powdered iron ores with carbon as a reducing agent in the multimode microwave reactor. The grains in compacted powder absorb microwave energy selectively at microscopic level. It creates thermal non-equilibrium state microscopically and enhances chemical reactions and the phase mixing at the grain boundaries very rapidly. The visible light spectroscopy monitored the reactions. Upon the application of the microwaves with nitrogen atmosphere, the powders gets heated and radiates light according to the blackbody emission up to 650°C. The small non-equilibrium hot spots rise, move and finally burst to brighter emission to blackbody all over the surface at this temperature, that consisted line spectrums of CN and atomic Fe. The line spectrums oriented from CO molecules have not been detected yet. The solid-solid reaction could be expected between the iron oxides and carbon to produce CO2 directly. The loosing of sample weight was accelerated during the excess-emission. These are the clear evidence that microwave excites thermally non-equilibrium state and accelerates reduction process. The reduction finished at 1380°C and the very pure pig iron was produced. It contained with impurities of 1/20–1/10 of Mg, S, Si, P and Ti in comparison to the pig irons produced by modern conventional tall kilns in the steel industries. The necessary amount of carbon was 2/3 compared to conventional kiln to produce the unit weight of steel, if we applied renewable energy or nuclear power for the microwave excitations.

10:20 AM
Homogeneous Heating in Microwave Processing: Xiang Sun1; Jiann-Yang James Hwang2; Shangzhao Shi1; Xiaodi Huang1; 1Michigan Technological University

Microwave processing has been under continuous development as an advanced heating method in modern industries. However, problems with uneven heating still remain. Although heating uniformity is highly dependant on the properties of the materials being heated, proper furnace design to prevent uneven field distribution is another important factor. As an alternative to experimental measurements and adjustments to find appropriate furnace parameters, computer simulation is a convenient method for modeling, understanding, and improving the uniformity of microwave heating. This paper discusses current modeling technologies as well as applicable techniques for improving microwave heating uniformity. The purpose is to give a basic understanding on how to find, analyze, and minimize the problems associated with uneven heating in microwave processing.

10:45 AM Keynote
Evolution of Ironmaking: Joseph J. Poveromo1; 1Quebec Cartier Mining Company

Technical progress in ironmaking will be discussed in three sectors: blast furnace ironmaking, direct reduction and alternative ironmaking to feed electric arc furnaces and ironmaking for waste oxide processing. The contributions of iron ore producer, Quebec Cartier Mining, in each sector will be outlined. The relevance to ironmaking of the fundamental research in transport phenomena and chemical reactions of Julian Szekely and H. Y. Sohn will be noted.

11:10 AM
Development of the Coke Gas Desulfurization Technology: O. I. Platonov1; 1Gipronickel Institute, JSC

The process for cleaning of coke gas involving removal of hydrogen sulfide from coke oven gas in a regenerative “scrubber-stripper” system, with acid gas reporting to a Claus sulfur recovery unit (SRU) and tail gas being recycled in a raw coke gas scrubber, has been developed. The core problem of this process is the presence elemental sulfur in the SRU off-gas, which may deposit on gas drive equipments and blower and thus disrupt operation of the SRU. The new technology for treatment of the SRU off-gas developed for a Claus unit operating by «Russian Metallurgical Company» (Magnitogorsk, Russia) is presented. It includes a catalytic hydrolysis/hydrogenation step, where all sulfur-bearing components like sulfur dioxide and carbonyl sulfide are converted to hydrogen sulfide. The SRU treating off-gas at Magnitogorsk consists of three main units: gas pre-heater; catalytic hydrosulfurization reactor and waste gas cooler. The pre-heater is used to maintain a temperature level of the process gas required for catalytic conversion (beyond 330–350°C). Oxygen, utilized as an oxidizer, minimizes volume of the waste gas. The operational experience gained since July 16, 2004 shows that the new technology provides a deep purification of the Claus tail gas from elemental sulfur. As compared to the known SCOT process, the technology in question does not require separate stages of hydrogen sulfide removal and enrichment that simplifies its implementation at lower capital and operational costs.
Recycling process of inorganic wastes discharged from city life, such as incineration bottom ash and fly ash, has been developed. In this process, the stabilization of heavy metals, mainly lead, from the incineration bottom ash. Since the fly ash contains a large amount of chloride, heavy metals in the ash are easily chlorinated. On the other hand, the addition of the chlorination agent is a key point for applying this method to the bottom ash, because it hardly contains chloride. The effect of different variables such as a kind of chlorination agent, adding quantity of it and temperature on the elimination ratio was investigated and the harmlessness of the residual ash was evaluated. The preferable condition was proposed from the recyclability of the bottom ash.

9:15 AM Keynote
Anerobic Bioremediation of Metallurgical Wastes Using Organic/Water Emulsions: Robert W. Bartlett; Independent Consultant

Hazardous metal contaminants in liquid and solid wastes and from ground spills are important environmental problems in many metallurgical production operations. Acid rock drainage, from mines and huge quantities of permeable mine waste, is probably the most ubiquitous example. Fixing mine waste contaminants in situ has been practiced, using sulfate reducing bacteria (SRB) and organic reagents as electron donors to create anaerobic conditions and precipitate metal sulfides. Solubilities of hazardous metal sulfides are much lower than those obtainable with hydroxide or carbonate precipitation. Aqueous solutions of sugars and alcohol have been percolated into mine wastes with good results. However, maintaining anaerobic conditions permanently is unlikely, as these solutions are eventually washed out of solid waste and contaminated ground by inflow of either groundwater or meteoric water, allowing reoxidation from entering air. Emulsions of inexpensive, non-aqueous organic droplets dispersed in water provide earth wettability equal to aqueous solutions and easy percolation into both the ground and mine waste. Subsequent breakdown of the O/W emulsion provides permanent retention of the organic phase, attached to earth particles, that secures lasting anaerobic conditions, precipitates metals as sulfides and prevents re-oxidation of these sulfides. This process and its optimization are described, including experiments with sand-filled columns representing a vertical section through solid waste. Results of organic and metal retention in solid waste are provided from analyses of acid mine water drainage before and after waste treatment.

9:40 AM Break

8:00 AM Keynote
Halide Entrapment from Polymers Using Alkali Compounds: Scott A. Shuey; Josh Montenegro; Edgar E. Vidal; Patrick R. Taylor; Colorado School of Mines

The processing of post-consumer materials is an area being addressed by many industries and multiple engineering disciplines. While metal scrap and high-value uniform waste streams tend to find their way back to their respective parent processes, the more complex and low-cost ubiquitous materials, such as Polyvinylchloride (PVC) and Polytetrafluorethane (PTFE), tend to show up in many processing streams. From a metallurgical perspective, pyrometallurgical processing of a mixed metal/organic/oxide waste material allows for the recovery of thermal energy in conjunction with the recovery of metal values. The evolution of halogenic acids during elevated temperature processing can create complications with both the materials of construction of the processing equipment as well as gas stream processing. The need for dust collection coupled with a high acid content, necessitation high-volume scrubbing, increases the costs associated with gas handling. Control of the halides through entrainment as a solid in-situ during processing would simplify downstream processing. Alkali-halide complexes are being evaluated by researchers at CSM for mixed metal/polymer waste material treatment, recovering halogens as salt complexes.

8:25 AM
Stabilization of Heavy Metals and Chlorine Removal in Municipal Solid Waste Incineration Bottom Ash by Carbonation Process: Gi-Chan Han; Nam-II Um; Kwang-Suk You; Ji-Wan Ahn; Hee-Chan Cho; Korea Institute of Geoscience and Mineral Resources

In Korea, most Municipal Solid Waste Incineration (MSWI) bottom ash currently generated is landfilled, while in some European countries such as Germany, the Netherlands about 50% of the stockpiled MSWI bottom ash is used as secondary building material, in road construction. But bottom ash has the potential leaching of harmful cations and anions such as copper, lead, zinc, chlorine, sulfate, therefore, the final management of ash depends on regulatory requirements and disposal objectives. In EU countries, mainly in Germany, weathering of the bottom ash for a period of 3-6 months before their final disposal or their eventual utilization is the most commonly employed method due to its low investment and operation costs. In weathering period, oxidation, neutralization, dissolution and precipitation, especially carbonation are some of the reactions that can occur in the weathering of bottom ash undergo their most significant changes. But the weathering mainly plays an important role in diminishing the leaching of heavy metals, not anions such as chloride has been revealed by many researchers. In this study, the artificial carbonation with washing was used for the removal of union such as chlorine, and the stabilization of heavy metals. Environmental quality improvement of the bottom ash and generated wastewater characteristics were investigated according to the changes of flow rate of CO2(g), liquid to solid ratio, reaction temperature and so on.

8:50 AM Invited
Elimination of Heavy Metals from Municipal Inorganic Wastes by Chlorination Volatilization Method: Hiroyuki Sano; Hidemasa Kodama; Toshiharu Fujisawa; Nagoya University

Recycling process of inorganic wastes discharged from city life, such as incineration bottom ash and fly ash, has been developed. In this process, harmful components in such wastes are eliminated by a chlorination volatilization method, and then a stabilization treatment is conducted for residual harmful components. Finally, functional materials, such as humidity control materials, are produced from the harmfulness treated inorganic wastes. Elimination of heavy metals from the incineration fly ash by this method had been already investigated and the effectiveness of this method was reported. In this study, this method was applied to the elimination of heavy metals, mainly lead, from the incineration bottom ash. Since the fly ash contains a large amount of chloride, heavy metals in the ash are easily chlorinated. On the other hand, the addition of the chlorination agent is a key point for applying this method to the bottom ash, because it hardly contains chloride. The effect of different variables such as a kind of chlorination agent, adding quantity of it and temperature on the elimination ratio was investigated and the harmlessness of the residual ash was evaluated. The preferable condition was proposed from the recyclability of the bottom ash.
time on the volatilization behavior.

10:20 AM
Lead Removal from Contaminated Soil by Sequential Application of Chlorination by Mixed Salt and Water Extraction: Fumiatsu Sato; Hiroyuki Sano; Toshiharu Fujisawa; Nagoya University

In recent years, an increasing number of urban soil contamination cases have been found during redevelopment of former factory sites. Hydroclassification technique, separating heavily contaminated fine soil particles from contaminated sites, is one of the economical remediation techniques for contaminated soil by heavy metals, but the separated fine soil particles are generally landfilled because of the difficulty in removing strongly adsorbed heavy metals on them. In the previous study, the authors have investigated the mechanism and the optimum condition of chlorination-volatilization technique to eliminate heavy metals from inorganic waste and found it was needed to heat up around 1273K. In this paper, a new remediation technique for lead contaminated fine soil particles is proposed. This technique is composed of chlorination and subsequent warm water extraction. In the chlorination step, water-insoluble lead complex is chlorinated to be water-soluble lead chloride without volatilization, by heating the soils with MgCl₂-CaCl₂-KCl salt mixture at relatively lower temperature. By subsequent warm water extraction, lead chloride is leached out. Effects of chlorination conditions, such as time, temperature, composition of the salt and added salt ratio, on lead behavior were investigated. It was proved that lead concentration could be reduced below Japanese environmental standard.

10:45 AM
Treatment of Zinc-Containing Wastewater by Immobilized SRB Sludge with Inner Cohesive Carbon Source: Xiao Bo Min; Central South University

As for treatment of zinc-containing wastewater, traditional SRB (sulfate reducing bacteria) process was used, however, there exists two defects, like toxicity of heavy metal ions and high efficient COD (chemical oxygen demand) value. In this study, a new technique, called ISIS process (immobilized SRB sludge beads with inner cohesive carbon source), in which SRB sludge is embedded in carrier of PVA (polyvinyl alcohol) with carbon source that adsorbed on certain material, is put forward for the first time to overcome the two defects existing in traditional SRB process. Furthermore, it has been shown that compared to traditional SRB process, ISIS process increases average zinc removal rate up 30%, average sulfate reduction rate up 20%, and decrease average effluent COD value to meet discharge standards. If activated carbon is selected for carbon source adsorption and fixing material, and PVA for immobilization material, the zinc removal rate can reach above 98% under the conditions of 35°C and pH 6. Meanwhile, the mechanism of zinc removal has been determined according to the results from SEM (scanning electronic microscope) and XRD (x-ray diffraction). Project (50508044) supported by the National Natural Science Foundation of China.

11:10 AM
Waste Water Purification from Ions of Heavy Metals: Tamaz Lezhava; Jondo Gvelesiani; R. Agladze Institute of Inorganic Chemistry and Electrochemistry

The basic purpose of the research consists in clearing the waters polluted by ions of heavy metals, these waters are similar to quarry waters polymetallic deposit or waters–solutions of underground leaching of poor polymetallic ores. For this purpose new electrochemical ways and polymetallic deposit or waters–solutions of underground leaching of poor polymetallic ores. For this purpose new electrochemical ways and processes are investigated. Aqueous and Electrochemical Processing I

11:35 AM
A Chlorination Process Applied to the Recovery of Alumina and SiC Reinforcement from an Aluminium-Matrix Composite: Horacio E. Nassini; Ana E. Bohe; Comisión Nacional de Energía Atómica; Consejo Nacional de Investigaciones Científicas y Técnicas

Metal matrix composites (MMCs) have emerged as a novel class of materials for structural, aerospace, automotive, electronic, thermal management, and wear applications. Compared to unreinforced metals, MMCs present advantageous physical, thermal and mechanical properties, such as enhanced specific strength and stiffness, improved wear and creep resistances, and higher temperature capabilities. Discontinuous reinforced metal matrix composites (MMCs) have been gaining wide acceptance as important engineering material in automotive, aerospace, and electronic industries. Since the ceramic reinforcements are still quite expensive and contribute significantly to the MMC final cost, the feasibility of their recovery from the composite material scrap and further recycling is a factor of increasing interest. Chlorination process is an attractive method for the metal recovery from complex materials. The process which is performed at high temperatures, allows to turn all the metals contained in the material into their respective chlorides. In this particular case, the constituents of composite metallic alloy matrix can be transformed in gaseous chlorides and they can be dragged by the gaseous stream, while the ceramic reinforcement does not react and remain as a solid residue in the reaction bed. In the present work, a theoretical and experimental study is given for the recovery of Al₂O₃ and SiC particles and fibers from a commercial aluminum-matrix composite produced by molten metal mixing route. A thermodynamic analysis considering all the possible reactions with chlorine was firstly carried out, and then, the conditions for the optimum separation of the Al₂O₃ particles from the metallic matrix were determined by thermogravimetry.

Thermo and Physicochemical Principles: Aqueous and Electrochemical Processing I

Tuesday AM
Location: Boardroom East
August 29, 2006

8:00 AM
Chemical Modeling of Calcium Sulphate Solubility in Hydrometallurgical Process Solutions: Haixia Liu; Vladimíros G. Papangelakis; University of Toronto

Calcium sulphate precipitation, mainly as gypsum, during neutralisation of acidic hydrometallurgical process solutions can lead to excessive scaling problems. In this work, a self-consistent fundamental chemical model is presented based on the OLI software platform. The model employs the new Mixed Solvent Electrolyte activity model of OLI. A thermodynamic model database has been developed and calibrated on experimental data from sulphate and mixed sulphate-chloride solutions. The model predicts very well the solubility of calcium sulphate within a wide temperature range and can be used to assess the scaling potential of a particular process stream composition. The effect of temperature, acidity, chloride concentration, and divalent metal concentration on the solubility of calcium sulphate in multi-component process streams is also discussed.
Technical Program

8:25 AM
Hydrometallurgical Processing of Zinc Sulfide Raw Materials: Andrey V. Tarasov; E. M. Timoshenko; P. E. Romanov; Giintsvernet
Based on the data available in the literature and the practical experience of new metallurgical plants, a method has been proposed and relevant studies conducted for metallurgical processing of zinc sulfide concentrates. Process conditions and parameters have been identified, which ensure high levels of recovery of zinc into solution. This is achieved by leaching concentrates under the normal pressure at a temperature of ~90°C in the presence of ferric iron ions. Sulfide sulfur is converted to elemental sulfur in this process. To produce elemental sulfur it is necessary to maintain oxidizing conditions in the system, characterized by a positive Eh value. In order to eliminate the interfering effect of elemental sulfur formed in the process, it is possible to add surfactants into the concentrate pulp. The proposed technology has certain advantages as compared with the high-temperature pressure leaching and is considered as a basic technology to be applied to increase zinc production at one of the Russian zinc plants.

8:50 AM
Interfacial Emulsion Formation Originated from Organic Phase in Copper Solvent Extraction: Xiaorong Liu; Guanzhou Qiu; Yuehua Hu; Shanghai Institute of Technology; Central South University
Interfacial crud generated in copper solvent extraction is an unhomogeneous O/W emulsion that consists of organic phase, aqueous phase and solid particles. In order to determine what kind of components in organic phase promotes the emulsion, the organic phase separated from the interfacial crud provided by Dexion Copper Mine in Jiangxi, China was analyzed for its components by combined gas chromatography-mass spectroscopy. It is found that many kinds of emphiphiles containing such hydrophilic groups as carboxyl, carbonyl, or acylamine existed in organic phase, most of which were originated from the reagent degradation. Conclusively, Lix984N will degrade gradually during a prolonged contact with the acidic aqueous feed and strip reagents. Lix84 and nonylphenol, as effective components of Lix984N, degraded almost completely after long-term recycling. As a result, the effective components of Lix984N were far lower in concentration than the dense-aromatic impurities derived from diluent and the degradation products in total. The degradation of Lix984N would deteriorate solvent extraction, disengagement performance and result in more serious interfacial emulsion.

9:15 AM
Preparation of Gold Catalysts from Gold Dissolved in Aqua Regia: Eun Duck Park; Eun-Yong Ko; Kyung Won Seo; Min Kang; Jae Eui Yie; Ajou University
Gold unlike other noble metals such as platinum, palladium, and rhodium has been regarded as being an inert element for catalysis. This is closely related to the difficulty in preparing well-dispersed gold particles over supports. Since simple methods for preparing nano-sized gold catalysts are disclosed, lots of works have been reported on preparations and applications of gold catalysts. Most gold catalysts have been prepared form AuCl3 which is quite expensive to hinder its commercial application. Gold is recovered from numerous industrial sources as a metallic state. Therefore, this can be an economic raw material for gold catalysts. In this work, some preparation variables for gold catalysts from gold dissolved in aqua regia was examined. Its catalytic activity for CO oxidation was also studied. Gold catalysts were prepared by a co-precipitation method. The pH of an aequous solution of gold and metal precursors was adjusted by an addition of a base. The initial gold concentration, the final pH, an aging temperature, and the pretreatment condition were found to be critical factors for the active gold catalysts. These were closely related to the amount of residual chloride and the particle size of gold. Schwank J. Gold Bull. 16, 103 (1983); M. Haruta, Catal. Today, 36, 153 (1997).

9:40 AM Break

9:55 AM
Purification of Phosphoric Acid by a Mixture of Hydrophobic and Hydrophilic Extractants: Laila A. Guirguis; Hisham K. Foud; Fatma A. Salem; Nuclear Materials Authority
Impurities are removed from crude phosphoric acid (57.75% P2O5) with a mixture of low and high molecular weight alcohols, one of which is hydrophilic and the other is hydrophobic namely; methanol and hexanol. In a single stage, the phosphate values segregate to the high molecular weight alcohol fraction and the impurities segregate to the low molecular weight alcohol fraction. The optimum ratio for extraction is found to be 0.5 part methanol, one part impure acid and four parts hexanol where an extraction percent of more than 95% is achieved. Re-extraction of the phosphate value from the solvent is obtained by 6% phosphoric acid and the different factors affecting the re-extraction process have been studied. Finally, the purified acid is concentrated under reduced pressure and passed through activated carbon column, whereas the alcohols are re-circulated. The produced phosphoric acid was found to be in good match with the international specifications of food grade quality acid. A technological flow sheet is elucidated.

10:20 AM
Standard Fingerprint Pattern of Raman Spectrum of Octamolybdate Anion in Aqueous Solution: Daojin Cuo; Wen-Mi Chen; Bin Jiang; Hong-Zhao Liu; Central South University; Changsha University; Central South University
In the field of production of molybdate industry, octamolybdate is an important isopolyomolybdate formed by acidification of weak alkaline molybdate solution, which is obtained by extracting with ammonia from its roasted ores. The method of Raman spectroscopy is usually used to identify octamolybdate anion in aqueous solution. However, there have been more than four different type patterns of Raman spectrum of octamolybdate anion in aqueous solution reported in the previous papers using the method of comparison of Raman spectrum of solution with that of solid of known octamolybdate structure. That is to say, there has not been the direct standard fingerprint pattern of Raman spectroscopy of octamolybdate anion in aqueous solution. The authors have solved the problem by using Raman spectroscopy to measure saturated solution of ammonium octamolybdate hydrate crystal. Under the experimental condition controlled strictly, ammonium isopolyomolybdate hydrate crystal was prepared by using a set self-designed double-walled intermittent-type reaction device and the method of acid-sinking. The crystal was characterized to be ammonium octamolybdate hydrate crystal by Raman and FT-IR spectroscopy. By dropping a little distilled water to grain surface of the crystal and keeping solid-solution coexist for 24h, saturated solution of the crystal was prepared, and measured by Raman spectroscopy. The results show that the highest vibrant frequency of main characteristic Raman spectrum of the saturated solution is 966.2 cm⁻¹ and only smaller 0.9 cm⁻¹ than that of the crystal, and that the intensity of main characteristic Raman peak at 966.2 cm⁻¹ is weaker than that at 965.3 cm⁻¹, and that its main pattern characteristic can be described to be “double peaks with a weak-outside”. Standard fingerprint pattern of Raman spectrum of octamolybdate anion in aqueous solution has been thus established.

10:45 AM
Study on Phase Equilibrium and Physicochemical Properties of Me2+-NH4+-SO42—H2O System at 298 K: Chang-Hong Peng; Si-Guo Mu; Yi-Feng Chen; De-Wei He; Shao-Hua Ju; Central South University; Hunan Metallurgical Institute of Professional Technology
Solubility phase equilibrium in the ternary system of Me2+-NH4+-SO42—H2O (Me2+ represented Mn2+, Zn2+ and Fe2+) was studied by the isothermal method at 298K and physicochemical properties of the saturated solution such as density, refractive index and pH were also investigated. The experimental results show that the solubility isothermal phase diagrams of these systems consist of three invariant branches, two invariant points and three crystallization fields. Corresponding to the three crystallization fields, there have three phases of solid, that is MSO4·H2O, (NH4)2SO4 and (NH4)2Me(SO4)2·6H2O, respectively. At the eutectic point, the concentration and the refractive indexes of the saturated solution change evidently. Otherwise, the pH value change slowly in all the systems. The calculated results of the density and refractive index agree with the experimental results.
11:10 AM
Study on the Anodizing of AZ31 Magnesium Alloy in Environmental Friendly Electrolyte: Xia Yu; ‘Central South University

Anodizing behaviors of magnesium alloys AZ31 at constant applied current, based on the electrolyte solution free of chromate or fluoride, were investigated. The anodizing process was influenced by the electrolyte greatly. Therein, the oxylate salts played a determinant role which led to the occurrence of the two totally different processes, and they were stable and sparking process respectively. During the stable process, a brown thin film was formed, however the sparking process led to the formation of white hard thick film. The two kinds of films were both porous. The corrosion resistance tests showed that both the two kinds of films can improve anti-corrosion properties of magnesium alloys. The anodizing process was also affected many process parameters, such as the concentrations of electrolyte solution, applied current density as well as solution temperature, etc. And those factors had different effects on the two processes. High temperature benefited the stable process but had negative effects on the sparking process. The morphology of anodizing film was observed by SEM and the structure of film was analyzed by XRD. From the results obtained at different anodizing time, the mechanisms of film formation were revealed. The functions of some kinds of additives including some organic and inorganic materials, such as ammonia, glycercyl alcohol and PVP were also studied.

11:35 AM
Complex Treatment of the Tetrahedrite-Siderite Mineral Deposit in Silver Mária Bana, Slovakia: Juraj Schmiedt; F. Sekula; F. Molnár;
‘Technical University of Košice

Tetrahedrite and siderite are two main valuable minerals present in the silver Mária Bana deposit. The tetrahedrite concentrate prepared from it by flotation has certain specific properties from the metallurgical point of view. Siderite is concentrated in the flotation tailings. The paper presents results of the laboratory and pilot-plant testing of the combined hydrometallurgical and pyrometallurgical methods proposed for treatment of the tetrahedrite concentrate and siderite waste. The testing conditions were based on the thermodynamic analysis of the reactions that proceed in the process. The proposed technology makes it possible to separate copper from sulphur, mercury and iron in a straightforward way. Copper, after its refining, can be subsequently treated in the finishing operations. At the same time it is a valuable source of precious and noble metals. The siderite-containing flotation tailings can be converted to iron of the technical purity and slag. The proposed method is a good starting point for the development of the closed-cycle technology.

Thermo and Physicochemical Principles: Nano and Composite Materials II

Tuesday AM Room: Russeau West
August 29, 2006 Location: Catamaran Resort Hotel

8:00 AM Keynote
Synthesis of Compact Nanocrystalline Oxides by the Hard Plastic Deformations Methods: N. M. Chebotaev; A. Gedanken; B.A. Gihvezikii; A. V. Fetisov; A. Ya. Fishman; E. A. Kozlov; T. E. Kyrennykh; L. I. Leontiev; S. V. Naumov; A. M. Patselov; S. A. Petrova; V. P. Pilugin; V. B. Vyhodets; R. G. Zakharov; M. I. Zinigrad; ‘URAL Division of the Russian Academy of Science; ‘Bar-Ilan University; ‘Russian Federal Nuclear Center; ‘College of Judea and Samaria

The present work presents the original data concerning using a high pressure torsion method and a shock wave loading technique to produce compact oxide nanomaterials and investigations of the effect of severe plastic deformation on a microstructure, crystal lattice and stability of these compounds. This allowed us to compare two ways of deformation action that can be characterized as quasi-static and dynamic effect, correspondingly. Particular attention was paid to a stoichiometry and surface composition changes upon severe plastic deformations. A procedure for studying chemistry of the oxide nanomaterials by means of nuclear microanalysis and Rutherford back scattering has been worked through. For surface studies the X-ray photoelectron spectroscopy has been used. It was shown that both distortion methods permit to produce massive nano-scale oxide materials from the coarse-grained powder during a single technological cycle. Bulk nanocrystalline materials based on LaMnO₃, TiO₂, and ZrO₂/Y₂O₃ were obtained by the quasi-static deformation technique. Nanoscaled ceramics of CuO, MnO₂, and LaMnO₃ were produced by the dynamic deformations. The density of the nanoceramics comes to 99%. Size effects and specific imperfection of the nanoceramics obtained lead to a set of particularities of physical properties.

8:25 AM
Synthesis of Ultrafine Particles of Aluminum Nitride by Evaporation of Aluminum in Argon + Ammonia Gas Mixture: Seiji Yokoyama; Sadao Kokubo; Masahiro Kawakami; ‘Toyoohashi University of Technology

In this study, molten aluminum was evaporated in gas mixture of argon + ammonia to synthesize the aluminum nitride and to study the evaporation rate, which was production rate of the condensed particles, in a reactive gas flow. Experiments were carried out under various partial pressures of ammonia, temperature and total gas flow rate by using a levitation melting apparatus. The feature of this method is to produce the ultrafine particles of metallic compounds without impeding the vaporization of metal. The characteristics of the condensed particles were studied by TEM, XRD and analysis of concentration. The evaporation rate increased by addition of small amount of ammonia to argon, but it was constant even if the partial pressure of ammonia increased. In the region that the evaporation rate remained unchanged, aluminum nitride was formed. The aluminum nitride was polygonal, and mean size of it was approximately 50 nm, which was not influenced by the experimental conditions. The particles of metallic aluminum were also found. The ratio of aluminum nitride to the condensed particle was about 92 mass% judging from the analysis of concentration of nitrogen. The observation of TEM revealed that the particles of aluminum nitride formed by the reaction between the ammonia of the gas mixture and the aluminum particles that were formed by the condensation of aluminum vapor. Beyond some ammonia partial pressure of the mixed gas, aluminum did not vaporize due to a formation of aluminum nitride on the surface of the levitated aluminum.

8:50 AM
Synthesis of W, WC and WC-Co Nanopowders by Chemical Vapor Condensation Process: Jin-Chun Kim; Byoung-Kee Kim; ‘Korea Institute of Machinery and Materials

Research on nanomaterials has been fairly active in the last several years to develop new processes and apply them. The driving force has been the potential to obtain unique physical, mechanical, electric, magnetic and tribological properties. Various kinds of methods have been investigated and developed to synthesize nanostructured powders, their consolidation processes, nanocrystalline bulk materials and thin film materials. Non-agglomerated W-based nanopowders (W, WC, WC-Co) were synthesized by chemical vapor condensation process by using metal-organic precursors. Characteristics of the as-prepared W-based nanopowders with the carrier gases and reaction atmospheres were investigated. Consolidation of the WC and WC-Co nanopowders were conducted by the spark plasma sintering process and the conventional P/M process. Co in CVC WC-Co nanopowder showed intricate long-stand structure because of intrinsic magnetic properties of Co phase. The SPSed WC-Co nanocomposites provided better hardness than the that of the commercial submicron powders.

9:15 AM
CFD Simulation of Flame Spray Process for Silica Nanopowder Synthesis from Tetraethyloxysilicate (TEOS): B. Wan; Y. Ji; H. Y. Sohn; H. D. Kang; T. A. Ring; ‘University of Utah; ‘Korea Institute of Geoscience and Mineral Resources

The process to synthesize silica nanopowder by the gas phase thermal oxidation of tetraethyloxysilicate (TEOS) in a diffusion flame reactor was simulated using a commercial computational fluid dynamic (CFD) code. The
fuel combustion process and silica particle formation and growth in the flame are modeled. The temperature, velocity and particle size distribution (PSD) fields inside the reactor are computed. Chemical reaction rate and population balance model (PBM) were used to calculate the particle formation and growth and PSD. The final results are compared with experimental data.

9:40 AM Break

9:55 AM

Chemical Vapor Synthesis and Characterization of Aluminum Nanopowder as a Precursor of Hydrogen Storage Materials: Jin Won Choi; Hong Yong Sohn; Young Joon Choi; Gilsoo Han; Zhigang Zak Fang; University of Utah

Nanosized aluminum powder will be an important starting material for the preparation of several hydrogen storage materials due to low cost, light weight and high binding capacity for hydrogen. Nanosized aluminum powder was prepared by a chemical vapor synthesis (CVS) process in a tubular reactor. This CVS reactor was designed so that reactant powders can be fed into separate evaporators inside the reactor by means of specially designed powder feeders. This process for aluminum powder synthesis used a high-temperature reaction between a vaporized aluminum precursor AlCl3 and Mg vapor. After the product powder was collected by bubbling the off-gas through ethanol, the powder composition and grain size were determined as functions of the AlCl3/Mg ratio in the feed, residence time, and temperature. Titanium-doped aluminum powder has also been synthesized based on the reported improvement in the hydrogen storage properties of such a material. Doping was achieved by feeding titanium chloride into the reactor during the process of the aluminum-powder synthesis. The properties of the powders were subjected to various instrumental analyses.

10:20 AM

Enhanced Properties of High Capacity Nanostructured Metal Hydrides: Brady G. Butler; Jun Lu; Zhigang Zak Fang; Hong Yong Sohn; University of Utah

Many high capacity metal hydrides exhibit a high degree of stability in the hydrogenated state. This stability leads to a number of significant design problems with regard to the low temperature kinetics and thermodynamics of dehydrogenation. Nanometric metal hydride materials provide a promising route for increasing the reaction kinetics while altering the thermodynamic stability of the material. The use of nanometric metal hydride materials for hydrogen storage has largely been absent because of the difficulties associated with the synthesis of these materials. In this paper, research results on the synthesis of lithium based metal hydrides by vapor phase reactions are presented. The lithium based compounds that have been made in our lab include nanosized powders of metallic Li, LiNi, LiNH2, and LiH. The vapor phase process has also been used to custom engineer Li-based materials with other alloying elements or doping elements. The dependence of the characteristics of these materials on synthesis process parameters is studied. The effects of nanoscaled particle sizes on the kinetics of dehydrogenation and hydrogenation reactions are also explored.

10:45 AM

Hydrothermal Synthesis and Surface Modification of BaTiO3 Ultrafine Particles: Guo Jun; Li Qihou; Lui Zhihong; Central South University

Owing to its excellent dielectric and piezoelectric performance, barium titanate ultrafine particle is widely applied in multi-layered ceramic capacitors, electro-optical apparatus, thermal varistors, piezoelectric switches, nonlinear varistors, as well as electric power converters, etc. In this study, BaTiO3 ultrafine particles surface-modified with stearic acid are synthesized by the hydrothermal method in a system of BaCl2-TiCl4-NaOH. The effects of original pH value in solution, temperature, time, concentration of reactants on structure and morphology of barium titanate ultrafine particles are investigated experimentally. The formation mechanism of different crystallite BaTiO3 particles is discussed, and it is considered that in a hydrothermal system, the main factors determining BaTiO3 crystallite are H+ replacement of Ba2+ causing H+ deficiency and anatase growth units involving in crystal growth, which clogs the axial channel for Ba2+ transference. By means of increasing the alkalinity of system and barium content, H+ deficiency and involvement of anatase growth units in crystal growth could be effectively controlled. The results show that when mole ratio of NaOH to TiCl4 is 10 and ratio of Ba to Ti 1.8, and time 8 hours, high purity tetragonal BaTiO3 ultrafine particles with a narrow grain-size distribution and nonporous surface are obtained at 240°C. The particles have excellent flowability, which is ascribed that the surface polarity of barium titanium powder modified with stearic acid is changed and the interaction between the particles is weakened.

11:10 AM

Vaporization Behavior of Group VIA to VIIIA Crystalline Carbonyls: Dhanesh Chandra; K. H. Lau; University of Nevada; SR1 International

Metal carbonyls are of great importance in chemical vapor deposition (CVD), composite materials fabrication, and other near-net shape technologies. Carbonyl CVD application applies to deposition of high-purity metallic/ alloy coatings. Vapor pressures of solid Os8(CO)24, Rh8(CO)17, Ru6(CO)18, Ir8(CO)18, Re6(CO)18, Os4(CO)18, Cr6(CO)18, and W(CO)6 carbonyls have been measured using gravimetric-torsion effusion system. The vapor pressure data is used for many low and high temperature CVD applications. Interesting decomposition/disproportionation vaporization behavior has been noted for Rh8(CO)17, Ru6(CO)18, and W(CO)6. The vaporization studies of Rh8(CO)17 showed virtually complete decomposition to Rh metal and the measured molecular weight of the effusing gas from the solid Rh8(CO)17 was 27.75 g/mol, close to that of carbon monoxide as compared to 1065.56 g/mol for the value of solid Rh8(CO)17. Electron microscopic characterization, X-ray line broadening results for Rh carbonyl has been performed on the vaporization product. However, Ru6(CO)18, Os4(CO)18 showed very complex behavior. The molecular weights of the vaporizing species have been estimated and the numbers of vaporizing species are proposed. For example, there was partial decomposition of Ru6(CO)18 to approx. 52% metallic Ru and CO gas during vaporization, as suggested by the difference in the molecular weight of the vaporizing species of 1075.8 g/mol compared to the actual value of 639.33 g/mol. The dimer Co3(CO)8 partially disproportionate to tetramer Co6(CO)18, monomer Co(CO)4, and CO gas. Whereas, the Os8(CO)24, Cr6(CO)18, and W(CO)6 have shown virtually no disproportionation. The total vapor pressures of all the above-mentioned carbonyls, partial pressures of various species, average molecular weights of the effusing gases, equilibrium constants for the vaporization reactions, their enthalpies, entropies, and Gibbs energies will be presented. Program funded by U.S. Bureau of Mines and NSF.

11:35 AM

Development of Copper Based Metal Matrix Composites by Powder Metallurgy Method: R. Thiraviam; T. Somakumar; A. Senthilkumar; Sethi Institute of Technology; Thigagaraj College of Engineering

Cu-Al2O3 composite has been attracting researcher’s interest in recent years, since it can provide many advantageous characteristics. Cu-Al2O3 composite materials are extensively used as materials for products, which require high thermal and electrical conductivities, high strength and excellent resistance to high temperature annealing such as electrode materials for lead wires, relay blades, contact supports and electrode materials for spot welding. The main requirement for these materials is a homogenous distribution and small size of oxide particles in the copper matrix. In our experimental study, Cu-Al2O3 (10-20 vol %) composite powders were prepared by powder metallurgy route namely high-energy milling, compacting and sintering at temperature of about 5500°C and furnace cooled. The fracture toughness, vicker’s hardness and corrosion resistance was evaluated. SEM, AFM and optical microscope examination was carried out samples with different conditions. The studies revealed that the alumina particles dispersed in copper matrix enhance the mechanical properties of the copper-alumina MMC. The fracture toughness of the copper-alumina MMC (20% vol) increases with increasing alumina content. Corrosion test and wear test were also conducted to predict the corrosion and wear resistance. It showed a drastic improvement in corrosion and wear resistance. The fracture toughness of copper - alumina MMC increased with increasing density factor. In summary the copper – alumina MMC has better mechanical properties than the base metal.
The interaction parameter, $W$, being 2.7 kJ/mol. Enthalpy of SO$_2$...characterised by the DSC thermograms via TA Q10 DSC Instrument.

8:00 AM Keynote

Activities of Lead and Zinc Oxides in CaO-SiO$_2$-FeO$_2$-Al$_2$O$_3$, Slag: Katsunori Yamaguchi$^1$; Shigeru Ueda$^1$; $^1$Iwate University

The zinc, lead and alumina contents in copper smelting slag are increasing with the increase in waste recycling. The recovery of base metals such as Zn and Pb from copper converter slag is important from both an economical and environmental perspective. As a fundamental study of the metal recovery by reduction process, activity coefficients of ZnO and PbO in the CaO-SiO$_2$-FeO$_2$-Al$_2$O$_3$, slag under iron saturation at 1573K are derived from the data of slag-metal equilibrium experiments. On the basis of the obtained data, the activity coefficients of ZnO and PbO in the CaO-SiO$_2$-FeO$_2$-Al$_2$O$_3$, slag were compared with those of the CaO-SiO$_2$-FeO$_2$ ternary system.

8:25 AM

Liquid Miscibility Gap in the Ag-Ge S System: Huerman Eric$^1$; $^1$University of the Witwatersrand

The high temperature liquid miscibility gap in the Ag-Ge-S pseudobinary portion of the Ag-S system has been redetermined by very carefully conducted equilibration-quenching experiments. Samples were contained in evacuated and sealed silica capsules. The stratified liquid phase compositions were obtained by chemical analysis. The miscibility gap extends from 12.8 to 33.3 atomic percent at the monotropic temperature of 906°C and closes at around 1250°C. Thermodynamic properties of the liquid solutions, including the limiting activity coefficient of sulfur in molten silver were expressed analytically by using the sub-regular solution model which proved to be in excellent agreement with the experimental findings.

8:50 AM Invited

Solubility of SO$_2$ in Na$_2$SO$_4$ Melts and Thermochemistry of the Na$_2$SO$_4$-Na$_2$S$_2$O$_3$ System: Ray Y. Lin$^1$; John F. Elliott$^2$; $^1$University of Cincinnati; $^2$Massachusetts Institute of Technology

Solubility of SO$_2$ in Na$_2$SO$_4$ melts at temperatures between 1160 and 1250 K under gas mixtures of SO$_2$, O$_2$ and argon was investigated applying a thermogravimetric analysis technique. Together with the activity of NaO in the melt determined with a high temperature electrochemical cell, thermochemistry of Na$_2$SO$_4$-Na$_2$S$_2$O$_3$ melts was investigated. Results showed the SO$_2$ solubility in molten Na$_2$SO$_4$ increases with decreasing temperatures. Together with data from Flood and Forland (1947) at 828-928 K, it was concluded that the Na$_2$SO$_4$-Na$_2$S$_2$O$_3$ melt behaves as a regular solution with the interaction parameter, $W$, being 2.7 kJ/mol. Enthalpy of SO$_2$ dissolution in molten Na$_2$SO$_4$ was calculated to be -137.71 kJ/mol for infinite dilute solutions. The only other data found in the literature on thermodynamics of this system (Koskin et al. 1975) was excluded from further analysis since their data appeared to have included points in the two phase region.
Thermo and Physicochemical Principles: Steel Making; Liquid Steel Processing and Reactors

Tuesday AM
August 29, 2006
Room: Russeau Suite
Location: Catamaran Resort Hotel

8:00 AM Keynote
Oxidation and Decarburization in TRIP Steels: Tamara L. Baum1; Richard J. Fruehan1; Sridhar Seetharaman2; Carnegie Mellon University
External oxidation during in-line heat treatment of TRIP steels can cause problems for the subsequent coating process. This research aims to understand the kinetic rates of internal oxidation, external oxidation and decarburization and their interdependence under different gas atmospheres and temperatures. A steel sample containing 0.14 wt. % C, 1.8 wt. % Mn, 0.6 wt. % Si and 1 wt.% Al was used initially. Thermogravimetric techniques are used to examine the net mass change in a sample during heat treatment, and the results show an initial mass decrease and later an increase, indicating decarburization is initially faster than oxidation. Additional interrupted experiments were done to obtain samples for carbon and metallographic analysis. The dependence of these rates of mass change on the water vapor content in the gas phase is quantified and compared to theories predicting oxidation and decarburization.

8:25 AM
Colesman is Used as Flux Agent in Steel Production: Levent Ozmen1; Erk Inger1; National Boron Research Institute
In this study coesmite [CaB2O4·5H2O] is used as flux agent in steel production. Dissolving velocity, metal-slag reactions and the solubility of (MgO)in the slag are all investigated. The coesmite is a mineral containing varying amounts of (B2O3) mainly found as boron source in Türkiye and USA.

8:50 AM
Determination of Optimum Calcium Carbide for Deoxidation of Slags: R. Javier Santiago1; Luis A. Mombello1; Electrometalúrgica Andina S.A.
The lack of information on calcium carbide reaction mechanisms in steel production, leads to erroneous concepts about the evolved phases and also causes distrust when using this powerful deoxidant in the steel industry. This paper tries to find answers for numerous questions as to which is the optimal quality needed (calcium carbide content) to obtain the best results. The paper will focus on the follow-up of different deoxidants operations in the different steel makings and will try to determine if the eutectic points, due to their lower fusion points, influence its reduction capacity and verify if eutectic calcium carbide reacts in a more efficient manner while reducing iron and manganese oxides. Also the grain size variable will be analyzed and its influence on the carbide’s reactivity and reaction time with the slag and foam generation. This is a very important variable to keep in mind, because it is supposed that the bigger grain sizes develop lower reaction rates, directly affecting the treatment time.

9:15 AM
Continuous Cooling Transformation Behavior of an As-Rolled Dual Phase Steel with Low Carbon and Low Alloy: Tao Li1; Yumei Pu1; Guang Chen1; Jianping Zhang1; Jian Zhang2; Nanjing University of Science and Technology; Technological Center of Maanshan Iron and Steel Company Limited; Nanjing University of Science and Technology
The development of DP (Dual Phase) steels and TRIP (Transformation
Induced Plasticity) steels has received much attention in recent years due to their high strength and simultaneous good ductility, which provides the potential for weight reduce and resource savings on certain components in automobile or other industries. So a controlled rolling process was simulated in the present study by thermomechanical simulator (Gleeble1500) for producing DP steels on a kind of low carbon steel containing a small amount of Si and Cr. The F+M dual phase microstructure has been obtained during continuous cooling processes of a wide cooling rate range from 10K/s to 60K/s. The grain size of the dual phase steel developed can be refined to less than 5 microns through the mechanism of deformation induced ferrite (DEF) transformation. The ultrafine ferritic grains are equiaxed with high-angle boundary, and the martensite islands of an average size less than 5 microns disperse uniformly in the ferrite matrix. The ultrafine martensite islands not only inhibit the growth of ultrafine ferritic grains and improve the bonding of F/M interface, but also increase remarkably the strain hardening rate in the processing of the present Dual-Phase steel. As a result, the tensile strength of ultrafine grained Dual-Phase steel reaches higher than 1000 MPa. The result shows that an ultrafine grained Dual-Phase steel of low carbon and low alloy is promised to exhibit desired F+M microstructure by means of this new TMCP process.

9:40 AM Break

9:55 AM Keynote

A Fundamental Study of Oxygen-Melt Reactions in the AOD Process: David G. Robertson; Gantasala Satyanarayana Rao; ’University of Missouri

Leveraged drops of Fe-18%Cr-2%C were reacted with oxygen-argon mixtures to study the reactions that occur in the AOD process, where the gases are injected into the melt and form bubbles. In the laboratory an argon-oxygen pulse, followed by pure argon, was flowed past the levitated drop to simulate the transient conditions in the gas phase as the bubbles rise in the melt. Oxide layers formed on the drops immediately when they came into contact with gas pulses containing 75% or more oxygen. Once the oxygen flow had ceased, the oxides reacted with the carbon in the drops to form CO gas and eventually disappeared. The de-carburization reaction occurred without oxide formation when the gas contained 50% oxygen or less. Melts that were sampled after EAF tapping, ready to be charged into the AOD, showed a higher tendency to oxide formation and consequent carbon boil than pure ternary Fe-18%Cr-2%C alloys made in the laboratory. The actual steel samples contained significant impurities, such as 0.25% Si and 0.56% Mn. A similar effect of oxide-forming impurities had been observed previously with binary Fe-C alloys. Movies were taken of the oxide formation and decomposition, and the results will be presented, along with data on the experimental conditions, including temperature and oxide compositions. The results are important because they give an insight into the reaction mechanisms in the AOD, which must be understood in order to improve and model the process.

10:20 AM

The Use of Calcium Carbide in Steel: R. Javier Santiago; Luis A. Mombello; ’Electrometalúrgica Andina Saic

The normal methods of steel production produce oxidizing slags in the electric furnace (or in the converter) and reducing slags in the ladle. During the tapping of the furnace part of the slag is normally carry over to the ladle, which is the primary carrier of iron and manganese oxides. The oxides present in the slag are found in equilibrium with the oxygen in the steel. Later, the steel is deoxidized in order to reduce the oxygen activity level to a lower level, below the equilibrium with the slag. Consequently the slag is a potent source of oxygen during the refining operations, for which reason, it must convert this oxidizing slag into reducing slag and in this way, avoid future steel reoxidation. Calcium carbide is an acetylene which produces acetylene by hydrolysis. It is a potent reducing agent used in the production of acetylene gas, for the desulphurization of cast-iron and in slag treatment of steel (secondary metallurgy). This paper focuses on the analysis of the use of calcium carbide in slag treatment, in order to understand the intervening reaction principles, as well as to offer steel producers a summary of the advantages of this powerful deoxidant which permits conversion of the oxidizing slag (from the ladle) into reducing slag, achieving improved steel quality and obtaining a decrease in alloy consumption.

10:45 AM

A Study of Droplets during Top Lance Blowing: Annie Nordqvist; Anders Tillander; Pär Jönsson; Gunilla Runnsjö; Kaj Grönlund; ’Volvo Powertrain Sweden; ’Royal of Technology; ’Outokumpu Stainless Avesta Works; ’CORR-CONTROL

Laboratory trials were performed in an induction furnace to study droplet formation during lance blowing. Compressed air was blown on a molten iron bath consisting of iron alloyed with carbon and silicon. Steel droplets were collected using a specially designed sampler. The average steel droplet composition and the oxide layer thickness were determined using scanning electron microscopy combined with energy dispersed spectroscopy. In addition, the concentration gradient of elements was determined using a microprobe. It should be noted that a specially designed technique had to be developed in order to prepare the droplet sample. The size distribution of the droplets was also determined using the microprobe. It was found that the carbon content in the droplets was lower than the carbon content in the hot spot area and the bulk. The decarburization rate however was the same for the droplets as for the hot spot area and the bulk.

11:10 AM

Experimental Study on the Simultaneous Desulfurization and Denitrification by Duct Injection: Qin Hui Li; ’Tianjin Northern China Geological Exploration Bureau

The highly active absorbent with oxidation based on fly ash, lime and additive was prepared. Experiments of simultaneous desulfurization and denitrification were carried out using fixture bed and duct injection. The influential factors for the absorptive capacity of the absorbents were studied. The absorptive capacities of 120.7 mg for SO2 and 43.7 mg for NOx were achieved at a Ca/(S+N) molar ratio 1.2, respectively, corresponding removal efficiencies of 87% and 76%, while spent absorbent appeared in the form of dry powder. The optimal temperature and humidity of flue gas treated with this process were shown to be approximately 50°, and 5% respectively. The mechanism of removal for SO2 and NOx was investigated. In comparison with traditional dry FGD, this process appears to have lower cost, less complicated configuration and simpler disposal of used absorbent. The valuable references can be provided for industrial application by this process. The foreground of application will be vast in China and in the world.

11:35 AM


It is known for a long, that the reaction of oxygen with carbon, silicon, iron and many other elements is exothermic. The heat of released from these kind of reactions can decrease the time of fusion of iron steel for metallurgical purposes in the electrical arc furnaces. By decreasing the time of fusion, we increase the rate of process and the amount of production. So, by blowing oxygen in to the furnace, we can reduce the consumption of electricity and save money. There are many problems in the procedure of the oxygen blowing. In this project, we investigated the theoretical aspect of the oxygen blowing and its side effects into the arc electric furnaces. We also set up and oxygen blowing System in to the arc electrical furnace of metallurgy department of Machine Sazi factory. This process reduced the consumption of electricity up to 22% and increased the rate of production, by reducing tap – to – tap time up to 15% in this project; we also created all oxygen blowing systems and its control.
Hot metal flow and heat transfer in a blast furnace hearth significantly affect the hearth wear. Due to difficulty to make measurements inside the hearth during operation, computational fluid dynamics (CFD) has been identified as a useful tool to elucidate the internal state of the blast furnace hearth. In this research, a 3-D CFD model has been developed. It includes a complete real geometry including deadman, hot metal flow domain, blowing layer, skulls, refractories, ram, and steel shell. Convection boundary conditions are specified on the outside surface of the steel shell and bottom. It can simulate non-uniform refractory thermal conductivity distributions and thermal connections, as well as actual asymmetric wear profiles. It can simulate both steady and unsteady sate as well as both laminar and turbulent flows. It can include species calculations as well as multiphase (hot metal and slag) flows to predict detailed profile of the liquid level during tapping. It has been extensively validated using both laboratory experimental data and plant measurements. It has been used to analyze the velocity and temperature distributions and wear patterns. Parametric studies have been performed to evaluate the impact of geometry and operating conditions. In this paper, the development of the 3-D CFD hearth model will presented and discussed along with detailed validations and several applications on existing blast furnaces.
maximum position of microwave reflection is easy to contract. It is expected that this new technology could detect the raceway collapse phenomena in short time and that the stability of raceway in coal injection is different from that in all coke operation. Secondly, the reduced stockline surface profile was measured by the reflection intensity of microwave struck from the furnace top after blow-off with stockline reduced, and investigation was made on the countermeasures for changes in the raceway depth and furnace body profile during operation. As a result, it has been clarified that flow-down of coke into the lower part of blast furnace and inflow into the raceway are greatly subject to the existence of deadman which is the packed structure of the lower part of furnace, and further, they are closely related to dynamic behavior of the raceway, and affect changes of the furnace body profile.

4:40 PM Invited
Numerical Analysis on Blast Furnace Operations by Multi-Dimensional Mathematical Model Based on Multi-Fluid Theory: Jun-Ichiro Yagi1; Hiroshi Nogami1; Mansheng Chu1; Tohoku University

A mathematical model has been developed for simulating the blast furnace operation with carbon composite agglomerates charging based on multi-fluid theory and reaction kinetics. In this model, the behaviours of carbon composite agglomerates are considered based on previously reported experimental research and conservation equations, and reduction rate of carbon composite agglomerates is introduced. A series of calculations are performed to examine the effect of charging carbon composite agglomerates. The model calculation gives two-dimensional distributions of process variables and information on the overall operational parameters. It reveals that in-furnace temperature levels significantly decrease and the reduction of carbon composite agglomerates is retarded with carbon composite agglomerates charging ratio. The furnace performance is remarkably improved with the increase in carbon composite agglomerates rate. The productivity tends to increase while coke rate and total reducing agent rate show decreases at the different degree.

5:05 PM
Numerical Investigation of the Self-Reduction Process of Pellets in a Rotary Kiln with Post-Combustion to Produce DRI: Jose Adilson Castro1; Cyro Takano2; Marcelo Breda Mourao2; Jun-Ichiro Yagi3; Alexandre Jose Silva3; Federal Fluminense University; 4University of Sao Paulo; Tohoku University

The growing demand of scrap to supply the electric arc furnace has driven to search for new alternatives of raw material. The DRI produced using self-reducing pellets has become competitive due to the potential use of a wide range of carbonaceous materials such as coal, charcoal, biomass etc. In this context, the rotary kiln process using improved technologies such as post-combustion and self-reducing burden is a promising source of high quality raw materials. This paper presents a mathematical model of the rotary kiln process designed for self-reducing pellets and post-combustion. The model is based on the transport equation of two-phase flow, energy and mass transfer. The solid material is composed of a typical self-reducing pellet. The model considers the solid phase (C, volatiles, Fe2O3, Fe3O4, FeO, Fe, H2O, SiO2, Al2O3, MgO, P2O5, K2O, Na2O, CaO and gangue) and the gas phase (N2, O2, CO, CO2, H2, H2O, SO2, SO2 and SiO). For each of the above components a conservation equation is solved and the mass and energy transport is accounted. The set of differential equations are coupled by the rate equations describing the kinetics of the several reactions, which take place within the rotary kiln. All the conservation equations are solved based on the finite volume method applied for a three-dimensional cylindrical coordinate system. Simulation results are presented for global parameters such as metallization degree, productivity, gas utilization ratio and calorific value. Inner conditions such as three-dimensional gas and solid temperature pattern and compositions are discussed.
Technical Program

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difficult-to-handle material such as scrap anodes and purchased scrap copper. Recent experience with designing, building, and starting up an ISASMELT facility, applied in primary smelting of copper concentrates, has led the authors to speculate on how suitable the ISASMELT process would be for copper converting, given its low fugitive gas release and its ability to accept a variety of feed types. This paper reviews the potential metallurgical challenges posed by converting copper matte in an ISASMELT vessel and considers possible engineering and design challenges posed by the inclusion of this technology into a new or refurbished copper smelter.

2:45 PM Invited

Technical Innovations in the Mitsubishi Process to Achieve Four Years Campaign: Toru Taniguchi; Teruyuki Matsutani; Hideya Sato; 1Mitsubishi Materials Corporation

The existing Mitsubishi Process line at Naoshima Smelter and Refinery has been operating successfully since 1991, and its present production capacity is 270,000tpy of copper. Furnace relining works have been carried out every two years to coincide with the compulsory bi-yearly boiler inspection, but the next target is to extend the furnace refractory life to four years, while still undergoing the mandatory boiler inspection every two years. Although the damage of hearth bricks beneath lances in the Smelting furnace was a matter of concern, it was reduced by controlling gas velocity and evening solid distribution to each lance. The life of bath level bricks in the Converting furnace was also a concern, four-years continuous use of the bricks was achieved in the course of the last two campaigns. Several other improvements were also carried out to the cooling systems during the shutdown in 2005 to ensure longer campaign life. This paper summarizes recent improvements implemented to enhance the advantages of the Mitsubishi Process.

3:10 PM Break

3:25 PM Invited

ISASMELT - 6,000,000 TPA and Rising: Philip S. Arthur; 1Xstrata Technology

The ISASMELT process is a submerged lance smelting technology operating in smelters in Australia, the USA, Belgium, India, Germany, Malaysia and China. Further plants are under construction in Peru and Zambia. Following the invention of the Sirosmetal lance technology Mount Isa Mines recognized the potential in the novel top blown bath smelting process and embarked on a development program that has lasted more than 25 years. After successful operation of pilot plants and demonstration plants producing copper and lead, Mount Isa Mines decided to license the technology to external companies. Since the purchase of Mount Isa Mines by Xstrata in 2003, Xstrata Technology has assumed responsibility for transferring the technology to ISASMELT licenses. In the 15 years since the first commercial furnaces started operation plants have been constructed (or are under construction) with a combined annual smelting capacity of more than six million tonnes of concentrates or secondary raw materials. Process development continues on the commercial scale plants at Mount Isa and elsewhere. Many of the improvements implemented by plant operators have been passed on to, and adopted by, other licensees. Exchange of ideas and technical improvements occurs through ad hoc visits to fellow licensees and through regular licensee workshops arranged by Xstrata Technology. This paper updates the reader on the status of various ISASMELT plants either operating or under construction. It highlights the role that the technology provider’s operational experience plays in ensuring that new smelting plants ramp up quickly to nameplate capacity.

3:50 PM Invited

Inco Flash Furnace Froth Column Modifications: Jin Liu; Malcolm H. I. Baird; Paul Kenny; Brian Macnamara; Ahmad Vahedi; 1Inco Ltd; 1McMaster University

In the early 1990’s, Inco successfully installed two new flash furnaces as part of their SO2 abatement project to reduce SO2 emissions from the Copper Cliff Smelter by 60%. The flash furnace off-gas is cooled and cleaned through two new Monsanto Dynawave gas cleaning systems that replaced the traditional venturi scrubbing system. It was discovered that the flash furnace production capacity is often limited by the capacity of the gas cleaning system. The key task is to eliminate pressure drop from the system. The froth column is responsible for by far the largest pressure drop in the gas cleaning system. Initially, the column was fitted with 22 plates. In 1994, both #1 and #2 froth columns were modified by reducing the number of plates in each column from 22 to 18 and increasing the interplate spacing on lower plates. With increasing demand for more throughput in the flash furnaces, further modifications on the froth columns were made in 2005. This paper describes these modifications and results together with some fundamental analysis of the froth column characteristics.

4:15 PM Invited

Direct Blister Copper Smelting Process – Outokumpu’s Methods to Increase Feasibility: Esa J. Peuraniemi; Markku Lahtinen; 1Outokumpu Technology

Copper smelting to form blister in one single step has always been possible. In spite of obvious benefits, it has been economically viable only with few special concentrates having high enough Cu/Fe and Cu/S ratio. Outokumpu Blister Flash Smelting is currently applied at three operations, and two others will be commissioned in near future. With typical chalcocite concentrates two main obstacles have prevented wider adaptation of direct blister processing: slag formation and heat generation. Oxygen potential in the reaction shaft must be high in order to produce blister as sulphur content is targeted around 0.2%. If large amount of iron is oxidized, as well as sulphur, inevitably copper is oxidized also into slag. High copper content of slag as well as substantial tonnages of slag derive to costly recovery operations to obtain discardable slag. Almost complete oxidation of sulphur and iron releases high amount of heat that traditionally has been solved by lowering oxygen enrichment of the blast deriving to oversized off-gas line and acid plant. One challenge in direct blister smelting relates to the attack of aggressive high-copper containing slag against furnace refractory lining. In continuously operated Outokumpu Direct Blister Flash Smelting this is taken care with even solids feeding. Stable settler enables the stationary slag against refractory lining to create a protective autogenous layer between aggressive slag and vulnerable refractory. These direct blister smelting challenges are addressed from equipment and process development point of view and, new solutions to overcome them are presented and discussed.

4:40 PM Invited

The State of the Art in Nickel Smelting: Direct Outokumpu Nickel Technology: Tiuula Mäkinen; Pekka A. Taskinen; 1Outokumpu

In 1959 Outokumpu started up a nickel smelter and refinery at Harjavalta. The flash smelting – Peirce-Smith converting route was applied, and the converter matte was further refined to nickel cathodes. In 1995 the production capacity was increased from 17 000 mt/a to 52 000 mt/a, based on the Direct Outokumpu Nickel Smelting Process (DON). The additional refinery capacity is based on hydrogen pressure reduction, producing nickel powder and briquettes. In the DON technology, high-grade nickel matte with low iron content is produced in the flash smelting furnace directly without converting. The metal values in the smelting slag are recovered in an electric furnace as an iron containing Ni-matte. The mattes produced differ from the conventional nickel mattes, and therefore focused R&D efforts have been made in order to cope with their melting points, fluidities and settling properties. The low melting points of the high-grade nickel mattes produced in the DON furnace have pointed out challenges in the furnace design, in particular in the hearth and its thermal engineering. Also key issues of the DON technology are smelting of high-magnesia concentrates, the recoveries of nickel and copper, as well as those of PGM’s and cobalt. This paper deals with the experience of the DON technology gained over the first ten years of operation, including the significant environmental impacts. Selected results of the thermodynamic modelling of the mattes and high-magnesia slags are reviewed. Also the design principles of the FSF and EF are discussed.

5:05 PM Invited

Two-Zone Vaniukov Furnace: New Opportunities for Copper and Nickel Production: M. V. Knyazev; A. G. Ryabko; L. B. Tsybulev; L. S. Tsemekhin; 1Gipronickel Institute JS

New method for processing of copper and nickel production feeds has been developed and tested at pilot unit with 10 t/hr capacity. The process allows
Technical Program

Single-stage treatment of ore feed, including the one with high magnesium oxide content, resulting in the production of rich matte, high-grade matte, or metallized alloy for further leaching, dump slag and off-gases suitable for production of elemental sulphur, liquid sulphur dioxide or sulphuric acid. Results of testing and principal technical and economical parameters are presented.

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Legal, Management, and Environmental Issues: Management of Environmental, Recycling and Waste Treatment I

Tuesday PM  Room: Kon Tiki Ballroom  Location: Catamaran Resort Hotel
August 29, 2006

1:30 PM Keynote
Environmental Improvements at Onsan Smelter: Kyung-Soo Jeong; Han-Gil Kim; Seung-Ho Shin; ‘LS-Nikko Copper Inc.

Since the start-up of Onsan Smelter in 1979, LS-Nikko Copper has grown into the competitive smelter through continuous development. Carrying out several environment improvements, especially the intensive investment for reducing SO2 emissions has been executed, such as de-sulfurization plants, fugitive gas capturing, TMS. In addition, LS-Nikko Copper has spent more than 10 million USD every year for improving the environmental condition recently. To be global leading smelter in every aspect especially in environment, LS-Nikko Copper plans to inspire environment-friendly mind, co-operate with shareholders, and participate in global convention. This paper describes what we have done improvements in environment conservation at Onsan plat and briefly introduces sustainable vision to the most green smelter.

1:55 PM
Environmental Issues in Drying Copper Sulfide Concentrates: Shaolong Chen; Hannu J. Mansikkaviita; ‘Kumera Corporation

To enhance the smelting furnace performance, the copper sulfide concentrates are normally dried prior to feeding into the furnaces. In both direct heated rotary dryers and flash dryers the hot gas is used as heating medium to dry the concentrate. The hot gas may need to be cleaned when it is produced from fossil fuels containing high sulfur. If the anode furnace gas is used, then the pollutants in the hot gas are not just sulfur dioxide but also un-burnt hydrocarbons generated during the reduction phase. The hot gas passing through the dryers starting from temperature of several hundred degrees centigrade can cause sulfur oxidation of copper sulfide concentrate in presence of oxygen in the gas. Selection of steam dryers for this kind of conditions would be an ideal solution to avoid polluting the process gas as drying is done with indirect contact to the steam at relatively low drying temperature and high water vapor content in dryer off-gas. The emission can be significantly reduced. The off-gas cleaning units are also simple and small.

2:20 PM
Solution of Environmental Safety Issues at a Zinc Plant: V. V. Geykhman; Gl. A. Kazanbayev; P. A. Kozlov; V. A. Lukyanchikov; ‘Chelyabinsk Zinc Plant

1. Air pollution abatement: the CZEP complies with the regulatory maximum permissible concentrations (MPC) of 39 pollutants released to the atmosphere with air emissions. The use of fluxing additives in the Waels process and modernization of gas treatment equipment makes it possible to reduce the dust content in off-gas to the MPC level (5 mg/Nm³) and the sulfur dioxide content down to 1 g/m³. Use of advanced catalysts in the sulfuric acid manufacture process ensures stable autotrophic performance of the process, a conversion efficiency of at least 99.8% and the residual sulfur dioxide content at the outlet of the system of not more than 0.05%. 2. Protection of water bodies: overall water re-use system and water recycling systems in the main shops of the plant ensuring a water re-use degree of 95.6%. 3. Solid waste: all types of waste generated in the process of zinc concentrate treatment (i.e. lead and copper-containing residues, copper-containing Waels slag, sludge from wastewater treatment facilities and from the acid plant) are treated to produce commercial-grade products and semi-final products sold to consumers.

2:45 PM
Environmental Problems of Metallurgical Plants in Polar Regions and Ways for Their Solution (Norilsk Region as an Example): Andrey V. Tarasov; L. I. Leontiev; Zh. I. Rozenberg; ‘Gintsvetmet; ‘A.A. Baikov Institute of Metallurgy; ‘Norilsk Nickel

Emission of sulfur-containing gases causes most adverse impact on the natural environment in the process of nonferrous metals production. Under the conditions of Polar regions, in particular in the region of the Norilsk Mining and Metallurgical Complex (Russia), this problem requires a special approach taking into account potential economic and socioeconomic consequences. By reducing the iron sulfide content of flotation concentrates by using new flotation reagents inhibiting pyrrhotite flotation and by applying advanced process flowsheets for flotation it is possible to increase the nonferrous metals content of flotation concentrates by 5% or more along with a corresponding reduction in SO2 formation during their subsequent pyrometallurgical processing. The ways can be used to resolve the environmental problems in the Norilsk region in the process of nickel and copper production, are based on the improvement of methods for elemental sulfur recovery from metallurgical off-gas by non-conventional techniques, the sulfur recovery from metallurgical gases by production of liquid sulfur dioxide and the technology for pyrometallurgical treatment of sulfurine concentrates without SO2 formation. Another opportunity is the development and commercial introduction of hydrometallurgical technologies for treating copper-nickel sulfide ores.
Technical Program

Tuesday PM

4:15 PM

The Formation of Cr(VI)-Containing Stainless Steel Plant Dust and the Stabilization Thereof: Andrie Mariana Garbers-Craig; Guojun Ma;
University of Pretoria; Wuhan University of Science and Technology

The entrainment of charge materials, evaporation or volatilization of elements and ejection of slag and metal by spitting or the bursting of gas bubbles are mechanisms whereby stainless steel plant dust are generated from the electric arc furnace and refining converter. TCLP and ASTM D 3987-85 tests on dust that was collected from the baghouse filter system of a South African Stainless Steel plant showed that this dust can be considered hazardous according to South African legislation, due to the high degree of Cr (VI) leachability (~1.3mg/l for TCLP and ~8mg/l for ASTM vs. regulation threshold of 0.05mg/l in drinking water). The dust is therefore considered to be harmful to both the environment and human health, due to its high solubility in water and carcinogenic properties. It should therefore be treated before being stockpiled or land filled. This paper consequently describes an investigation into the formation of Cr(VI)-containing stainless steel plant dust and the stabilization thereof in a sintering process, whereby the dust was mixed with a silica-rich clay. It is postulated that Cr(VI) form when the (Mg,Fe,Mn,M,Cr)3O4 spinel phase, Ca(OH)2 and CaF2 (all of which are present in the dust) react. This reaction was found to take place both at ambient and at high temperatures (1100°C). Stabilization of Cr(VI) in the dust could be achieved at an optimum sintering temperature of 1100°C for a 50mass% dust : 50mass% clay mixture. Chromium emission during sintering was found to be within environmental limits.

4:40 PM Invited

Environmental Impact of a Metallurgical Complex in Soil Contamination: A. Cullaj1; B. Hoxha1; A. Cullaj2; University of Tirana; University of Elbasan

During a period of 15 years the metallurgical and chemical complex of Elbasan containing more than 15 principal plants, producing cast-iron, steel, coke; nickel carbonate, nickel, cobalt, chromium and other products, discharged into air, river water and soil an extensive amount of hazardous wastes containing high toxic substances. A monitoring study for the levels of heavy metals in soils nearby the former plant is carried out for the first time. Very high levels (total and extractable) of contaminants nickel, cobalt and chromium are found in samples taken from a relatively waste territory including the city of Elbasan, situated 8 kilometres far the plant. The most polluted samples present a total content of about 2000 mg/kg Ni, 180 mg/kg Co and 3000 mg/kg Cr. These levels exceed several times the phytotoxic thresholds and present a potential hazard for the inhabitants. Several possible ways of remediation are also discussed.

5:05 PM

Effective Bacterial Reduction of Hexavalent Chromium under Alkaline Conditions: Wenjie Zhu1; Liyuan Chai1; Ji-Whan Ahn1; Sun-Hee Cheong1; Hyun-Seo Park1; Korea Institute of Geoscience and Mineral Resources

Hexavalent chromium is a widespread environmental contaminant. An Achromobacter sp. strain nominated Ch-1 can reduce soluble and toxic chromate to the insoluble and less toxic Cr(III) in aerobic cultures, no Cr(VI) decrease was observed in anaerobic cultures. In contrast to other chromium(VI) reducing microorganisms, Ch-1 showed higher chromium(VI) reduction at high pH. Reduction performed under alkaline conditions at pH 7 to 11, optimum is pH 10. During the reduction, pH decrease observed may caused by production of acidic metabolic byproducts from aerobic respiration. In the present study, the ability of Achromobacter sp. Ch-1 to reduce Cr(VI) during growth was evaluated with lactate as an electron donor. In NB medium, Ch-1 reduced 100% of 24mM of Cr(VI) in 35h, but only 73% of 30mM of Cr(VI) after 48h of inoculation. Reduction was inhibited by metal ions like, Ag+, Cu2+, Zn2+, slightly inhibited by Mn2+, and not effected by Mg2+. Results revealed that reduction of Cr(VI) also increased with the increasing of concentrations of lactate, complete reduction was achieved at the concentrations above 4g/L. HPLC analysis demonstrated Cr(VI) reduction was associated with the consumption of lactate. There was a large quantity of dark blue sediment generated in the culture during Cr(VI) reduction by Ch-1. Energy dispersive X-ray (EDX) analysis showed that the major element composed the formed sediment is chromium presented as Cr(OH)3 precipitate. The features characterized Cr(VI) reduction by Achromobacter sp. Ch-1 are high Cr(VI) concentrations and high pH.

New, Improved and Existing Technologies: Aqueous Processing III: Preparation and Synthesis

Tuesday PM
August 29, 2006
Room: Boardroom West
Location: Catamaran Resort Hotel

1:30 PM
Preparation of High Functional Aragonite Precipitated Calcium Carbonate: Jeong-Hwan Kim1; Ji-Whan Ahn1; Sun-Hee Cheong1; Hyun-Seo Park1; Korea Institute of Geoscience and Mineral Resources

The liquid-liquid reactive process (solution process) is often adopted as a synthetic method of precipitated calcium carbonate (PCC) in a laboratory study because of its simplicity in the operation or its easiness in the control of process variables. Also the effects of characteristics of limestone ores as a raw material in the synthetic system of PCC on the synthetic characteristics of PCC have been investigated. The purpose of this study is to synthesize the aragonite precipitated calcium carbonate by the solution process using Ca(OH)2 slurry and Na2CO3 solution as main reactants. In the synthetic systems, in order to control of the nucleation rate, shape factor was considered as the most important factor. Single phase aragonite PCC could be synthesized under a variety of controlled experimental conditions such as ionic strength, solution composition, concentrations of additive ions and temperature. The pure aragonite was synthesized by adding the Na2CO3 solution to the Ca(OH)2 slurry containing several concentrations of NaOH solution at 75°C and under the addition rate of Na2CO3 at 3ml/min. The formation yield of calcite decreased when the NaOH concentration was increased. In conclusion, in the case of the reaction of the 2.5M NaOH solution over 210minutes, single-phase aragonite with an aspect ratio of 20 was obtained.

1:55 PM
Preparation and Characterization of Ultrafine Magnetite Powder: Yang Xi Yun1; Central South University

Ultrafine 0.1µm (µm) spherical magnetite powder was prepared successfully by hydrothermal reaction of ferrous sulfate and sodium hydroxide with activated pyrite as reducing agent in the temperature range 120-140°C. XRD and XPS analyses indicate that pH value and pyrite amount have a direct influence on the composition of the product. Stoichiometric Fe3O4 can be obtained only when pH value is 12 and the molar ratio of pyrite/ferrous sulfate is 1:1.8. The hysteresis loop of Fe3O4 shows a ferromagnetic behavior with a saturation magnetization of 75.2 emu/g and a coercivity of 1520e.

2:20 PM
Preparation and Structural Characteristics of Cobalt-Modified Magnetite: Yang Xi Yun1; Central South University

Magnetite was prepared by hydrogen reduction method. For a conversion to cobalt-modified magnetite, the magnetite particles were suspended into a solution containing Co2+ and Fe2+ to precipitate a cobalt ferrite layer on the surface. pH value influences the particles composition directly, the desirable CoFe2O4 is obtained as pH value is 12. The coercivity increases with the increase of cobalt content, cobalt efficiency reaches a maximum value at cobalt content of 2.71wt%. With cobalt modification, the magnetite particles have the similar lattice constant and squareness ratio to that without cobalt modification. TEM and XPS analyses indicate that the acicular morphology is retained during the coating process, the epitaxial growth layer consists of CoFe2O4 and 0.3Co2O3-CoFe2O4 at cobalt content of 2.71wt% and 5.03wt%, respectively.
The ultrafine, monodispersed, spherical cobalt powder has been fabricated by reducing cobalt hydroxide with glycol. It were investigated that the effect of NaOH concentration on the reaction rate and the effects of the concentration of cobalt hydroxide and surfactant on the morphology and particle size. The particles were characterized by the X-ray diffraction (XRD), scanning electron microscope (SEM), laser diffraction particle size analyzer and BET specific surface analyzer respectively. The XRD shows that the cobalt powders exist mostly in face centered cubic (fcc) structure, a little in simple hexagonal. The cobalt powders prepared at Co(OH)₂ – 2.150g/L, NaOH 40 g/L, and surfactant 30g/L, its average particle size, specific surface area and cobalt content, were 0.88µm, 2.705m2/g, and more than 99.5% respectively.

3:10 PM Break

3:25 PM
Synthesis of L(+)-Calcium Lactate Using Precipitated Calcium Carbonate in Lactic Acid Fermentation: Sun Hee Cheong1; Ji Whan Ahn1; Jeong-Hwan Kim1; Choons Han1; ‘Korea Institute of Geoscience and Mineral Resources; ’Kwangoon University

The objective of this study was to synthesize the L(+)-calcium lactate using precipitated calcium carbonate in lactic acid fermentation. Generally, precipitated calcium carbonate (CaCO₃) has three types of polymorphism such as calcite, aragonite, and vaterite. It occurred abundantly in several natural minerals and it is used in large amounts in the rubber, plastics, pulp and paper industry. Usually, precipitated calcium carbonate is not used as calcium source in food and drug industry contrary to a shell, hen eggshell, ostrich eggshell and whey calcium in Korea. The reason why precipitated calcium carbonate has little absorption rate in itself and that is lack of high technology applied to the food chemistry. In our preliminary study, we synthesized precipitated calcium carbonate by reacting calcium hydroxide with sodium carbonate in solution process. Calcium lactate is the most widely used as salt of lactic acid with high absorption rate and used to the food and drug chemistry as a calcium additive and/or tissue reinforcing agent in variety of processed agricultural products and pickled foods. Generally calcium lactate has two racemates such as L(-)-lactate and D(-)-lactate. Especially, it is well known that L(+)-lactate is more soluble than D(-)-lactate and L(+)-lactate is generally produced from lactose by homo-fermentative lactic acid bacteria such as Lactococcus spp. Lactobacillus planatarum, Lactobacillus casei, Lactobacillus curvatus and Pediococcus spp. Therefore, we can expect to manufacture the L(+)-calcium lactate from lactic acid combined with precipitated calcium carbonate using bioconversion in progress of lactic acid fermentation.

3:50 PM
Preparation of Monodisperse Rhombohedron-Type Nickel Oxalate Particles from a Highly Condensed Nickel Hydroxide Suspension: Zhihong Liu1; Qihou Li1; Kan Ai1; Duomo Zhang1; Takashi Okamoto2; Masazumi Okido2; ‘Central South University, ’Nagoya University

Monodisperse micron size nickel oxalate particles with rhombohedron morphology were prepared from condensed nickel hydroxide suspension by a novel gel-sol process proposed by one of the authors. Firstly, condensed nickel hydroxide gel was formed by fast adding 1 mol dm⁻³ NaOH solution into 0.2 mol dm⁻³ nickel chloride solution, and then oxalic acid solution with a concentration of 0.25 mol dm⁻³ was dropped into the gel dropwise through a pump with a pH controller at preset pH value, and in this step, nickel hydroxide gel was converted gradually into monodisperse nickel oxalate sol. The formation of the nickel oxalate particles was found to proceed through a dissolution-recrystallization mechanism from the nickel hydroxide gel. The product particles exhibited a rhombohedron shape with micron size long axis and sub-micron size short axis. The effects of such factors, as temperature, surfactants, et al., on the particles sizes and morphologies, were evaluated experimentally.

4:04 PM
Separation of PET from PVC by Column Flotation: Elsa Agante1; Inácio Rodrigues1; Teresa Carvalho1; ‘Instituto Superior Tecnico

Recycling of solid wastes, a common practice nowadays, requires, to increase products value added, the separation of the different materials. The separation of one plastic from mixtures of different types of plastics is not easy due to their similar physical properties, but different techniques are available, from automatic sorting systems based on optical sensors to techniques adapted from mineral processing, namely gravity, froth flotation and electrostatic processes. In the last decade, many researchers have addressed the separation’s problem of different polymers. One proposed technique is the classical froth flotation performed in agitated cells. Froth flotation is a versatile and relatively cheap process widely used in mineral separation. It is based on the different behavior of particles in the presence of an inter-phase air-water, which depends on the materials surfaces properties. Froth flotation can be affected by some variables such as impeller speed and air flow rate. Agitated cells, when used with low density materials, like plastics, can produce over-stated turbulence that prevents the adhesion and collection of particles in the froths. In this case, separation is favoured by column flotation smoother hydrodynamics. This paper proposes the separation of PET from PVC by column flotation. The experimental work was carried out in a column of 9mm diameter and 1m high. The effects of some operating conditions, such as depressors concentration, pH and proportion of plastic in the mixture (feed grade) on products grade and recovery were evaluated and the best flotation conditions for complete separation between these plastics were established.

5:05 PM
Separation of Pyrite Minerals from Magnetite Slimes by Hydrophobic Floculcation: Rasool Hejazi1; Bahram Rezaei1; Abbas Sami1; ‘Amirkabir University; ’Shahid Bahonar University

Fine particles float poorly and less-selectively under normal flotation conditions. One of the promising methods for fine minerals is the utilization of the principle of Floculation. Hydrophobic floculation flotation (or floc flotation) was tested on a magnetite concentrate that was finely ground to be micron particles, for producing a concentrate with sulphur grade less than 0.1%. After that, slurry dispersing with water glass as dispersant, pyrite fines were subjected to hydrophobic floculation induced by xanthate and a small amount of kerosene then the slurry was transferred to a flotation cell for recovering the hydrophobic flocs. The experiments carried out indicated that through one-step rougher and two-step cleaner flotation, sulphur grade was reduced from 1% to 0.1%. It has been found that the separation efficiency of the floc flotation process closely correlates with the main parameters of hydrophobic floculation such as xanthate addition, conditioning time and kerosene addition.
New, Improved and Existing Technologies: Non-Ferrous Processing I

Tuesday PM
August 29, 2006
Room: Toucan
Location: Catamaran Resort Hotel

1:30 PM Keynote
Aluminum Extraction in Ionic Liquids at Low Temperature: Venkateswarulu Kamaravaram; Ramana G. Reddy; University of Alabama

Ionic liquids are novel salts used as potential non-aqueous electrolytes for aluminum electrolysis at low temperatures. In the present research di-alkylimidazolium chloride ionic liquids such as 1-butyl-3-methylimidazolium chloride ([BMIIM]Cl) and 1-hexyl-3-methylimidazolium chloride ([HMIM]Cl) were investigated for aluminum electrolysis. The melt formed by mixing ionic liquid with AlCl₃ is termed as chloroaluminate melt and is composed of several polymeric chloroaluminate anions. Ionic liquids were studied as electrolytes for aluminum electrowinning and electrorefining of aluminum based materials (A356, A360, and Al-MMC) at low temperatures. Experiment of parameters such as temperature, applied voltage and concentration of electrolyte on electrorefining process was studied. High purity aluminum (>98%) deposits were obtained on copper cathode. At a cell voltage of 1.0 V vs. Al/Al(III), the energy consumption for electrowinning aluminum alloy (A356) was about 3.0 kWh/kg-Al. Low energy consumption and no pollutants emission are the main advantages of this process. Mechanism of aluminum electrodeposition in these chloroaluminate ionic liquid electrolytes was investigated using cyclic-voltammetry and chronoamperometry techniques. Aluminum electrodeposition on copper substrate in AlCl₃-[BMIIM]Cl melts was found to be quasi-reversible process with a charge transfer coefficient of α = 0.40. Chronoamperograms obtained at voltages in the range (-0.1 to -1.0 V) revealed that the initial stages of aluminum deposition was instantaneous nucleation followed by diffusion controlled growth of three-dimensional nuclei. The diffusion coefficient of electroactive species AlCl₃ in these melts was found to be 6.5 × 10⁻⁹ cm² s⁻¹ from Cottrell equation and 3.9 × 10⁻⁹ cm² s⁻¹ from the dimensionless current-time transients.

1:55 PM
A Comparison of Conventional Copper Anode Furnaces with the New Elliptical Anode Furnace Concept: Michael Potessier; Helmut Antrekowitsch; Hans Rinnhofer; Uwe Zulehner; University of Leoben; Maerz-Gautschi Industrieanlagenbau GmbH

In the primary and secondary copper industry the anode furnace is the most important process step in the refining procedure to reach an enhancement in value and quality of copper by selective oxidation and reduction. By combining the advantages of the conventional tilting hearth furnace and the benefits of the drum type furnace a new aggregate was developed and patented. The cross-section of the furnace is elliptical and the whole unit is tiltable. During the melting period the contact surface between the burners and the bath or the scarp is enlarged – resulting in an increased energy input. For the refining period the furnace is rotated, guaranteeing a high bath level. Due to the longer residence time of the gas in the copper melt, not only the gas consumption is reduced but also the efficiency of the refining process is improved. This investigation shows a metallurgical comparison between the new anode furnace concept with the elliptical cross section and the conventional, tiltable hearth anode furnace as well as the drum type anode furnace. The reduction of the amount of contaminants was calculated by thermodynamic programs and supported by CFD modeling. The investigation covered the refining of blister copper from primary metallurgy, from secondary metallurgy as well as from a mixture of both copper melts. The paper underlines the possibilities for a reduction of the tap-to-tap time and for an increase in production capacity, which can be achieved by applying the new furnace concept in comparison to the conventional furnaces.

2:00 PM Invited
Development and Creation of Modern Metallurgical Technology for Antimony Production with Gold Recovery from Domestic Gold-Antimony Concentrates in Russia: Andrey V. Tarasov; F. A. Myzenkov; Gintsvetmet

The technology developed by the authors uses new methods for raw material smelting in electric furnaces, a new autogenous method and apparatus for subliming smelting for antimony trioxide production and separation of antimony and gold. Concentrate produced from the ore deposits in Yakutia has the following average contents of main constituents, % by weight: 29.4 Sb, 1.2 Fe, 13.1 S, 40.0 SiO₂, 0.2 As, 2.6 CaO and 45 g/t of Au. Unlike the technology used abroad a new autogenous method makes it possible to increase considerably specific capacity and reduce loss losses with antimony trioxide by several times. At the same time mineralogical composition of trioxide has improved considerably – it has mainly a cubic base with prevalence of senaranmorite. The content of a main component (Sb₂O₃) in the final product has increased from 99.0% up to 99.6% which means better quality and makes it suitable for use in special technologies. Despite a lower antimony content of the concentrate (22.4% as compared with over 33% as common in the world practice), an antimony recovery of 85.3% into a commercial-grade product has been achieved, as well as a gold recovery of 96.65% into a gold-antimony alloy. The technology for processing gold-antimony materials developed and introduced at the Ryaztsvetmet plant is unique in the world with respect to gold recoveries.

2:45 PM Invited
Developments with Imperial Smelting Process: Roger W. Lee; Roger Lee Consulting

The commissioning of the first full-scale Imperial Smelting Furnace in 1950 was a technological breakthrough in the pyrometallurgical smelting of zinc offering significant advantages over the existing retort processes. However, for most zinc concentrates the electrolytic zinc process continued to be more economical. Therefore, the ISP specialised in treating concentrates that were less amenable for treatment by either the electrolytic zinc process or the lead blast furnace. Subsequently, improved mineral processing techniques led to a decrease in the availability of these concentrates so the smelting of secondary materials assumed greater importance. This led to the development of techniques such as hot briquetting and tuyere injection. In 2002 over 1 million tonnes of zinc and 400,000 tones of lead were produced by the Process. However, in the 2002-3 the economics of the Process became extremely difficult because of low metal prices and increased operating costs. This resulted in the closure of four ISP smelters in 2003 and two in 2005. Nevertheless, two new ISP smelters are scheduled for commissioning in China in 2006 where local economic conditions continue to favour the process. It is considered that the future of the process is closely linked to its ability to consume secondary materials and an examination will be made of its potential for conversion to 100% secondary operation. Apart from a reduction in raw materials costs, a substantial reduction in operating costs would ensue from not operating sintering and sulphuric acid plants.

3:10 PM Break

3:25 PM Keynote
Furnace Cooling Design in Pyrometallurgical Processes: Performance, Selection and Application Criteria: Karel Verscheure; Andrew Kevin Kyllö; Andreas Filzwieser; Bart Blanpain; Patrick Wollants; University of Melbourne; METTOP Metallurgische Optimierungs GmbH

Reliable furnace cooling technology is a domain of increasing concern to the pyrometallurgical industry as it can significantly increase process intensities, productivity and campaign times of furnaces. Although there are many advantages in using cooling systems, they also impose a variety of problems mainly related to safety, heat losses and sustainability of the operations. The choice of cooling system is hence a matter of trade-offs and differs for every metallurgical application. This paper gives a review of different cooling designs used in the metallurgical industry, their performance and the safety aspect of different designs are discussed more in detail.
A fundamental study was conducted on a new process for producing scandium (Sc) metal or aluminum-scandium (Al-Sc) alloy by the carbothermic reduction of scandium oxide (Sc₂O₃). In this study, aluminum (Al) and calcium chloride (CaCl₂) were used as the collector metal and flux for the reduction, respectively. A mixture of Sc₂O₃, Al, and CaCl₂ in a tantalum crucible was placed inside a stainless steel reaction container, and the feed mixture was reacted with calcium (Ca) vapor at 1273 K for 6 h. After the reduction experiment, the reaction product (CaO), CaCl₂ flux, and excess Caeductant were removed from the obtained alloy sample by leaching using an aqueous solution. The formation of Al-Sc in the Al matrix phase of the alloy was confirmed by x-ray diffraction (XRD) and electron microprobe analysis (EMPA). This result indicates that Sc₂O₃ was successfully reduced to metallic Sc and alloyed in situ to form liquid Al-Sc alloy during the reduction. When Al was not used in the reduction experiment, a complex oxide (i.e., CaSc₂O₅) was formed, and the reduction was incomplete. Through this study, it is demonstrated that Al-Sc alloy can be directly produced by the carbothermic reduction using CaCl₂ flux and Al collector metal.

Today traditional of oxidic materials is mainly carried out in typical facilities like shaft furnaces, rotary kilns, reverberatory furnaces etc. Based on carbothermic reduction the reaction is either done by the formed carbon monoxide or the dissolved carbon. Typical problems occur because of interactions with the refractory lining, low reaction rates and therefore long retention times, as well as inefficient yields. A new development based on an inductively heated coke bed shows an interesting alternative to the above mentioned processes, with a solution for most of the mentioned problems.

A lot of trials were carried out with typical metal containing industrial wastes. The results showed a high metal yield in combination with a very fast reduction by forming a metal-slag mixture that can easily be separated in a simple settling unit. Even if a valuable metal is transferred into the gaseous state a separation and recovery can be carried out in a simple way. By the use of a special developed induction equipment that offers a wide variety of settings, different materials can be treated in an efficient way. Reduction is done directly at the high surface of the coke lumps, as well as by the carbon dissolved in the melt-slag mixture. This guarantees a high reduction rate while different temperatures can be adjusted so that uncontrolled solidification is prevented. An off gas mainly consisting of carbon monoxide is formed, that offers an efficient energy recovery. With this an optimization of the overall energy balance becomes possible.

The kinetics and mechanism in thermal decomposition of the calcium carbonate have been widely studied, it would seem a simple system however a wide range of factors as particle size, gaseous environment, purge gas velocity, CO₂ partial pressure could affect largely the kinetics of the reaction. The reaction is usually studied by thermogravimetric techniques. The aim of the present work is to present the gas chromatography (GC) as an alternative method of analysis in the kinetic studies in reactions that involve gaseous products. Some advantageous of this method is the easily and reproducibility in the measurements in situ of gaseous product of a decomposition reaction under isothermal conditions. By the other hand, it could be applied for the analysis of more complex system that involve different gaseous products or intermediates of the reaction. GC was employed as a useful tool to study the kinetics in the thermal decomposition of calcium carbonate. The reaction was followed measuring the CO₂ produced in the decomposition of the calcium carbonate with a furnace-gas chromatograph (GC) on-line system. One of the advantages of the GC method is the possibility to perform in-situ characterization and quantification of the gaseous products for obtaining kinetics parameters; the method is simple and shows a good repeatability too. The decomposition of calcium carbonate was carried out in isothermal conditions at temperatures from 550 to 715°C with nitrogen as purge gas. Several gas velocities were used to determine the adequate flow that minimizes the effect of diffusion as rate controlling step.


Technical Program

Tuesday PM

2:45 PM  Decomposition of Ionic Xanthate and Its Characterization through the UV-Spectrophotometry Technique: Beatriz Ramírez; Ramiro Escudero; Francisco J. Tavares; ‘Universidad Michoacana de San Nicolás de Hidalgo

Xanthates are anionic collectors normally used in flotation devices to modify the hydrophobic surface of sulphide minerals. Xanthates are heteropolar compounds and in acuous media they dissociate into ionic xanthate and alkali-metal ions; nevertheless their behavior is not well understod yet. This work characterizes the six reactions describing the decompositon of the ionic xanthate in acuous media by analyzing the set of spectra from a UV-Spectrophotometer. Results show the effect of pH on the stability of certain compounds which can be usefull to explain the relationships among xanthates and the hydrophobicity of some surfaces (or ions dissolved).

3:10 PM  Break

3:25 PM  Invited


In the early 1940’s, the Caron ammonia – ammonia carbonate leach process was used to produce nickel from Mayari ores at the Nicaro plant in Oriente Province, Cuba. While plant operation was generally successful, it was not broadly economical and was shut down. The plant was later restarted in the 1950’s and a number of investigations initiated to resolve the more serious operational and performance issues. Processing steps studied included iron reduction (chemistry – nickel and iron, reductant, equipment), ore variabiliy (homogeneity and consistency of mineral concentrations, serpentine vs. laterite), leach solution strength, nickel recovery (temperature – reduction and leaching, reoxidation) and a variety of other topics. These studies and their findings will be discussed. Caron himself obtained good results on these ores in the laboratory. They could not be duplicated in the field, the reasons for which will be reviewed. (Note: the ore looked like garden dirt; charcoal made from palm trees was one of the reductants attempted; and ammonia was the leach solution. Mixing the three, so to speak, was to yield nickel.)

3:50 PM  Non-Traditional Methods of Heavy Metals Precipitation from Solution in the Form of Sulphide: M. I. Kalashnikova; I. M. Sheerenson; M. V. Keskinova; V. V. Chetvertjakov; ‘Gipronickel Institute

In hydrometallurgical technological flowsheets several methods of target components removal from solution are used. One of these methods is non-ferrous metals removal in the form of rich selective or collective concentrates. In the present work pyrometallurgical mattes, thiosulfate containing solutions and pulps, iron powder with elemental sulphur and calcium sulphate were used as the precipitator. It was shown that depending on precipitator compound and process parameters non-ferrous metals precipitate from solution in the different forms with varying content of components including NiS\textsubscript{2}, NiS, Ni\textsubscript{2}S\textsubscript{3}, NiS\textsubscript{2}, (Ni,Co)S\textsubscript{2}, CuS, Cu\textsubscript{1.97}S; Cu\textsubscript{0.97}S.

4:15 PM  Effects of Ore Mineralogy on the Bioleaching of a Nigerian Complex Sulphide Ore with Mixed Cultures of Mesophilic Bacteria: Peter Olubambi; Sehlisele Ndlovu; Joseph Olutunde Borode; ‘University of the Witwatersrand; ‘Federal University of Technology

The effect of ore mineralogy on the bioleaching of metals from complex sulphide was studied by investigating the bioreaching of zinc and copper from bulk complex sulphide ore from Ishiau, Nigeria, using mixed cultures of Thiobacillus ferrooxidans, Thiobacillus thiooxidans and Leptospirillum in mechanically stirred reactors at varying particle size. Mineral phases within the varied particle sizes of 53, 75 and 106µm were identified using X-Ray Diffraction and Scanning Electron Microscopy (SEM), while the elemental distribution within the varied particles sizes were determined by X-Ray Fluorescence (XRF) and Optical Emission Spectrometry using Inductively Coupled Plasma- Optical Emission Spectrometer (ICP-OES). Bulk ore and the leached residues were examined by Scanning Electron Microscopy (SEM) and X-Ray Diffraction. The highest bioleaching recoveries were obtained at particle size of 75µm, while particle size of 106µm gave the least recoveries. Lower recoveries at particle sizes of 53 and -53µm were as a result of their higher silica content which effects pH, iron mobility and oxidation.
Physical Vapor Deposited (PVD) coatings, especially TiN and CrN, are widely being used in tribological applications to improve performance and service life of cutting tools, die molds and machine parts because of their chemical stability and resistance to acid attack. A key attribute of geopolymer technology is the robustness and versatility of the manufacturing process; it enables products to be tailor-made from a range of raw material sources (waste and/or virgin) with specific properties for a given application at a competitive cost. Despite these key technical and environmental attributes, it is the ability to add significant value to coal ash or and/or metallurgical slag waste streams which drives the commercial development and uptake of the technology.

1:55 PM

Comparison of Oxidation Behavior of Nitride Based Hard Ceramic Thin Film Coatings Using Thermal Analysis Techniques: Nuri Solak; Fatih Üstel; Sihëyla Aydinî; Mustafa Ürğenî; Ali Fuat Cakirî; ' İstanbul Technical University; Sakarya University

Physical Vapor Deposited (PVD) coatings, especially TiN and CrN, are being used in tribological applications to improve performance and service life of cutting tools, die molds and machine parts because of their hardness, wear, corrosion and oxidation resistance. In service conditions, these coatings are exposed to oxidative atmospheres at high temperatures due to friction. In this media coatings oxidize and service life decreases. Therefore, performance of the coated materials not only depends on mechanical properties but also on oxidation behavior. In this study, CrN, TiN and Ti-B-N coatings were deposited onto H13 hot working tool steel and alumina substrates by arc-PVD. The coatings were characterized with respect to their mechanical and structural properties. Oxidation behavior of the coatings on alumina substrates was investigated by TG/DTA. Coated H13 substrates were oxidized in a tube furnace under atmospheric conditions at specific temperatures determined from TG/DTA tests of the same coating on alumina substrate. The oxide scale morphology was characterized by scanning electron microscopy and X-ray diffraction. Oxide scale thickness and change and TG data were used to calculate oxidation reaction activation energies.

2:00 PM

New Eco-Process for the Preparation of Metal Oxide Varistors: Renaud Metz; Jonathan Morel; Ramón Payá; Mehrdad Hassanzadeh; 'UCBL-CNRS-SNPE; UCBL-CNRS-SNPE/AREVA; 'AREVA

The DOPA process (Direct Oxidation of a Precursor Alloy) was used to prepare ceramic powders based on doped SnO2 and ZnO. The DOPA process consists essentially in the direct oxidation of a homogeneous precursor alloy. A unique advantage of this process is its rather benign environmental impact since no dangerous reactants are used and no harmful by-products are generated. Only oxygen and the alloy metals participate in the chemical reaction to produce the multi-component oxide. Homogeneous alloys of niobium, cobalt and chromium doped tin have been prepared. The molten metal alloy is atomised in air using a double fluid nozzle to produce metallic powders. A subsequent thermal treatment is carried out to fully oxidise the sprayed metal alloy powders. These raw powders are used to prepare a ceramic powder through a mill homogenisation and atomisation process. The ceramic powder is then uniaxially compacted in disc shape and sintered in an oxidising atmosphere. The resulting sintered bodies are metallised on their flat faces and the cylindrical surface is passivated using lead free glass enamel. These ceramics present excellent semiconducting properties with non-linear (non-ohmic) characteristics. The DOPA process is found to be an attractive procedure to obtain ceramic powders for the preparation of SnO2 varistors.
by the spark plasma sintering (SPS) method at 1600°C. The dense Si₃N₄ samples had good mechanical properties (18.7 GPa Vickers hardness, 3.3 MPa m/2 fracture toughness and 363 MPa strength) and excellent chemical and oxidation resistance. The synthesized composite powders were also densified to high densities (> 90 % of theoretical values) by SPS technique. The results obtained in this study can be seen as a new route to prepare important silicon-based structural ceramic powders with various compositions/properties from cheap starting materials which makes them potential for wide range of applications.

3:50 PM

Study of Grinding Process of Titanium Carbide Produced with Self-Propagating High Temperature Synthesis (SHTPS): Z. Kovziridze; G. Tabatadze; D. Gventsadze; D. Donadze; ‘Georgian Technical University

It is stated that the specific character of SHTPS-preparations of TiCx consists in crystal lattice strength reflecting the condition of synthesis in “burning wave”. The use of roentgenographic and other methods of analysis allow to estimate the effect of the conditions of synthesis, causing the carbon sublattice defect, on grinding intensity of TiC-phases. The study of the kinetics of vibro-grinding of TiC-phases in ethanol and benzene medium allows to establish high grinding intensity of the phases close to stoichiometry and the possibility of producing high dispersion powders (S̃ₐ = 4.5-6 m²/g).

4:15 PM

Effect of the TiC Addition on the Corrosion Resistance of AlO₃-C Refractory: Qingcai Liu; Yi Liu; Jian Yang; ‘Chongqing University

The effect of the TiC addition on corrosion resistance of the Al₂O₃·C refractories in melting reduction melts has been studied by quasi-station immersion and rotary immersion. The corrosion rate of Al₂O₃·C refractories is decreased with the TiC addition. The corrosion mechanism of Al₂O₃·C refractories is oxidation of graphite carbon by the oxides of the melts and the formation of deteriorate layer. The factors that influence the corrosion rate are iron oxides content of the melts, relative rotary rate of refractory specimens in melts and the molten bath temperature. The corrosion mechanism of Al₂O₃·C refractories in the melting reduction melts has been investigated.

4:40 PM

Use of Refractory Carbides in Technique: Z. Kovziridze; N. Nizharadze; G. Tabatadze; ‘Georgia Technical University

The development of modern technique makes increased requirements to heat resistant refractory cutting tool materials. So, at present the investigations are continued for receiving new materials distinguished for their specific properties. The material received by us on the basis of silicon carbide and synthetic corundum with silicon nitride binder are characterized with high refractoriness, thermal stability and resistance to molten metals and aggressive gaseous medium. The technology of thermocouples protecting casing production from these materials is developed. Different size casings are produced and tested at metallurgical, machine building and other plants with the aim to establish their resistance and to measure the temperature of molten metals. Positive results are obtained. Nowadays, by introducing additives into composition, the work is carried out with the object to improve the properties of these materials. On the basis of the known tungstenless hard alloy TiC-Ni(Mo) a new hard alloy is received where nickel dispersively strengthened with aluminum (circonium) oxide prepared with a new technology is used as a binder. It is known that the mentioned oxides increase thermal stability of metal phase. Physico-mechanical properties of the obtained new hard alloy are considerably higher compared to the existing one that is absolutely proved by the stability of cutters made of this alloy at metal cutting processing.

5:05 PM

Effect of Relaxation and Other Transitions on the Conductivity of Conductive Polymer Composites: J. N. Aneli; M. S. Kutsia; ‘Institute of Machine Mechanics of the Georgian Academy of Sciences

There are many experimental works on the investigation of temperature effect on the conductivity of polymers filled by carbon materials. However frequently the establishment of current nature in the polymer heterogeneous systems becomes difficult. This fact is explained by complexity of calculation of different physical or chemical phenomena passing in materials at variation of the temperature. Among these phenomena it must be noted some morphological changes in the structure of polymers. These changes reflect on the structure of conductive system of composites. So, it was shown, that the character of temperature dependence of thermal noises level and conductivity of some polymers filled by carbon black essentially depend on some relaxation transition in the polymeric matrix. In this paper the effect of difference transitions in polymer matrix of filled by carbon black some polymers and rubbers have been investigated. In the wide temperature range. The importance of such investigation is due to possibility of application of resistive temperature sensors based on conductive polymeric composites (CPC) to measuring technology. The experiments has been carried out in the cavity with regulation of temperature in the range 110-650K. The resistance of samples was measured by four electrodes method. The samples were obtained by hot pressing of dry mixture of powdered components at chosen temperatures, pressures and cooling time in the case of plastics and by peroxide Vulcanization of the elastomers in the case of the rubbers. The samples were produced on the basis of the following thermoplastics: low density polyethylene, polytetrafluoroethylene, polycarbonate and polydimethylmethylenilsiloxane.

5:30 PM

Synergetic Effect in Conductivity of the Polymer Composites Based on Phenolformaldehyde Resin: J. N. Aneli; Z. Kovziridze; D. I. Gventsadze; N. G. Japaridze; ‘Georgia Technical University

For the improvement of technical characteristics of polymer composites two or more fillers are used often. It is important both type of fillers and their masses ratio in the general content of them. It is known, that the definite (optimal) magnitude of the ratios can lead to such phenomenon, as so called synergetic effect, which is expressed in increase of some physical or chemical properties corresponding to optimal (for given system) ratio of filler masses. These properties are more higher than that for analogous composites containing only one filler from given blend of fillers, if the concentration of this filler is equal to general concentration of fillers other composites. The application of synergetic effect in the polymer composite technology is connected with economic use of the materials, which is expressed in decrease of the expenditures of some deficit component and technology. The present work devotes to investigation of synergetic effect in the composites based on phenolformaldehyde resin (PFR) with double fillers. Two types of fillers were used in each composite (the carbon black (CB) with high and low conductivities, metal powders of copper, iron and nickel). The dependence of conductivity of composites on the ratio of fillers was investigated.

Thermo and Physicochemical Principles: Non-Ferrous Processing: Thermodynamics II

1:30 PM Keynote

Phase Relations and Activities in the Cu-Fe-S-X and Cu-Fe-S-C-X (X = As or Sb) Systems and Distribution of Precious Metals Relating to Reduction Smelting of Copper: Kimoto Itagaki; Leandro Voisin; ‘Tohoku University

As a fundamental study for smelting the copper matte with high contents of arsenic and antimony in a strongly reducing condition, phase relations between the liquid matte and copper-rich alloy phases in the Cu-Fe-S-As or -Sb quaternary system and between the liquid matte and iron-rich alloy phases in the Cu-Fe-S-As or -Sb system saturated with carbon were determined at 1473K by a quenching method. Activities of arsenic and antimony in these systems were also measured at 1473K by Knudsen cell-mass spectrometry. Furthermore, distribution ratios of silver, gold and platinum between the liquid matte and copper-rich or iron-rich alloy phases were determined in
relation to the arsenic or antimony content in the systems. On the basis of these data, elimination of arsenic and antimony from the matte to the iron-rich alloy (spiss) and recovery of the precious metals in reduction smelting of the copper matte were evaluated. It was suggested that addition of the pig iron to make a strongly reducing condition and form the iron-rich alloy, which is fluid at smelting temperatures, will be useful for fixing arsenic in the spiss.

1:55 PM Invited Volatilization Behavior of Minor Elements during Non-Isothermal Oxidation of Copper Concentrate Particles Falling in One-Dimensional Laminar Gas Flow: Yasuhiko Fukunaka; H. S. Sohn; 2Kyoto University

Copper concentrate particles of 200 to 300 mesh size were fed from the top of vertical reaction tube of 2.8×10⁻² m ID and 2 m long with an O₂-N₂ gas mixture. The reaction tube was heated to 900 K to 1100 K. The copper concentrate particles were very rapidly oxidized and melted down during their descent in the reaction tube. The particle temperature were calculated by combining an un-reacted core model, mass transfer between gas and particles, and heat transfer between gas, particles and tube wall. The particle temperature reached its maximum within a distance of 60 cm from the top of reaction tube, and it attained at 2000 K at higher oxygen partial pressure. The most particles were melted at the oxygen partial pressure above 20 kPa.

An appreciable amount of As, Sb and Pb in the concentrate particles was eliminated in the upper portion of the reaction tube and the rate of elimination are explained by the rate of mass transfer of volatilized species through the gas film on the particle surface and the variation of particle temperature during the descent.

2:20 PM Thermodynamics of Tapping Molten Copper: Steven Wright; 1Francis R. Jorgenson; Andrew P. Campbell; 2CSIRO Minerals; 3BHP Billiton

BHP Billiton’s Olympic Dam copper flash smelter employs the direct blaster process for smelting high grade copper concentrates. SO₂ evolution during tapping gives rise to safety and environmental concerns. A thermodynamic model for the blister copper system (Cu-Fe-S-O) was used to predict the volumes of SO₂ evolved. Thermodynamics was used to evaluate the slag chemistry inside the furnace. The blister copper model was used to explore the relationship between %S and %O in the copper and the amount of SO₂ evolved on cooling. The volume of SO₂ evolved was sensitive to the O content with reduction to levels below 0.2 - 0.15% likely to suppress SO₂ evolution on cooling. Concentrations of S and O in tapped copper samples from trials clustered around the equilibrium line at an average temperature of 1275°C and a partial pressure of SO₂ of 1 atm. A number of potential process options to suppress SO₂ evolution on tapping were investigated thermodynamically. Some of the options require treatment of the blister in a forehearth separare furnace, while others have impacts on current practises in the flash furnace. The opportunities that these options present are discussed.

2:45 PM Modeling of Minor Elements in Copper Smelting Processes: Chunlin Chen; 1Ling Zhang; Steven Wright; Shouyi Sun; Sharif Jahanshahi; 1CSIRO

Thermodynamic data of Sb from the literature in the liquid copper, matte and slag have been assessed and optimized using models from literature. The modelling results for Sb in matte, slag and liquid copper are discussed. Validation of the developed databases on the distribution of Sb among the various phases against the literature data is presented. The effect of the CaO/SiO₂, Fe/SiO₂, temperature and matte grade on the transport of Sb in the copper smelting process is discussed. The Sb distribution behaviours in practical and bath smelting processes are analysed. The developed databases have been used for the calculation of the distribution of minor elements among the matte, slag, copper and gas phases under varied operation conditions during copper smelting process. Similar work has been done for other elements such as As, Bi, Pb, Zn, Sn, Cr, Se and Te and some related examples will also be presented and discussed.
Technical Program

4:40 PM
Thermodynamics Analysis on Reducing-Matting Smelting of Sulfide Ore of Lead, Antimony and Bismuth which Using Ferric Oxide as Sulfur Fixed Agent: Chao Huang; Chaobo Tang; Yongming Chen; Motang Tang; Duomo Zhang; Central South University

The thermodynamics analysis on reducing-matting smelting of sulfide ore of lead, antimony and bismuth which use ferric oxide as sulfur fixed agent was first analysed. Due to the analysis of reaction mechanism, ferric oxide is first reduced to ferrous oxide, then ferrous oxide produce reducing-matting reaction with sulfide ore and reducing agent as reaction equation: FeS + FeO → Fe + FeS + CO2. The reaction thermodynamic calculation shows that the reducing-matting reactions of lead sulfide, antimony sulfide, and bismuth sulfide are feasible, but is infeasible for zinc sulfide. These conclusion provide a feasible method for solve the pollution produced in the smelting of sulfide ore of lead, antimony and bismuth.

Thermo and Physicochemical Principles:

Steel Making: Thermodynamics and Kinetics

Tuesday PM
August 29, 2006
Room: Russeau Suite
Location: Catamaran Resort Hotel

1:30 PM
Activity Coefficient of Nitride in Slag as a Measure of Slag’s Ability to Remove Nitrogen from Liquid Metal: Peng Fan; W. D. Cho; University of Utah

Nitride capacity is usually employed as the measure of slag’s ability to remove nitrogen from liquid metal, since nitrogen distribution ratio between slag and metal can be calculated from nitride capacity provided that the value of oxygen activity in liquid metal is available. However, during liquid metal refining processes, oxygen activity in liquid metal is usually unknown and thus it is impossible to get nitrogen distribution ratio from nitride capacity under this usual condition. In this paper, thermodynamic analysis indicates that the activity coefficient of nitride in slag can be used to measure slag’s ability to remove nitrogen from liquid metal, because nitrogen distribution ratio between slag and metal can be calculated from the activity coefficient of nitride in slag provided that the content of oxygen potential controlling element like Al in liquid metal is available. Review of reported nitrogen removal studies and our recent study has verified that for a given Al content in metal, the lower the AlN activity coefficient in slag is, the higher the nitrogen distribution ratio.

Predicting Surface Tension and Viscosity of Molten Slag

3:25 PM Keynote
Predicting Surface Tension and Viscosity of Molten Slag: Toshihiro Tanaka; Masanori Suzuki; Osaka University

The information on viscosity and surface tension of molten slag is indispensable to design new refining procedures in ferrous and non-ferrous processes. For example, the authors have tried to develop “Capillary Refining” to remove impurities in liquid metals by applying capillary absorption of molten slag with those impurities into solid fluxes which have a lot of small capillary tubes. It is necessary to adjust the above physico-chemical properties to adequate conditions on the capillary penetration. In the present paper, we discuss our recent trial to predict surface tension and viscosity of molten slag in multi-component systems. We have derived a thermodynamic model to predict the surface tension of molten slag by using ionic size, molar volume and surface tension of pure components. In addition, we have applied neural network computation to evaluate the viscosity of molten slag. We found good agreement between the predicted and experimental results.
agreement of the calculated results with experimental values of the surface tension as well as the viscosity in various slag systems.

3:50 PM
Bubble Formation and Dynamic Slag Foaming Phenomena: Seshadri Seetharaman; Abha Kapilashrami; Morten Gornerup; Ashok Kumar Lahiri; 1Royal Institute of Technology; 2Corus RD&T; 3Indian Institute of Science

Slag foaming proves to be both blessing and curse for the process productivity, depending on where in the process it occurs. In pyrometallurgical processes, slag foaming is often a result of chemical reactions taking place in the slag. As the slag composition and reaction rates are changing, foaming occurs under dynamic conditions. In the present work, slag foaming was studied with XRF. The foam displayed a fluctuating behaviour, unaccountable by existing models. The concept of foaming index was found not to be satisfactory in describing the foam, resulting in the need for alternative theories. The rate of fluctuations was seen to be related to the difference between rate of gas generation and rate of gas escape from the system (Ug-Ue) as well as the bubble sizes. Thus, model development of dynamic foaming phenomenon has to take the effective chemical reaction rate as well as the bubble sizes into consideration. The first step in obtaining foam is to form bubbles. In the present work, gas bubbles were generated through chemical reaction at interface between two immiscible liquids and the bubble formation was studied optically. The gas bubble size was seen to be uninfluenced by the reaction rate. However, bubble formation was seen to take place in one of the phases and since the bubbles consequently traversed the interface under the influence of buoyancy, the viscosity of the first phase was found to influence the final bubble size where increased viscosity would yield a larger bubble size.

4:15 PM
Transport Phenomena and CFD Application during Process Metallurgy: Lifeng Zhang; 1Norwegian University of Science and Technology

The transport of fluid, heat and particles (bubbles and solid inclusions) in flowing molten steel is investigated in steel refining ladles, the continuous casting tundish, continuous casting mold and strand, and steel ingot casting processes. Inclusion removal from the molten steel by flow transport and bubble flotation, and inclusion growth by collision and diffusion are discussed. Removal of impurity elements such as [C] and [O] during steel refining are reported.

4:40 PM
Mixing and Mass Transfer Rates in a Model CLU Converter: Admire Chaendera; Hurman Eric; 1University of the Witwatersrand

An experimental study on the effect of the slag phase, bath height and gas flow rate on the mass transfer rates and mixing time in a one-fifth water model of a 100 ton CLU converter was conducted. Praffin was employed to represent the slag phase. The mixing time, which was determined by a tracer method employing sulfuric acid, increased with increasing bath height and decreasing flow rate at a given slag proportion in the bath. The mixing time data was related to the specific energy dissipation rate through the variables; gas flow rate, bath height and bath weight. Mass transfer rates were determined by measuring the dissolution rate of benzoic acid cylinders in the bath. Mass transfer rates decreased with increasing bath height and decreasing gas flow rate. A relationship between the derived mass transfer coefficient, gas injection rate and bath height was established. An attempt was made to extrapolate the results to the industrial scale vessel.

5:05 PM
Coupled Thermodynamic and Kinetic Modeling of a Top-Blown Bath: M. Ersson; A. Tillander; L. Jonsson; Pär Jönsson; 1KTH

A fundamental mathematical model of lance blowing on a bath surface has been developed with a view to increase the understanding of various phenomena in top blown oxygen converters. The model is based on the Navier-Stokes equations and turbulence is predicted using the k-ε model. In the present model the deformation of the liquid surface, caused by the impinging gas jet, is described using a VOF formulation. The mathematical model results have been verified by comparing predicted penetration-depth data with experimental results from physical model trials. The fluid dynamic modeling has also been coupled with the thermodynamic software package ThermoCalc to predict the reaction rate/distribution occurring in the vessel. The focus has been on carbon and a qualitative comparison of the predicted carbon content in the hot spot area and in droplets with experimental data from laboratory trials have been done.
Refining of Blister Copper to Remove Nickel: Alexander Ivan Volkhin; Alexander Ivan Volkhin

Two main techniques are applied in the metallurgical practice for removal of nickel from blister copper: 1) maximum transfer of nickel into fire refining slag and 2) maximum transfer of nickel into anode copper with subsequent nickel recovery in the form of sulphate or metal. At the Kyshtim electrolytic copper refinery a method has been tested for nickel removal from blister nickel in the form of sulphate or metal. This method has been used to make the starter melt using these modified slances. Although it was still under development at that time, the time for making initial bath-melt was reduced by about half.

Effect of Calcium Oxide Content in Feed Charge on Performance

Residues in slag by achieving a residual zinc content of final slag in the order of 1%.

Kinetics and Mechanism of Copper Slag Cleaning by Injection of Natural Gas: David E. Langberg; Michael Somerville; Tony Briffa; ‘CSIRO; Xstrata Copper - Mt Isa Mines

Recovery of dissolved copper from discard slags is a critical consideration affecting the economics of copper smelting. Slag cleaning is frequently carried out in electric furnaces, however reduction by injection of natural gas in a holding furnace may offer a lower cost alternative in some circumstances. As the residence time of the injected gas is short, the factors controlling the rate of reduction need to be clarified in order to optimise the design of the slag cleaning furnace. A series of medium scale (200 kg) reduction tests to investigate the rate of reduction of copper-containing slags by injection of natural gas-nitrogen mixtures between 1150-1250°C was carried out by CSIRO Minerals. The composition of the gas in the top-space of the reactor was found to be significantly more reducing than the slag, indicating that thermodynamic equilibrium was not established between the slag and the gas in the bubble plume. An apparent first order rate law was observed between the rate of oxygen elimination from the bath and the magnetite concentration of the bath.

9:15 AM Effect of Calcium Oxide Content in Feed Charge on Performance Indicators of Smelting in Sparged Bath: M. Yu. Malkova; V. V. Kozyrev; Andrey V. Tarasov; ‘Gintsvetmet

In the course of research aimed at improving the performance of the Vanyukov smelting process (VP) for treating sulfur raw materials in a pilot-scale furnace it has been found that an increase in the calcium oxide content up to 12% to 14% in case of smelting to produce high-grade matte results in a decrease in the copper content of slag by 0.05% to 0.3%. The residual copper content of slag can be computed by a formula taking into account an increase in the calcium oxide content of the feed material and that in the slag. In the course of research for improving the performance of the zinc-containing slag fuming process with blowing of the slag bath with combustion products of natural gas it has been found that the silica and calcium oxide contents have an effect on the degree of zinc sublimation. In case of slag containing 24.4% SiO₂ and 6.95% CaO by weight (SiO₂:CaO ≈ 3.51), the residual zinc content of slag was 3.25%. The minimum residual zinc content of 1.95% was obtained in case of slag containing 22.5% SiO₂ and 14.5% CaO by weight (SiO₂:CaO = 1.55). An increase in the CaO content of slag up to 16% by weight with a ratio of SiO₂:CaO = 1.25 to 1.35 permits minimization of zinc losses in slag by achieving a residual zinc content of final slag in the order of 1%.

9:40 AM Break


The Converting Furnace (C-furnace) of the Mitsubishi process has solely provided opportunities for producing blister copper continuously from molten matte. Continuous converting originates from the proven technology for controlling the behavior of magnetite in lime-ferrite slag of Cu₂O-CeO₂ system. Recent improvements in the C-furnace operation have included the slag controls reflecting the impact of minor oxides on the magnetite behavior. Although previous investigations have focused on the magnetite behavior, sulfur has also affected the C-furnace operation because it is of practical importance to avoid the precipitation of gypsum from lime-ferrite slag and the separation of matte from blister copper. This paper will quantify the behavior of sulfur in C-furnace with respect to the gypsum formation and matte separation, and discuss better controls for the C-furnace operation.

10:20 AM Invited Smelting of High Impurity Concentrates via Teniente Converter: Cesar M. Acuna; M. Sherrington; ‘Codeco; ‘Training Management Inacap

Scarcity of high grade copper low impurity content ores is a reality and the processing of low grade dirty concentrates is a need. In spite of this fact, innovative strategies have to be looked at to comply with day to day more stringent environmental regulations. From this perspective the production of matte grades over 70% in copper presents several merits, but it must be contrasted with the fractional distribution of impurities reporting to the condensed phases. The processing of high arsenic feed to white metal will result in rather moderate fractions of arsenic to the gas, but high deportment to the matte phase.

10:35 AM Invited Gasification of Blast Furnace Slag for Energy Recovery: Sung-Sil Park; Jong-Shin Chang; Tony Briffa; ‘CSIRO; Kowang-Min; ‘CSIRO

As the residence time of the injected gas is short, the factors controlling the rate of reduction need to be clarified in order to optimise the design of the slag cleaning furnace. A series of medium scale (200 kg) reduction tests to investigate the rate of reduction of copper-containing slags by injection of natural gas-nitrogen mixtures between 1150-1250°C was carried out by CSIRO Minerals. The composition of the gas in the top-space of the reactor was found to be significantly more reducing than the slag, indicating that thermodynamic equilibrium was not established between the slag and the gas in the bubble plume. An apparent first order rate law was observed between the rate of oxygen elimination from the bath and the magnetite concentration of the bath. The dissolved copper concentration was closely correlated with the rate of oxygen elimination from the bath and the magnetite concentration of the bath.

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Specific Features of Autogenous Smelting of Sulfide Raw Materials Using Oxygen-Flame Process: Valery M. Paretsov; A. V. Tarasov; 1Gintsvetmet

Most recent developments made in the Gintsvetmet Institute in the field of technologies and equipment for single-stage autogeneous smelting of copper sulfide raw materials to produce white metal and blister copper on the basis of oxygen-flame smelting process and separation of highly basic calcium-containing slags have been discussed. This technology includes the oxygen-flame smelting process (KFP Process) to produce highly basic self-disintegrating ferrite-calcium slags with their subsequent flotation to recover copper and a basically new sparging smelting process (FBP Process) to produce combined slags subjected to decopperizing inside the same furnace. Results of special investigations of the slag structure obtained in the KFP and FBP processes substantiating selection of their chemical and phase composition have been presented. It has been demonstrated that the above processes meet the stringent world-level requirements to advanced technologies with respect to energy conservation and environmental safety with different scales of production and within a wide range of specific conditions of particular operations.

Study on the Reducing-Matting Smelting of Stibnite Concentrate to Produce Antimony Directly: Yongming Chen; Mo-Tang Tang; Chao Huang; Chao-Bo Tang; Weiyi Yao; Sheng-Hai Yang; 1Central South University

In order to eliminate the serious environmental pollution of low concentration of sulfur dioxide smoke in antimony smelters, a new smelting process that is named as reducing-matting smelting was proposed in this paper. The effects of technical conditions such as smelting temperature, smelting time, the amount of pyrite cinder and the amount of additive on the smelting of stibnite concentrate have been investigated. The results show that the optimum conditions are as follow: the amount of pyrite cinder is 1.2 times of its theoretical amount. The addtional amount of soda and sodium sulfate is 15% and 72.6%, respectively to the amount of stibnite concentrate when the total amount of sulfur is 30%. The reducing-matting smelting is carried out at 1100° for 2h, then the smelting temperature raise to 1200° for 50min. Under the optimum conditions, the direct and the total recovery ratio of antimony is 90.99% and 98.87%, respectively, and the fixed ratio of sulfur is higher than 99%. In conclusion, sulfur in stibnite concentrate is fixed completely in matte and the environmental pollution of sulfur dioxide smoke is avoided in principle. At the same time, valuable metals in pyrite cinder can be extracted effectively. More important, crude antimony is produced directly in one-step and extracting process is simplified greatly. Generally speaking, reducing-matting smelting process has great significance and potential application in the technical renovation of antimony smelters and the utilization of pyrite cinder.

Sulfidizing Process of Pyrrhotite Concentrate: L. S. Tsemekhn; L. N. Yertseva; V. T. Dyachenko; 1Gipromet Institute JS

In the current operational environment, development of a technology allowing removal of low-metalized iron sulfides out of pyrometallurgical processing routes has become a matter of high priority. The present work is dedicated to investigation of the sulfidizing process of ore pyrrhotite concentrate with recovery of a sulfide material, enriched with non-ferrous metals, and waste pyrite, with downstream separation by a certain beneficiation method. A run of tests involving heating of the pyrrhotite concentrate in vacuum-sealed ampoules, in the presence of elemental sulfur, within temperature range 200-600°C has been carried out. The obtained products have been examined by X-ray phase analysis and X-ray microanalysis. Its has been established that under certain conditions products of the pyrrhotite concentrate sulfidizing may be: a) pyrrhotite solid solution bearing Ni 1.9 5.4 mass% and Co– up to 0.35 mass%; b) monosulfide solid solution of a pentlandite-like composition; c) pyrite containing Ni 0.22-0.26 mass % and Co– below 0.1 mass %.

Treatment of Acid Mine Drainage Containing Iron Ions and Arsenic for Utilization of the Sludge: Hiroshi Nakazawa; 1Iwate University

The acid mine drainage in abandoned Horobetsu mine in Hokkaido, Japan, contains arsenic and iron ions, total arsenic 10ppm, arsenite 8.5ppm, total iron 379ppm, ferrous iron 260ppm, pH1.8 in average. The mine drainage is neutralized up to pH7.5 resulting in the formation of iron hydroxide. Arsenic is removed by co-precipitating with iron hydroxide. As there is not enough space to build a sludge dam in the abandoned mine, the sludge is filtered with a pressure filter and transferred into a landfill. In order to cut down on the running cost, it is required to utilize the sludge. Iron content in the sludge is high so that the sludge could be used as raw materials, but it is difficult to utilize because it contains arsenic. Arsenic is removed more easily than arsenite, and it co-precipitates with iron hydroxide in the range of pH3-4, indicating that arsenic could be removed without the precipitation of ferrous iron from the mine drainage if arsenite is oxidized to arsenate preferentially. We found that arsenite in the mine drainage was oxidized to arsenate biologically below pH2.0. In this study, we have investigated the bio-oxidation of arsenite and the arsenic removal from the acid mine drainage contain iron ions for the utilization of the sludge.

Evaluation of Environmental Burden and Economic Impact with “Landfill Mining Activity” Based on the Waste Input-Output Model: Kazuyo Yokoyama; Takashi Onda; Tetsuya Nagasaki; 1Tohoku University

New environmental assessment model based on the Waste Input-Output analysis has been developed and applied for the “Landfill mining activity”. “Landfill mining” implies the digging up of the landfill wastes, the recovery of valuable material and energy resources and, thus, the reuse of the saved space as a new landfill site. In this study, the landfill wastes are assumed to be treated by the gasification/melting processes. Two kinds of reactors, the fluidized bed type (FB) and the shaft furnace type (SF), have been considered in this work as the typical gasification/melting processes adopted in Japan. In FB, the dug-up wastes are heated in the sand fluidized bed zone under reducing atmosphere, Fe and Al are recovered in the metallic form, and then, the gasification/melting of residues is made in the second zone. In SF, the waste is charged in the high temperature coke bed, and the gas is recovered together with molten metal and slag. Both processes generate electric power by the recovered heat and fly ash as waste to landfill. It has been found in this study that the both processes can reduce the total volume of waste and save the available landfill space. SF seems to have higher potential for decreasing
The present paper deals with the solid residues discharged by the metallurgical industry in Albania for the last tens of years. The results of two monitoring study on the solid residues of copper, iron and Ferro-chromium producing industries will be given. The first deals with the location, quantities and chemical composition of these residues and the second one with the impact of harmful ingredients of these residues in the environment. Some methods for the processing of these solid residues are also proposed in order to ensure a clean environment and to make not just possible but also and economically viable their secondary utilization.

9:15 AM
Power Plant Fly Ash – A Review of Beneficiation and Utilization: Haldun Kurama1; ‘Osmanzgi University

Worldwide, tremendous quantities of coal are burned to generate electricity. Disposal of coal ash as a by product of incineration is becoming an increasing economic and environmental burden. However a large amount of fly ash has utilized in the construction and cement industry due to the decreased heat rate of hydration and improved workability, the rate of generation clearly far outweighs consumption. The remaining part is generally land filled. Furthermore in recent years, the implementation of more stringent air quality regulations pertaining to coal-burning power plants have resulted the installation and use of combustion gas purification technologies including burners that generate lower levels of NOx in the combustion gases discharged to atmosphere. The use of such burners significantly increase the unburned carbon content of between 6 wt% to 25 wt % that is in the fly ash leaving the burner and causing the decrease of the quantity of available ash that is suitable for use constituents in concrete and shaped building product. In this paper, the used methods such as low temperature combustion, froth flotation, partial size classification and electrostatic separations to remove unburned carbon particles from fly ash is fully discussed. Utilization of fly ash as a value added product in areas such as novel materials, waste management, recovery of metals and agriculture is also reviewed with the aim of helping the expand of the usage of fly ash and reduce the environmental and economic impacts of disposal.

9:40 AM Break

9:55 AM Keynote
Arsenic Management in the Metallurgical Industry: The Chilean Experience: Armando Valenzuela1; Mario Sánchez2; Domingo Cordero3; ‘Chilean Copper Commission; Universidad de Concepción; Institute for Innovation in Mining and Metallurgy

Arsenic has been a common impurity in copper sulfide concentrates treated pyrometallurgically in Chile, which inevitably during the smelting-converting process reports in the final copper product affecting its properties, but also affecting environment as a very toxic occupational hazard. The enforcement of air quality standards, which regulate pollutants such as sulfur dioxide, particulate matter, and arsenic, has resulted in the implementation of pollution abatement plans and emission reduction schedules mainly by state-owned copper concentrate smelters. Investments associated with these plans incorporated gas-handling systems in order to capture polluting emissions. Electrostatic precipitators recover dusts containing mainly Cu and As which are leached to recover copper, while arsenic is disposed currently in the form of ferric arsenate. Gases containing high sulfur dioxide content are treated in plants to produce sulfuric acid, which is used in various classical and new hydrometallurgical processes. Additionally, smelters have effluents treatment plants for arsenic disposal either as ferric arsenate or calcium arsenate/arsenate. This paper reviews the environmental situation of the Chilean metallurgical industry, and the present trends for arsenic management are particularly emphasized since Chile is the world’s largest copper producer.

10:20 AM
Solid Residues of the Metallurgical Industry and Possibilities of Their Utilization: N. Lohja1; Z. Lleshi1; O. Gliozheni2; P. Gega2; 1Polytechnic University of Tirana; 2Ministry of Industry and Energy; 3University of Tirana; 4Institute of the Environment

Metallurgical industries are generally big producers of solid residues of various kinds. In contrast with the past where environmental sensibilities were not so elevated and the accumulated mass of these residues was not considerable, these days the solid residues are everywhere scrutinized among others in term of their harmful environmental impact and as possible materials for valuable elements extraction or secondary utilization. As a case study, the present paper deals with the solid residues discharged by the metallurgical industry in Albania for the last tens of years. The results of two monitoring study on the solid residues of copper, iron and Ferro-chromium producing industries will be given. The first deals with the location, quantities and chemical composition of these residues and the second one with the impact of harmful ingredients of these residues in the environment. Some methods for the processing of these solid residues are also proposed in order to ensure a clean environment and to make not just possible but also and economically viable their secondary utilization.

10:45 AM
On the Implementation of Municipal Solid Waste (Rubbish) Sorted Collection in China Cities: Deven He1; Liang-Hui Huang1; Li-Yuan Chai2; Yun-Yan Wang3; Bing Peng1; Xiaobo Min4; ‘Central South University

The increasing population and living standard in urban areas, have accompanied with the growing quantity and composition complexity of rubbish, which are causing well-known social effects of pollution, while rubbish (solid waste) is a recyclable resources. To convert rubbish into useful materials, the essential measure is to carry out sorted collection of rubbish. The preconditions of implementing sorted collection are presented in the paper. 1. Characteristics of rubbish composition and amounts of recyclable contents are basic condition to implement sorted collection. 2. The existing available technologies of recycling, economic benefit from recycling, and disposal scheme of residual rubbish are restrained condition for sorted collection. 3. Public understanding and support to sorted collection are the key to success. 4. The government policies to be favorable for sorted collection is the pledge of success. 5. The establishment of a steady solid waste recycling market is also a guarantee to implement sorted collection continuously. 6. To establish management system of rubbish recycling as soon as possible. Further, the methods and procedure of sorted collection are discussed in detail and beneficial comments and theoretical basis to promote sorted collection of rubbish in urban area are presented; it will contribute reference value to municipal solid waste management.

11:10 AM
Research on Combustion Temperature and Decontamination of Asphalt Smoke: Rui Huang1; Liyuan Chai1; Bing Peng1; Yunyan Wang1; ‘Central South University

The asphalt smoke is a hurtful gas in the process of alumina electrolysers and other industrial process. The proper combustion temperature and the combustion conditions are the important key of decontamination of asphalt smoke and economizing the supplied energy to keep the combustion process. Through a combustion device of asphalt smoke, a series of experiments and theoretical analysis are carried out to study the combustion temperature for completed reaction of all components of the asphalt smoke, and put forward the control method of the combustion conditions.

11:35 AM
Study of BOD of Dairy Effluent Using Various Microbes: Madhusudhamrao Vallabhaneni1; Rajinikanth Kondapaneni1; ‘Vignan’s Engineering College

Environmental problem is the major concern for any industry and there is a great need to that along green lines. Sangam Dairy being one of the most famous Dairy in A.P, produces wide spectrum of milk products. The BOD levels of effluent water of this industry with MIF treatment were found to be around 100 ppm. Lot of research has been expended in the past to bring down the BOD levels to bare minimum. The main objective of the present study is to minimize the BOD level to the required levels stipulated by environmental standards by employing various seeding materials. Different microbes like Bacillus Subtilis, Pseudomonas, Aspergullas, Staphylococcus, and Pencilium have been employed and BOD levels were analyzed. Various Reagents, solutions with different dilution levels have been successfully prepared. Initial and final Dissolved Oxygen levels were determined before and after incubation. From the data, BOD was evaluated for all samples and comparison analysis of various seeding material was dare to suggest the efficient seeding material for the ETP plant. Various reagents and samples with different dilutions were successfully prepared. Characteristics of BOD levels were determined by using BOD test. Various samples of different dilutions with various microbes were prepared and also ensure proper aeration to have sufficient DO. Titration was carried out for all the samples
The fact that a high fraction of ZnO in EAF dust exists in the zinc ferrite hydrometallurgical processes have been suggested and tested over the years operation, lower energy consumption and higher flexibility. Many compared to pyrometallurgical alternatives in terms of low temperature from EAF Dust Elimination of Zinc Ferrite for Hydrometallurgical Recovery of Zinc lead nitrate in reducing their detrimental effects.

We have developed a novel method - at the laboratory scale - comprising an ion-exchange separation and a membrane-electrolysis step for the purpose of zero-waste regeneration of spent HCl pickling liquors originating from hot-dip galvanizing of common steels. It is aimed at the parallel regeneration of HCl and iron. Conventional electrolysis experiments revealed that iron can be electrodeposited at high current efficiencies by maintaining the following conditions: 0.04-0.08 M HCl, 500-1000 A/m², 20°C and stationary electrolyte. Zinc in the solution did not disturb the deposition of iron, however it contaminated the product and it poisons the anion-exchange membrane required to tackle acidity during electrolysis. For a preliminary separation, ion-exchange tests were carried out to produce pure iron solutions. Beyond the equilibrium studies, column experiments were performed showing that low flow rates of the loading solution and small initial zinc concentrations are essential for separation. In the electrolysis experiments, a hydrogen diffusion anode was tested which proved to be efficient in respect of the major objectives.

A New Technology for the Control of Lead Nitrate Addition in Cyanidation: Guy Deschenes; Mike Fulton; Clint Smith; CANMET

In spite of the wide use of lead compounds to enhance cyanidation of sulphide-bearing gold ores, an industrial control method was only implemented 3 years ago. This study presents the results of an investigation that led to the development of the on-line control strategy for the lead nitrate addition. Two sulphide-bearing gold ores were used in the study. The relationship between the formation of thiocyanate and the addition of lead nitrate was quantified. Two methods for the determination of thiocyanate (visual titration and potentiometric titration) were assessed and proved reliable. The investigation established a link between the concentration of cyanides in the leach (pyrrhotite and chalcopyrite) and the efficiency of lead nitrate in reducing their detrimental effects.

Elimination of Zinc Ferrite for Hydrometallurgical Recovery of Zinc from EAF Dust: Guizhu Ye; Eric Burstrom; Massimo Maccagni; Lorris Bianco; Hakan Strippel; MEFOS

Hydrometallurgical zinc recovery from EAF dust has several advantages compared to pyrometallurgical alternatives in terms of low temperature operation, lower energy consumption and higher flexibility. Many hydrometallurgical processes have been suggested and tested over the years without success. The main reasons are: low leaching yield of zinc due to the fact that a high fraction of ZnO in EAF dust exists in the zinc ferrite structure which makes selective leaching of ZnO not possible; many of the proposals could not handle the halide in EAF dust. To eliminate these two disadvantages, two zinc ferrite elimination concepts have been tested and developed in the REZIN project of EU 5th Framework Programme. The two concepts for zinc ferrite elimination could be shortly described by the following chemical reactions: 1. ZnO*Fe2O3 + 2CaO = Ca2Fe2O5 + ZnOfree. 2. ZnO*Fe2O3 + C = Femet + CO2 + ZnOfree. These two concepts were investigated in details combined with a subsequent leaching step using the novel EZINEX process for recovery of zinc from iron from EAF dust. Leaching of pretreated samples has shown great increases of a zinc recovery yield. Zinc recovery of over 90% could be reached as compared to about 50% for no-pretreated samples. This paper will describe the two concepts in details.

Recovery of Ga, Ge, in from Zinc Residues by Hydrometallurgical Processes: Haibel Wang; Lei Zhang; Jiangshun Lin; Kaixi Jiang; Dingfan Qu; BGRIMM

China is the important country of reserves and products of Ga, Ge, In. They usually associates with lead and zinc ores such as Fankou, Dachang, Lanping mines. But until now these metals can not be extracted from zinc residues effectively. The main reason is that it is difficult to separate with zinc and iron. BGRIMM has carried out much research works on it. Hydrometallurgical processes were developed. Zinc residues was pressure leached with reducing agent such as zinc concentrates or SO2 at 110–130°C. The final concentrate of H2SO4 was 30–50g/L. The metals such as Zn, Fe, Ga, In were dissolved into solution. Pb and Ag in leaching residue could reach 20% and 2000g/t. The feed of solvent extraction was prepared from leaching solution by pre-neutralization – precipitation of Ga, Ge, In – acid dissolving. Then In, Ga, Ge were extracted by solvent extraction with P204 and G315 produced by BGRIMM. After stripping, metallic In and Ga were produced by electrowinning. GeO2 was produced by precipitation. The iron in raffinate was removed by hematite process. The solution after removal iron came back zinc neutral leaching stage. In 2003-2004, pilot tests were finished in BGRIMM cooperated with Fankou Lead and Zinc Mine Ltd. The extraction of Ga, Ge, In were 94%, 83%, 98% in leaching stage. The total recovery rate were 90%, 80%, 95%. The technology has a wide commercial use in the coming five years.

Recovery of the Chromium (III, VI) from Aqueous Solutions Using Ion Exchange System: Josiane Costa Riani; Versiane Albis Leão; Jorge Alberto Soares Tenório; Universidade de São Paulo; Universidade Federal de Ouro Preto

The release of heavy metals into the environment is becoming bigger due to human activities such as paintings and pigments industries, tanneries, metal finishing industries among others. Among metal releases, chromium is notable because this metal is carcinogenic. Thus, the aim of this work is to use an ion exchange system composed of one cationic resin column and one anionic resin column in order to adsorb the chromium (III, VI) of chromium electroplating effluents in order to recycle the water. The methodology consists of chromium adsorption tests using the ion exchange system with the resins: Purolite A 850 (polystyrene matrix, functional group quaternary amine) and Purolite C 150 (polystyrene matrix, functional group sulfonic acid). The contaminated solutions were passed through the columns with the assistance of a peristaltic pump. Samples of the outgoing solution were taken in order to control conductivity and pH and analyze the metals. The effects of the feeding outflow on the chromium adsorption were evaluated. The results show that the quality of the water collected at the end of the process is within the Brazilian standards for the discarding of toxic substances in the environment (CONAMA 357/05). Allowing, therefore, the water recycling in the process and also its discharging into rivers.
10:20 AM

Studies on Several Important Methods of Fe Removal from (Zn, Mn, Cu, Ni and Co) Hydrometallurgy: Wilson Zhang; Guanggui Mei; ‘Central South University

This paper described the study on several important methods of removing Fe in hydrometallurgy of Zn, Mn, Cu, Ni, Co and etc. including the methods of neutralized hydrolysis, ammoniojarosite and goethite, and the technical requirements and technical index of each method. Reactions for each major technological process have been expatiated based on the thermodynamic analysis.

10:45 AM

Study on Extracting Indium from Indium-Zinc Concentrates: Mo-Tang; Shi-Qing Li; Sheng-Hai Yang; Chao-Bo Tang; Shao-Hua Ju; You-Ming Chen; ‘Central South University; ‘Liuozhou Huaxi Group Corporation

A new process for extracting indium from indium-zinc concentrates was proposed in this paper. The process can directly extract indium from removed copper solution by P204, and cancel the stage of removing iron in the traditional process because of using iron and part of zinc in the In-Zn concentrates for direct preparing high quality Mn-Zn soft magnetic ferrites. The technologies in the processes, such as leaching the neutral leached residues with high concentrated acid at high temperature, reduction ferric and removing copper, and extracting indium, were investigated. The results showed that total recovery ratio of indium has been increased from less than 70% in the traditional process to more than 95%. This process has the advantages of largely simplifying the procedure of indium extraction, zero draining off of iron residue and zero emitting of SO2. So this is a clean production process.

11:10 AM

Sulfur Dioxide in Hydrometallurgical Technologies for Integrated Processing of Polymetallic Concentrates: Andrey V. Tarasov; E. M. Timoshenko; ‘Gintsvetmet

In order to improve the efficiency of hydrometallurgical processing of pyrrhotite concentrates, an integrated set of research has been carried out to investigate the use of sulfur dioxide in individual unit operations and as a leaching agent in the autoclave process as a substitute for oxygen. Treating iron-containing raw materials for production of nonferrous metals are based on the selective reaction of SO2 with iron sulfides and oxides. Iron is dissolved as sulfate, which can be treated in a separate circuit to produce iron-containing pigments or it can be disposed of after neutralization. Nonferrous and precious metals contained in pyrrhotite concentrate do not react with sulfur dioxide and remain virtually completely in the solid phase, i.e. high-grade sulfide concentrate to be treated by hydro- or pyrometallurgical methods. Elemental sulfur formed in the process of leaching is separated from the pulp in granulated form as a result of the use of special surfactants. The process of sulfide concentrate leaching with the use of sulfur dioxide is conducted at temperatures above the sulfur melting point (119°C) with distributed feeding of surfactant and under a partial pressure of sulfur dioxide of up to 0.3 to 0.5 MPa.

11:35 AM

High-Efficiency Reactors for Obtaining of Metal Powders: Tinatin Lezhava; ‘R. Agladze Institute of Inorganic Chemistry and Electrochemistry

The known methods of metal powder obtaining by electrolysis are characterized by following: process discontinuity, complexity of solution composition, complexity of the product unloading, low productivity of the process. A new model of the reactor with rotating cathodes have been developed, where obtaining of various forms (dendrite, spongy) of metal depositsions and their unipolarized derivation is possible by realization of ultra-high current densities (5000-50 000 A/m2) and low energy consumption (the bath voltage does not exceed 3-6V). The forms of the cathode deposits and granulometric composition regulated by the current density, electrolyte concentration, temperature and speed of cathode rotation. At the same by contrast to existing methods, high quality metal powder may be obtained from concentrated electrolytes without any specific organic or inorganic additives, which makes possible raise the intensity of the process. The reactor can be applied for electrowinning of metals with low adhesive capacity (Pb, Ag, Cu, Zn, Ni, Co etc.) and their alloys powders. Obtained products may be utilized in metallurgy, as well as in powder metallurgy (Gergian Patents #2004 1097 U; #2001 2535; #2001 2537; #1998 1492). An operating ability of the reactor is tested in laboratory and laboratory scales by the example of dendrite zinc and spongy copper isolation from the corresponding model sulfate electrodes. The advantages of the proposed method in comparison with its analogues are: efficient production, automation of the technological processes and improvement of environmental requirements.

New, Improved and Existing Technologies: Materials Processing II: Nano, Ceramic and Composite Materials

Wednesday AM
Room: Russeau West
Location: Calamaran Resort Hotel

8:00 AM Keynote

Antibacterial Evaluation of Carbon-Ceramic Composites: Osamu Tsumoto; Zenbe-E Nakagawa; ‘Akita University

We searched the development of antibacterial ceramics that can be used in the place without the presence of light so far. On the research, we found that three ceramics, such as CaO, MgO and ZnO, which have a strong antibacterial activity without the presence of light. In order to search the inorganic materials with stronger antibacterial activity, carbon-ceramic composites were synthesized, such as activated carbon dispersed with ceramic nano-particles, and ceramic coated with carbon, because carbon has high absorption performance for bacteria. In the case of activated carbon with nano-particles, the antibacterial activity increased with increasing the amount of ceramics and decreased with increasing carbonization temperature. In contrast to activated carbon with nano-particles, the antibacterial activity of the ceramic coated with carbon was similar to that of ceramic itself. In antibacterial ceramics, the activity of ZnO was in particular interesting. Because ZnO showed antibacterial activity in a neutral region, being different from CaO and MgO. The occurrence of antibacterial activity was supposed to be due to the generation of hydrogen peroxide from ZnO.

8:25 AM Invited

Synthesis of Metal Oxide Nanoparticles by Flame Spray Pyrolysis: Hee Dong Jang; Hankwon Chang; Chul Kyoung Lee; Yong Jae Suh; ‘Korea Institute of Geoscience and Mineral Resources; ‘Kumoh National Institute of Technology

Flame spray pyrolysis was applied to produce binary metal oxides nanoparticles such as lithium cobalt oxides, indium tin oxides from the aqueous solution of the precursor. A high enough flame temperature was used for the complete thermal decomposition of the aerosol precursor. Molar concentrations of the precursor solution, and the flow rate of combustion gas such as hydrogen are varied to control particle size, size distribution and crystal structure. Crystalline LiCoO2 and ITO nanoparticles with the average particle diameter ranging from 11 to 35 nm and from 11 to 20 nm were synthesized, respectively. The LiCoO2 powder was proved to have good characteristics as cathode active materials in charge/discharge capacity and cyclic performance. The transparency and conductivity of the ITO film prepared was quite acceptable for the industrial application.

8:50 AM

Nanotechnology-Based Water-Filtering and Purification Solutions for Emerging Biomedical Applications and Advanced Health Benefits: Ion Nemerencov; Nanowater

The idea presented in this paper is a novel concept of kremen-activated water-filtering and purification technology shows that a molecule-level mechanism can considerably enhance purity and quality of drinking water via biocatalyzed nanostructuring, positive energizing, and purification of processed water (“nanowater”) from any microorganisms or contaminations. It provides normal water with emerging biomedical applications and
unique health benefits. The water cleaning technology is based on the biocatalyst properties of black flint mineral stone (“kremen”) found in cer-tain parts of the world. The observed positive effects of nanowater result from its unique capabilites of saturating the human body with oxygen (O2), distributing water molecules evenly across the human body, and increasing the organism’s antioxidant complex through better assimilation of regulated nanowater particles which contain health-enhancing elements. The health benefits acquired by nanowater create an easy to apply the benefits in areas of human health, agriculture and medicine.

9:15 AM

Chemical Vapor Synthesis of WC-Co Nanocomposite Powders: Manolete Mena1; Taejong Ryu1; Hong Yong Sohn1; Gilsoo Han1; Young-Ug Kim1; Zhigang Z. Fang1; 1University of Utah

WC-Co nanocomposite powder is among the first group of materials with a promising potential for nanocrystalline-materials application. A chemical vapor synthesis (CVS) process that has previously been used for preparing the aluminides of titanium and nickel, and other metallic and intermetallic powders has been applied to the preparation of WC-Co nanocomposite powder. This CVS system was designed so that a tungsten precursor (WC powder) and a cobalt precursor (CoCl2 powder) were separately fed into each evaporator in a reactor by means of specially designed powder feeders. The reduction and carburization of the vaporized chlorides by methane-hydrogen mixtures produced nanosized WC and Co composite powder. The product is a very uniform mixture of the constituent powders, which is important to ensure a high quality of the bulk cemented tungsten carbide product after consolidation. In the present work, the effects of reaction temperature, CH4 to WCl6 ratio, CH4 to H2 ratio, residence time, and Co content on the powder composition and particle size were determined. The products were characterized using XRD, carbon analyzer, and TEM.

9:40 AM Break

9:55 AM Keynote


Self-propagating high temperature synthesis -SHS, or combustion synthesis, is an extremely versatile process that is essentially simple in concept, being based on an exothermic reaction, but is often difficult to control. The control of SHS reactions is based on developing a thorough understanding of both the thermodynamics and kinetics of the exothermic reaction(s) that are used to synthesize and shape the final product. This paper will discuss the application of SHS and the control of the SHS reaction parameters in the production of advanced materials, and its application in the manufacture of multi-functional components. The versatility of SHS will be demonstrated in: (i) the synthesis of a wide range of advanced materials that include metal matrix, intermetallic matrix and ceramic matrix composites (MMC, IMC, CMC), (ii) the production of components such as biomedical implants, drug delivery systems and bone cement, in-space fabrication and repair of shuttle tiles; functionally graded material components, (iii) joining of materials that are traditionally difficult to join, (iv) near net shaped manufacturing, (v) recycling of nuclear fuels.

10:20 AM

Preparation of the Solution Containing Metal Nano-Particles and Its Characterization: Toshiharu Hayashi1; Tsutomu Atsuki1; Reiko Kiyoshima1; Osamu Yamamoto1; 1Mitsubishi Materials Corporation; 2JEMCO Inc.; 3Akita University

We prepared aqueous solution containing spherical metal nano-particles, such as Au and Ag, with the size of a few nm by novel chemical processing; generating seeds of metal precursor by adding borane dimethylamine complex into the metal salt solution, and then growing simultaneously with aminoalcohol including in the solution. As-prepared metal nano-particles modified by chemical species were found to have three active performance as follows: (1) Nano-particles show a high dispersiveness in an aqueous solution in a long time, (2) nano-particles were sintered at room temperature, and (3) the metal films prepared from nano-particles have low resistivity at room temperature. By various measurements, it was found that 2-aminoethanol was modified on the surface of metal nano-particles. The sintering behavior of metal nano-particles were dependent on the elimination of 2-aminoethanol modified on its surface.

10:45 AM

Durability of Two Extractants for Pd(II) Separation, Thiodiglycolamide and Di-N-Hexyl Sulfide: Against a Mixed Solution of HNO3 and HCl: Hirokazu Narita1; Mikiya Tanaka1; Kazuko Morisaku1; 1National Institute of Advanced Industrial Science and Technology

Di-n-hexyl sulfide (DHS) has been extensively employed in the industrial processes for the palladium(II)/platinum(IV) separation. However, some problems (e.g., the slow extraction of Pd(II) with DHS, its low durability, etc.) have not been solved yet. Recently, we have found that N,N-di-methyl-N,N’-di-n-ocetyl-thiodiglycolamide (MOTDA) rapidly extracts Pd(II) in hydrochloric acid solutions with a good selectivity. Thus, in this study, the extractability for Pd(II) using MOTDA and DHS and their durability against a mixed solution of HNO3 and HCl was investigated by solvent extraction and FT-IR measurements. Both MOTDA and DHS selectively extract Pd(II) over Pd(IV) from 0.75 M HNO3-2.25 M HCl solutions. The extraction rate of Pd(II) with MOTDA is much greater than that with DHS. In the durability test, the extraction percentage of Pd(II) and FT-IR spectra were measured using MOTDA and DHS in contact with 0.75 M HNO3-2.25 M HCl solutions. The extraction percentage of Pd(II) with MOTDA hardly changes during the two-month contact; however, that with DHS decreases with an increase in the contact time. The FT-IR spectra showed that the peak corresponding to the sulfoxide formed by the oxidation of sulfide appears in the DHS system, but not in the MOTDA system. Consequently, it was found that MOTDA is more durable than DHS.

11:10 AM

Advanced Technology of Manufacture of Layered Composite Materials by the Method of Electro-Contact Heating under Pressure: David Nogacz1; 1Georgian Technical University

A new method of isothermal electro-contact diffusion welding of layered composites under pressure is offered. The scheme is developed and laboratory installation is created on which preproduction models of the layered composite of steel and aluminum is produced. A new method of electro-contact hot deformation is proposed for realization of diffusion welding by pressure of stratified blanks providing high-temperature isothermal process. In this case a rolling process or composite pressing is meshed with simultaneous electric current transmission in deformation center. Considering that a resistance of transient layer far exceeds the resistances of composite components, the heat release takes place intensively just in this layer. As the surfaces are approached over a distance of inter-atomic forces, the energy of boundary atoms easily reaches the energy threshold of capture with a formation of qualitatively new metallic bond. Proposed method, providing isothermal process in deformation center, excludes a necessity of previous preparation and protection of surfaces. In this case strength of layer connection may approximate or exceed a strength limit of cladding layer.

11:35 AM

Surface Material Compensation Film Thickness for Phase-Separated Composite Film: Chia-Fu Chang1; Chia-Hi Chan1; Zou-Ni Wan1; 1Kun Shan University of Technology

The method underlying this development is formulated in terms of multiple-scattering theory with the real-space representation. A method of preparing liquid crystal devices by phase separation of liquid crystal from its solution in a prepolymer, which results in adjacent layers of liquid crystal and polymer, is described. Liquid crystals in these phase-separated composite films exhibit electro-optical properties not observed in devices prepared by conventional methods, polymer dispersion, or polymer-stabilization methods.
Technical Program

12:00 PM
Synthesis, Structure and Performance Studies of LiFePO4-Based Cathode Materials for Li-Ion Battery: Xi Dai; Honghui Tang; Chuanfu Zhang; Ping Yang; ‘Central South University

The Li-ion battery cathode materials LiFePO4 and LiFe0.9Ni0.1PO4 were synthesized with FeC2O4·2H2O and Fe0.9Ni0.1C2O4·2H2O as Fe sources by high temperature solid-state reaction method. The FeC2O4·2H2O and Fe0.9Ni0.1C2O4·2H2O materials were produced by liquid co-precipitation method. The crystalline structure, morphology of cathode materials were characterized by X-ray diffraction and scanning electron microscopy. The composition contents and charge-discharge performances were measured by electrochemistry analysis and charge-discharge apparatus. The XRD patterns showed that both LiFePO4 and LiFe0.9Ni0.1PO4 samples were pure, well-crystallized, homogeneous olivine-type phase, with only about 0.4% Fe3+ impurities according to chemistry analysis results. Charge-discharge test showed the cathode materials possessed excellent performances in terms of specific capacity, reversibility, cycling stability and rate performance at room temperature. The first cycle discharge specific capacity of LiFePO4 was up to 150mAhg⁻¹ and was about to 140mAhg⁻¹ after 30 cycles at 0.1C rate. Additional, the discharge specific capacity of LiFe0.9Ni0.1PO4 was more than 120mAhg⁻¹ after 90 cycles almost without capacity fading at 0.5C rate.

New, Improved and Existing Technologies: Non-Ferrous Processing II

Wednesday AM
August 30, 2006
Room: Toucan
Location: Catamaran Resort Hotel

8:00 AM Keynote
Microwave Sintering, Brazing and Melting of Metallic Materials: Dinesh Agrawal; ‘Pennsylvania State University

Microwave energy has been in use for various applications for over 50 years. These applications include communication, food processing, wood drying, rubber vulcanization, medical therapy, polymers, etc. In the last two decades the microwave heating has also been applied very effectively and efficiently to heat and sinter ceramics. The most recent application of microwaves is the processing of metallic materials including sintering, brazing/joining and melting. This is unexpected in view of the fact that the bulk metals reflect microwaves. But if the metal is in the form of powder, it absorbs microwaves at room temperature and then gets heated very effectively and rapidly. This presentation summarizes the important developments in microwave processing of metallic materials. Microwave heating is recognized for various advantages such as: time and energy saving, very rapid heating rates, considerably reduced processing cycle time and temperature, fine microstructures and improved mechanical properties, better product performance, etc. It was recently observed that microwave energy can be very effectively applied to sinter metal powders and a specially designed microwave cavity can even melt bulk metals very rapidly and uniformly. Several common steel compositions, pure metals and refractory metals have been sintered in microwave to nearly full density with improved mechanical properties. Many commercial powder-metal components of various alloy compositions including iron and steel, copper, aluminum, nickel, Mo, Co, Ti, W, WC, Sn, etc. and their alloys have also been sintered in microwaves producing better properties than their conventional counterparts using 2.45 GHz multimode microwave system. This work has been further extended to join and braze bulk metal pieces, especially super alloy based turbine blades with very attractive advantages. The implications of these findings are obvious in the field of powder metal technology. Metal powders are used in industry for diversity of products and applications. The challenging demands for new and improved processes and materials of high integrity for advanced engineering applications require innovation and newer technologies. The newly developed microwave technology provides an opportunity to develop better and cheaper products.

8:25 AM
Effect of CaSO 4 Pelletization Conditions on Pellet Strength and Reactivity for Converting SO 2 to Elemental Sulfur by Reaction Cycles Involving CaSO 4/CaS: Moo Eob Choi; Hong Yong Sohn; Y. M. Z. Ahmed; F. M. Mohamed; Gilsoo Han; M. E. H. Shalahi; ‘University of Utah; ‘Central Metallurgical Research and Development Institute

A new process for converting sulfur dioxide to elemental sulfur by a cyclic process involving calcium sulfide and calcium sulfate without generating secondary pollutants was developed at the University of Utah. In this process, sulfur dioxide is reacted with calcium sulfide to produce elemental sulfur and calcium sulfate. The latter is reduced by hydrogen to regenerate calcium sulfide. In the present work, the effects of different pelletization conditions for the initial reactant calcium sulfate on the strength and reactivity of the pellets were determined. These conditions include the type, amount, and impregnation method of catalyst, binder amount, and sintering. Experiments were also performed to determine the effects of temperature in the range of 973-1173 K, pellet size, cycle repetition, and water vapor or carbon dioxide content in sulfur dioxide stream on the reaction rates of the cyclic process. Nickel-catalyzed fired pellets produced by the use of molasses or cement as a binder showed good reactivity as well as high compressive strength during the cyclic tests. The binder amount did not significantly affect the reaction rate.

8:50 AM
New Technology for the Treatment of Molybdenum Sulfide Concentrates: Kliment Y. Hakobyan; Hong Yong Sohn; Andrey V. Tarasov; Pavel A. Kovgan; Armen K. Hakobyan; Vladimir A. Briovkine; Vladimir G. Leontiev; Oleg I. Tsyhny; ‘Kapan Metallurgy and Enrichment Laboratory of the Academy of Science of Armenia/Nayro LLC; ‘University of Utah; ‘Gintsvetmet; ‘A. Baykov Institute of Metallurgy and Materials Science

A new technology for treating molybdenum sulfide concentrates has been developed. It includes roasting the concentrate in a special regime with water vapor, cooling and neutralizing exit gas, oxidation roasting of rhenium containing MoO 3, and the extraction of rhenium from exit gases. This technology allows economically efficient and environmentally safe processing of molybdenum concentrates: The degree of molybdenum extraction is 98.8%, rhenium-90%, sulphur-98.4%. The technology also ensures high extents of extraction of selenium and tellurium as well as the fixation of sulfur in the form of sodium sulfide or elemental sulfur.

9:15 AM
Processing of Lead-Zinc Raw Materials: Andrey V. Tarasov; A. B. Besser; Gintsvetmet

The natural resources of lead and zinc are primarily constituted by polymetallic and lead-zinc ores. Beneficiation of these types of ores to produce standard nonmetallic concentrates inevitably results in an increase in the loss of base and precious metals with tailings. An improvement in the grades of lead and zinc concentrates can be achieved by re-cleaner flotation, but it results in production of intermediate products (middlings) to which substantial amounts of lead, zinc, copper and precious metals report. Without an appropriate technology for treating such intermediate products, the recoveries of valuable constituents from lead-zinc ores would remain unsatisfactory. A process has been developed in the Gintsvetmet Institute for processing of polymetallic intermediate products produced at the ore beneficiation plants. This process is based on electrothermic smelting to produce lead bullion containing precious metals, commercial-grade copper-lead matte and high-zinc slags (up to 15-20% Zn) from which zinc can be extracted by slag-fuming or Waelz process. Tests have indicated that the recovery of lead from intermediate products into lead bullion and matte is about 83-85% and 13-14% respectively (the total recovery is 97-98%), while copper recovery into the matte and zinc recovery into the slag is 90-92% and 95-96% respectively. Precious metals (about 96-97%) report into the lead bullion.
Concentrated solar energy can be used as heat source for the production of metals. One of the most promising processes involves the solar carbothermic production of Zn from ZnO, which is investigated within the European research project SOLZINC, a collaboration involving institutes and industries from France, Germany, Israel, Sweden and Switzerland. The solar produced Zn can be used as commodity or as an energy carrier for further processing on demand to electricity in Zn-air fuel cells/batteries or to generate hydrogen by reaction with steam. In both cases the end product is again ZnO, which can be recycled back to the solar plant. In these cyclic processes Zn acts as a means to store and eventually transport solar energy. Second product of the solar process is a CO-rich offgas, which may e.g. drive a gas engine or may be split to hydrogen in a conventional reaction with steam. A pilot plant using 300kW concentrated solar power input has been constructed and operated successfully. 86mass-% of ZnO mixed with 14mass-% of charcoal are reacted to produce Zn and CO at a temperature of about 1200°C, yielding about 50 kg gaseous Zn per hour. Zn-dust with 95% purity is recovered from the offgas system that was designed to produce Zn for Zn-air fuel cells. Based on the results and findings from the pilot plant, a 2 tons Zn/h solar demonstration plant has been designed conceptually. Cost studies have been performed and scenarios for producing electricity or H₂ via these ZnO/Zn-cyclic processes are evaluated.

10:20 AM Invited
Aluminum Extraction via Batch Recirculation Electrolysis in Ionic Liquids: Mingming Zhang; Ramana G. Reddy; University of Alabama

This paper describes the aluminum electrowinning in a batch recirculation cell system using 1-hexyl-3-methylimidazolium chloride and aluminum chloride (ionic liquids) as electrolyte at low temperatures. The technique proposed to deposit aluminum from ionic liquid electrolyte was a three-component electrolytic cell system. Ionic liquid electrolyte was circulated between electrolytic cell and electrolyte reservoir by ceramic piston pump. The cell performance variables studied were the aluminum ion concentration, current efficiency and deposition rate as a function of current density, fluid hydrodynamic conditions, applied voltage, and process operating time during batch recirculation operation. Results indicated that the current density was directly proportional to the applied cell voltage and initial electrolyte concentration. During the electrolyte cell operation, the aluminum deposition rate was proportional to the current density and was inversely proportional to fluid velocity in the range between 0.005 and 0.100 m/s. Under batch recirculation operation at constant applied voltage of 3.0-4.0 V, it was found the current efficiency of 80%-90% of cathodic aluminum deposition can be achieved at temperature range of 80-120°C, and aluminum deposition rates were independent of applied voltage, but were proportional to the ions concentration and operating temperature.

10:45 AM
Processing Complex Copper Matte by Using Pig-Iron: Leandro Voisin; Kimio Itagaki; Alex M. Moyano; Jonkion M. Font; Tohoku University; Codelco-Chile; IM2 SA. Filial Codelco-Chile

A new alternative pyrometallurgical treatment is proposed for cleaning copper matte with a high content of arsenic. In the process, a given amount of pig iron is added to the liquid complex matte with a matte grade between 65 and 75% Cu under a reducing condition to produce three liquid phases of matte, copper-rich alloy and iron-rich alloy. In this study, firstly, a mass balance calculation was made on the basis of the reported data for the distribution ratios of the components among the three phases to look for the optimum condition where most of arsenic in the charge can be fixed in the less valuable liquid iron-rich alloy. By take advantage of the high concentration of arsenic in the iron-rich alloy it may be disposed in a yard with a smaller volume in comparison to the traditional processes, while the precious elements be effectively recovered in the liquid copper-rich alloy or liquid matte. Secondly, laboratory scale experiments were conducted to apply the process proposed to the matte produced in the slag-cleaning electric furnace in conjunction with the matte obtained from the Teniente Converter in Codelco-Norte’s smelter, Chile. The obtained results indicate that the process proposed for cleaning the complex matte will be promising.

11:10 AM
Non-Ferrous and Precious Metals Extraction from Complex Sulfide Concentrates by Pyrometallurgical Processing: Natasa Mitrovsk; Ljubisa Misic; Joksim Marinovic; Copper Institute

In world, as well as in Republic of Serbia, conventional ore reserves are almost exhausted, so the problem of their shortage is more and more expressed. On the other side, there are many locations with significant reserves of polymetallic ores which present huge potential but cannot be classically processed. Each of these classes of materials has particular mineralogical characteristics which affect their processing. Because of that it is necessary to develop particular technology for each unconventional ore in order to extract valuable elements. The aim of investigation was to define technology for complex processing of the Blagojev Kamen sulfide concentrate by pyrometallurgical procedure in order to valorize valuable non-ferrous and precious metals present, and profit with absolute respect of environmental protection laws. The complex composition of the Blagojev Kamen sulfide concentrate with high content of non-ferrous (15.59% Pb, 9.05% Zn, 2.37% Cu) and precious (697 g/t Au and 744 g/t Ag) metals was the main factor for technological procedure and collector selection. Laboratory investigations are done in four series according to technological scheme: oxidizing roasting, charge preparation (flux addition and agglomeration), smelting under reducing conditions, lead bullion refining. Dore metal refining to final products. It is concluded that precious metals are concentrated in lead bullion (up to 97.95% of gold and 93.37% of silver), which has similar composition to lead bullion produced in lead metallurgy. In this case, simplified technology is used for lead bullion processing because of low content of arsenic, bismuth, etc.

New, Improved and Existing Technologies: Steel

Wednesday AM Room: Cockatoo
August 30, 2006 Location: Catamaran Resort Hotel

8:00 AM Invited
Electromagnetic Processing of Materials - Past, Present and Future: Shigeo Asai; Nagoya University

Application of an electromagnetic force to materials processing, so called “Electromagnetic Processing of Materials (EPM)” has been recognized as not only a fundamental technology supporting metals industry, but also a cutting edge technology, especially in the fields of advanced materials processing. It first started as the application of Lorentz force to metals industry in 1980s when it was named an Electromagnetic Metallurgy. The name of “Electromagnetic Processing of Materials (EPM)” was firstly formally used in the Iron and Steel World Congress held at Nagoya 1990. The first Symposium of EPM was held Nagoya, 1994, followed by Paris in 1997, Nagoya in 2000, Lyon in 2003 and Sendai in 2006. Recently, by the advance in super-conducting magnets, a high magnetic field has become readily available and is being applied in various fields of science. In this trend many interesting phenomena relating to the high magnetic field have been found and a new academic field named “Science Relating with a High Magnetic Field” is going to open a gate. In order to connect the seeds sprouting from “Science Relating with a High Magnetic Field” with the needs of “Materials Science and Engineering”, the new field of “Materials Processing by Use of a High Magnetic Field” is going to grow under the umbrella of “Electromagnetic Processing of Materials”.

www.tms.org/Sohn2006.html
The economic growth in new developing countries such as China and Technological University has stimulated strong demands in basic materials such as steel. World steel production has exceeded the milestone of a billion tons a year recently. However, the blast furnace technology, which was invented in 1340 A.D., is still the fundamental route for today’s steel production. It is important to develop a new generation of steelmaking technology that can meet the society’s needs from the energy, environmental and economic standpoints in the 21st century. The new microwave and electric arc heating technology discussed in this paper provides a totally different mass and heat transfer mechanism from the conventional blast furnace steelmaking and offers a great potential to meet our society’s needs.

10:20 AM

The Goodfellow Expert Furnace System Optimization Process (Goodfellow EFSOP™) is a proprietary process that uses real-time and continuous off-gas analysis, along with process monitoring to optimize the operation of electric arc furnaces (EAF) for steelmaking. With the exception of off-gas composition, dynamic process measurements within the EAF are not possible due to the harsh operating environment. The Goodfellow EFSOP™ system provides a dynamic indication of the operating conditions within the EAF. Continuous measurement of furnace off-gas composition, along with other furnace operating parameters is used to elucidate the fate of chemical energy usage within the EAF including: the evolution of carbon from the molten steel bath; the in-leakage of air into the furnace; the extent of combustion above the molten steel bath and the occurrence of dangerous water-leaks from the furnace cooling system. The ability to measure the process reliably and continuously enables Techint Goodfellow Technologies Inc (TGTI) to implement dynamic process control of combustion within the electric arc furnace and to optimize the overall operation through adjustments to the EAF process based on off-gas measurement. This paper discusses the methodology and results achieved from several recent Goodfellow EFSOP™ installations in South East Asia.

10:45 AM
Potential Applications of Supersonic Liquid Streams in Steelmaking: Ernest Samuel Geskin; ‘New Jersey Institute of Technology

Supersonic liquid streams have a potential of becoming an effective material production tool. It was shown that at the speed of 1500-1750 m/s the water projectile are able to demolish concrete and reinforced concrete plates, forge, pierce and weld metals, to destroy with no explosion non-dischargeable mines, etc. The energy needed for the projectile acceleration can be supplied by the electrical discharge, chemical explosion, mechanical impact, etc. An experimental launcher studied by the NJIT’s Waterjet Laboratory constitutes a modified rifle where the powder combustion provides the energy needed for projectiles acceleration. A potential application of the supersonic liquid streams involves the replacement of the oxygen gas by the liquid oxygen in BOF and in the course of the direct steelmaking. This will enable us to increase the rate of processes and to improve the reactor design. Blasting of molten oxides by the hydrogen stream will eliminate CO2 emission and reduce the cost of metal production. Combining liquid jet and mechanical tools in the course of ore mining and grinding will reduce the cost of the formation of fine particles suitable for the solid state oxide separation. The presented paper reviews the results of the experimental study of supersonic liquid jets and discusses their potential applications in steelmaking.

11:10 AM Keynote
Modeling of Melting in Industrial Furnaces: Neeraj Kuari; Om Prakash; Ravindra Pardeshi; Amarendra Kumar Singh; ‘Tata Research Development and Design Centre Pune

Melting is an important unit operation to both ferrous and non-ferrous metal industries. A model for melting operation is presented in this work. Industrial melting often involves high degree of porosity (scrap melting, for example) of bed. Heating and melting of model involves all three modes of heat transfer, namely, conduction, convection and radiation. As opposed to solidification, melting has received less attention. In present work, a finite
volume based heat transfer model is developed for the melting of a porous mass. The model is based on continuum framework and accounts for change in porosity of bed as melting progresses. During the transient heating and melting process, the model predicts the evolution of solid, liquid and gas fractions. Radiation inside the porous mass is accounted through effective conductivity and convection through the porous mass is accounted through in increased conductivity of air. Using the model, the effect of important parameters such as porosity of bed and furnace temperature on melting time is studied. Cost-effective productivity of a furnace is directly linked to bed porosity of raw material, effective heat transfer and furnace temperature and the model is expected to provide a useful guiding tool for optimization of these process parameters.

Electrochemistry of Production of Materials Using Molten Salts

Molten salts have been used for the extraction of metals since the 19th century but, recently, many interesting processes have been investigated using mixtures of molten salts and different cathodic materials. In several existing processes, the cathode is simply discharged from melt but, in some cases, complications arise when the electrode potentials of the cations are relatively close. For example, the co-deposition of sodium with aluminium in the Hall-Heroult process which will be discussed in terms of electrode potentials of the components in the molten electrolyte. Similar considerations will also be given to the anodic reactions with respect to chlorine, oxygen, carbon dioxide or monoxide evolution from chloride-oxide melts. In some cases, the cathodic product interacts with the cathode to produce new and exciting products such as nanotubes from carbon or titanates and reduced titanium oxides from titanium dioxide. Depending on the electrode potentials, it is also possible to completely change the cathodic reaction from discharge of the cation in the salt to ionisation of the anions in the cathode. Examples will be given of the reduction of metal oxides to produce metals, high technology alloys and nanomaterials and the cathodic refining of liquid metals.

Electrokinetics of Lead Carbonate, Silica and Alumina and Their Applications on Treating Water Polluted with Lead: F. J. Tavera; R. Escudero

A study on the electrokinetics of lead carbonate, silica, and alumina, in aqueous media was carried out at different pH values. The behaviour of ζ potential was determined for these species in the pH range between 3 and 12. Homocoagulation of lead carbonate in aqueous media is analysed at its isoelectrical point. Lead carbonate heterocoagulation is analysed with silica, alumina, and silica – alumina mixtures at low pH values. The experimental results are considered for their possible application to treat residual water polluted with lead.

Self-Tuning Chemical Sensors for Molten Metals: R. Vasant Kumar; Derek J. Fray

Measurement and control of trace elements in molten metals are often critical in order to achieve optimum production, refining, alloying or recycling. Solid electrolyte sensors for monitoring oxygen and very recently for hydrogen have made major impact in the metal industry. It has not proved straightforward to develop solid electrolyte sensors for many elements that can be industrially applied in metal production. Novel self-tuning chemical sensors have been developed by the authors that may open up new technological opportunities. Three such examples will be presented in this paper: (i) a self-selecting oxygen-sulfur dual sensor using a composite beta-alumina/zirconia solid electrolyte; (ii) a copper sensor for liquid copper systems based on Cusion solid electrolyte; and (iii) an aluminium sensor based upon solid NaCl containing channels of molten salt electrolyte formed by electrochemical charging during measurement in molten zinc.
So far, we found an experimental condition that allows a continuous anodic dissolution of titanium for approximately 600 sec to feed titanium ions to TMHA-Ti,N medium although it is not long enough. In this presentation, we report the detail of the anodic dissolution and discuss what depresses anode current during the 600 sec.

10:45 AM
Evaluation of Carbon Materials Produced from Coconut Shell as Anodes for Lithium-Ion Batteries: M. A. Aziz; M. A. Alauddin; Khulna University of Engineering and Technology; Islamic University

The electrochemical performance of a series of carbon materials produced from coconut shells, which are very cheap and readily available in Bangladesh was investigated for their viability as anode materials in rechargeable lithium-ion batteries. X-ray diffraction technique was used to measure the interlayer spacing (d_{002}) of the produced carbon materials. A number of half-cells were prepared with the produced carbon materials from coconut shell as working electrode and metallic lithium as counter electrode with 1M LiPF_6 electrolyte in a mixture of ethylene carbonate and dimethyl carbonate. The discharge-charge profiles were measured for the different half-cells by using Arbin 24-channel Cyler. The value of interlayer spacing of the coconut-based carbon material was found to be 0.397 nm at 900°C, which is most suitable for lithium-ion insertion into the carbon structure without any expansion. The specific discharge capacity of carbon material from coconut shell heat treated to 900°C was found to be 1015.65 mAh/g. The coconut carbon material heat treated to 900°C delivered 335.22 mAh/g reversible capacity, which is comparable to the commercial carbon/graphite presently used in lithium-ion battery systems. The irreversible capacity loss and coulombic efficiency in 25th cycle of half-cell made with coconut carbon material were found to be 8.16% and 99.83% respectively. The carbon material produced from coconut shell can, therefore, be used as a potential anode for rechargeable lithium-ion batteries.

11:10 AM
Electrochemical Synthesis and Characterization of Tantalum Ethoxide: Sheng-Hai Yang; Yi-Feng Chen; Jian-Guang Yang; Shao-Hua Ju; Mo-Tang Tang; Guan-Zhou Qu; Central South University; Hunan Metallurgical and Polytechnical Institute

The electrochemical synthesis was conducted in anhydrous ethanol solvent mixed with conductive reagent when tantalum plate was used as anode and stainless steel plate as cathode. The effects of different conductive reagents (such as NH_4Br, (CH_3)4NCI, (C_4H9)4NCI) on the current efficiency of electrochemistry was more than 95%. The electrolyte, a mixed solution was then undergone air distillation and vacuum distillation to get the final product which was characterized by Fourier Transform Infrared (FTIR) spectroscopy, Raman spectra, 1H-Nuclear Magnetic Resonance (1H-NMR) spectroscopy. Carbon and hydrogen contents in the product were determined by elemental analysis instrument. Results consistently show that the product was tantalum penta-ethoxide.

11:35 AM
Prospects for the Use of Symmetric Alternating Current for Hydroelectrochemical Treatment of Various Metallic and Metal-Containing Materials with Selective Extraction of Valuable Components: F. A. Bruyukin; A. M. Levin; A. A. Palant; V. M. Paretsky; Gintsvetmet; Russin Academy of Sciences

It has been found that by superimposing symmetric alternating current over the process, the rate of nickel and cobalt leaching from metallized products with copper sulfate solutions increases by a factor of 1.5 to 2.0 and the apparent activation energy of the process investigated is reduced from 12 down to 6.6 kcal/mole. It appears especially attractive to use alternating current for anodic dissolution (oxidation) of metallic scrap of refractory metals and their alloys in ammonia electrolytes permits production of high-grade commercial products in the form of respective ammonium salts using a short and virtually reagent-free process flowchart. Similar approaches can be applied also for electrochemical processing of nickel and copper scrap in sulfuric acid medium with subsequent recovery of pure sulfate salts or electrolytic processing. Electrochemical technology for recycling of tungsten-cobalt (WC 15) and tungsten-rhenium (WR 20) alloys has been also investigated. In the former case, anodic oxidation of carbide alloy was carried out in nitric acid electrolyte with production of pure tungstic acid. The research conducted has indicated that the physicochemical effect of alternating current results in a lower activation energy of electrode reactions due to changes in the mechanisms of the electrode reactions themselves.

8:00 AM
A 2-D Mathematical Model of On-Grate Municipal Solid Waste Combustion: Abhisek Asthana; Yannick Menard; Philippe Sessiaceq; Fabrice Patisson; Denis Abitiz; School of Mines of Nancy

The incineration of Municipal Solid Wastes (MSW) is an attractive process for reducing the volume of the wastes and recovering their energetic value, which, however, requires to be strictly controlled in order to limit its impact on the environment. In this context, we have undertaken the mathematical modeling of the different sections of a typical incineration plant. The combustion of the waste bed, usually carried out on a moving grate, is at the core of the process. This paper presents the 2-dimensional, steady-state model that we have developed for simulating the MSW bed combustion. The model describes gas flow through the porous waste particle bed, the gas-solid reactions, conductive and radiative heat transfers, drying of the feed, pyrolysis and the emission of volatile species, combustion of the pyrolysis gases, the formation of char and its gasification by water vapor and carbon dioxide, and the consequent reduction of the bed volume. Pyrolysis kinetics distinguish between cellulose and non-cellulosic materials and are experimentally derived from our laboratory measurements. The calculated results give a deep insight into the various involved phenomena, an example being the complete consumption of oxygen in a large zone of the bed and the related appearance of a char gasification zone. The influence of various operating parameters, like the temperature and flow rate of primary air, is presented and explained. Finally, the effect of stirring the waste bed on the moving grate is analyzed for different stirring schemes.

8:25 AM
Commercial Research on Separation and Purification of Waste Acid in IT Manufacturing Process: Ju-Yup Kim; Jae-Woo Ahn; Chang-Hoon Shin; Junji Shibata; Jong-Gwan Ahn; Daeilgaebal/Research Center; Daejein University; Kansai University; Kigam

Separation and purification process for acids in a waste acid mixture discharged from IT relating industries was established by using solvent extraction. The extraction behaviour and extraction mechanism for each acids were investigated with suitable extractant. By analyzing the extraction and stripping isotherms in terms of the McCabe-Thiele method, a separation process was proposed for each acid recovery from the waste acid mixture. A pilot plant test of the proposed process was conducted using mixer-settler equipment.

8:50 AM
Desulfurization with Hydrogen Production by BS Process: Nobuaki Sato; Hiroaki Kanazawa; Etsuro Shibata; Takashi Nakamura; Shin Tomisaki; Hiroshi Kuroda; Hiroshi Shirasagi; Tohoku University; Nippon Steel Corporation

For decontamination of SO2 containing waste gases from industries such as ferrous and non-ferrous metal companies, desulfurization with hydrogen production by the reaction of Br2 and SO2 was proposed as bromine-sulfur (BS) process. In this process, SO2 is fixed as HSO2 in the presence of H2O forming H2SO4 and HBr. Then hydrogen is produced by the decomposition
Currently, the degree of recycling of those metals does not exceed 25% improving the degree of recycling of rare metals (W, Co, Ta, Ti, Nb).

Regeneration of carbide waste from hard-alloy (sintered carbide) for Processing Carbide Waste in Hard-Alloy Industry

Recycled in the brick production and as a result of such addition the relevant stone incorporation. Samples produced in 7 different groups and reference cement (PC 42.5) clinker as 10, 20 and 30% in association with 5% lime of all ashes were ground below 250 firing process of brick production in the cement industry was examined. First, in the present study the utilization of coal ashes appeared at the end of years. This work describes an extensive research carried out on the possible re-use of muds from glazing and pressing lines of a local tile company in the development of new wall and floor tile formulations. In order to achieve this, the waste material was firstly investigated in function of chemical and mineralogical compositions. Then, the particular focus was given to the evaluation of the effects of the presence of the waste materials in varying amounts on the thermal behaviour and physico-mechanical properties of the re-formed tile bodies. During the studies, XRD, SEM in combination with EDS, and thermal analysis techniques such as non-contact dilatometry were widely employed. The results indicated that it is possible to use the waste materials in the commercial tile production without deteriorating the relevant technological properties.

9:40 AM Break

9:55 AM Keynote

Chloride Capacity of FeO-Fe2O3-SiO2 Molten Slag at 1523 K: Akio Fuwa; Yu Yamashita; Fumito Tanaka; Waseda University; Mitsubishi Materials Corporation

There have been increasing in melting recycled scarp s in copper smelting processes, and thus growing interests in the chloride behavior in the slags. In this study, chloride capacity in FeO-Fe2O3-SiO2 slag at 1523 K has been measured with varying in PC12 from 5x10^-5 to 10^-5 atm. and the following oxygen partial pressures encountered in typical copper smelting furnace of: PO2=10^-10 to 10^-10 atm. at 1523 K. Discussion is made on the chloride capacity of FeO-Fe2O3-SiO2 slag in terms of its characteristics and the dissolved chlorine species.

10:20 AM Usability of Industrial Ashes in Cement Production as a Puzzolanic Material: Taner Kavas; Bekir Karasu; Ozlem Arslan; Afyon Kocatepe University; Anadolu University

In the present study the utilization of coal ashes appeared at the end of firing process of brick production in the cement industry was examined. First of all ashes were ground below 250 μm and then added to ordinary Portland cement (PC 42.5) clinker as 10, 20 and 30% in association with 5% lime stone incorporation. Samples produced in 7 different groups and reference one were undergone chemical analysis, specific surface area (Blaine) and mechanical tests. Consequently, it was determined that the ashes could be recycled in the brick production and as a result of such addition the relevant mechanical properties were improved.

10:45 AM Basic Principles of Environmentally Sound Electrochemical Technology for Processing Carbide Waste in Hard-Alloy Industry: V. A. Bryukvin; A. A. Palant; O. M. Gracheva; Gintsvettmet; Russian Academy of Sciences

Regeneration of carbide waste from hard-alloy (sintered carbide) manufacture is an important scientific and technical objective aimed at improving the degree of recycling of rare metals (W, Co, Ta, Ti, Nb). Currently, the degree of recycling of those metals does not exceed 25% to 35% of their total production even in industrially developed countries. This is attributed to a significant extent to the substantial drawbacks of the technologies applied for their processing (environmental pollution, limitations to the use of regenerated products for important applications, sophisticated equipment to be used). An innovative environmentally sound technology has been developed in the Institute of Metallurgy of the Russian Academy of Sciences for processing refractory metals of carbide waste and other carbides using asymmetric alternating current of industrial frequency (the electrolyte used for this purpose is nitric acid solution). The current efficiency under optimal conditions is as high as 96% to 98%. The process has been tested on bench scale. The following commercial-grade products are obtained: pure ammonium paratungstate, tungstic acid, cobalt oxide, titanium dioxide and tantalum-niobium concentrate. The total metals recovery is 98% to 99%.

11:10 AM Use of Borax Solid Wastes in Floor Tile Glazes: Bekir Karasu; Güray Kaya; Özge Özdemir; Anadolu University

Boron raw materials are amongst the most important natural sources for many industrial branches and their values become increasingly raised with the discovery of boron usage in many new technological fields. All the countries in the world are unfortunately not as lucky as Turkey and USA where major boron deposits are mainly located. It is widely known fact that on one side, boron is very precious component with its technological importance, on the other hand; only its limited sources are available. Therefore, even its wastes have to be evaluated and regained. In the present work wastes of Eti bor Kirka Borax Company of Turkey were used in floor tile opaque glaze frit recipes. Standard and newly produced glazes were applied on the pre-engobed floor tile bodies and single firing was employed. Final products were examined according to the certain standard tests and their microstructures were also investigated. All the results confirmed the evaluation of boron wastes in floor tile opaque glazes.

11:35 AM Utilizing of Borax Solid Wastes in Tile and Brick Bodies: Güray Kaya; Bekir Karasu; Anadolu University

Boron minerals are widely employed in various fields such as ceramic, glass, cement, metallurgy, etc. Although boron deposits of the world are limited, the production level of boron-based products is continuously increased. Turkey possesses approximately 73% of total world boron resources. Eti bor Kirka Borax Company of Turkey produces tincal concentrates and borax pentahydrates. During such productions considerable amount of concentration and derivation wastes appear. Having considered the increased rate of production it is quite obvious that the level of relevant wastes will also be raised. With this study it was aimed to utilize these wastes in tile and brick bodies and to convert them into a form environmentally and human friendly. Newly produced products were undergone to several standard tests for the determination of their shrinkage, water absorption, strength values and coloring parameters. Additionally, micro structural studies were conducted.

Thermo and Physicochemical Principles: Steel Making: Inclusions and Steel Cleanliness

Wednesday AM
Room: Russeau Suite
Location: Catamaran Resort Hotel

8:00 AM Keynote

Magnesium: Origin and Role in Calcium-Treated Inclusions: P. Chris Piatrovic; University of Pretoria

Calcium treatment of aluminum inclusions, to convert the alumina to molten or partially molten calcium aluminates, is a well-established treatment for steel, to improve the castability of aluminum-killed steel. However, the role of magnesium in calcium-treated steel is not fully clear, nor is the origin of the several per cent of magnesium oxide that is often present in calcium-treated inclusions. To study this, steel was sampled after calcium treatment
at an industrial steel plant, and the inclusions identified by energy-dispersive X-ray microanalysis (EDX) on polished sections of the samples (analyzing the samples in a scanning electron microscope). The predicted fraction liquid in the inclusion was estimated from the ternary alumina-magnesia-lime phase diagram. Inclusions with higher CaO contents generally had lower MgO contents, indicating that the calcium wire is not the origin of the magnesium in the inclusions; this was also confirmed by wet chemical analysis of the calcium wire. Instead, it appears that magnesium-alumina spinel inclusions form during extended ladle contact after aluminium killing and before calcium treatment. While such spinels have been stated to cause poor castability (clogging the submerged-entry nozzle), it is clear that calcium treatment successfully modifies the spinel inclusions to mixed alumina-lime-magnesia inclusions, where the magnesium content contributes substantially to liquefaction of the inclusions: for typical MgO contents of around 10%, the range of CaO ratios which yield liquid (or partially liquid) inclusions is extended substantially to lower CaO ratios.

8:25 AM
Limitation of Slag Entrainment in Tundish and Consequent Reduction of Ladle Heel: Jean-François Domgin1; Pascal Gardin1; 1 Arcelor Research and Development

The slag inclusions are one of the main problems in steel continuous casting because they can generate some defects on the final products. Slag has different origins: slag coming from the mould, from the tundish or from the ladle. That is why limiting the entrainment of slag from one vessel to the other is still a real challenge in order to improve the final steel cleanliness. Moreover, limiting slag entrainment into the tundish during ladle drainage is very interesting from an economical point of view because ladle heel can be simultaneously reduced. The proposed paper aims at presenting numerical results showing the impact of different parameters on the limitation of entrained slag from ladle to tundish during the ladle drainage. These parameters are process parameters, slag properties or external actuator acting directly on ladle slag behaviour. Numerical simulations based on the use of the CFD Fluent software illustrate the vortexing and non vortexing phenomena appearing during the ladle drainage. This numerical tool validated by experimental data acquired on a water model has been applied to industrial configurations. It shows that the slag properties (viscosity, surface tension…) or some modifications of parameters (slide gate opening, ladle bottom geometry…) have a positive effect on the slag entrainment and also on the reduce of the ladle heel. Finally, modelling of the behaviour of an external actuator injecting some gas in the casting hole region reveals interesting possibility for reducing slag entrainment from ladle to tundish during the final steps of the drainage.

8:50 AM
Modeling Steel Cleanness Based on Fundamental Principles and Concepts: Konstantinos Th. Mavrommatis1; 1RWTH Aachen University

Cleanness of steel is justified, measured and assessed in steel making processes through different concepts which are mainly based on operational, empirical parameters describing cleanness as a static state and property of the material, after finishing the processing operations. This is an a posteriori assessment of cleanness. To be able to produce steels of highest purity, the empirical parameters describing cleanness as a static state and property of the steel of highest purity.

9:15 AM Keynote
Formation of Spinel Phase in the Liquid Inclusions during Stainless Steelmaking Processes: Joo Hyun Park2; 2POSCO

The details of the microstructural characteristics of the CaO-SiO2-10%MgO-Al2O3-(CaF2) systems crystallized during slow cooling from 1873 K, which are critical to understanding the fundamentals of inclusion formation in the stainless steelmaking processes, were investigated using SEM and EDS. Especially, the effect of CaF2 on the crystallization behavior of the melts was studied. In addition, the phase equilibria at a specific temperature and composition during cooling cycles were computed using commercial thermodynamic software based on the Gibbs energy minimization principles and were compared to the measured results. In the system of B=1(CaO)/(%SiO2)=0.6 containing 30wt%Al2O3, the relative fractions of spinel and anorthite continuously increase with decreasing temperature from about 1573 to 1423 K, followed by the constant values at temperatures less than about 1373 K. In the liquid system of B=1.0, the spinel phase appears at temperatures greater than about 1623 K, followed by the formation of melilithe and their relative fractions increase with decreasing temperatures from about 1573 to 1473 K. The calculated results could explain the observed phenomena. In the system of B=0.6 containing 10wt%CaF2 and 30wt%Al2O3, the spinel phase was calculated to be in equilibrium with anorthite and merwinite. However, anorthite was not observed in the experiments. This could be understood from the changes in melt composition due to formation of gaseous fluoride SiF4. The size of spinel in the system of B=1.0 containing 30wt%Al2O3 decreased and thus the number of spinel per unit volume increased with increasing content of CaF2, up to 10wt%.

9:40 AM Break

9:55 AM Keynote
Estimation of Inclusion Size in Stainless Steel Coil Based on Statistics of Extreme Values: Shin-Ichi Nagashima1; Yu-Ichi Kanbe2; Nobuyuki Hashimoto1; Hidekazu Todoroki1; 1Nippon Steel Corporation

It becomes more important to control the composition of inclusions with increasing the demand for quality of products in terms of cleanliness. Along with the development of refining technology to make inclusions harmless, a study was made to develop how to predict the quality of final products. At first, observations of a number of defects revealed that the defects were caused by inclusions larger than 100 μm in diameter. Therefore it is required to detect relatively large inclusions in steel, whose existence is quite rare, to identify the quality. In order to estimate the maximum size of inclusions in a given sample, the method with statistics of extreme values has been applied for continuously cast (CC) slabs, hot-rolled coils and cold-rolled coils of type 304 stainless steel. For the CC slabs the diameter of inclusions, which were analyzed to be mostly silicate with globular shape, in the specimens were measured. For the coils, the width of inclusions was measured at the unit section perpendicular to rolling direction because it corresponds to the diameter assuming that the width of globular inclusions does not vary with rolled. Then maximum inclusion diameter in a specimen was calculated. As a result, the obtained values in the rolled coils are larger than in the slabs. This may imply that the measurement with the coils gives the values closer to the truth. Besides the measurement with the coils is even faster than with the slabs due to its simplicity of preparation of the specimens.

10:20 AM
Characterization of Precipitates in a Structural Titanium Microalloyed Steel by Transmission Electron Microscopy and Analysis by High Resolution (HRTEM): L. Béjar-Gómez1; A. Medina-Flores1; A. Bedolla-Jacuinde1; M. Sauvedra-Magaña1; 1Universidad Michoacana de San Nicolás de Hidalgo

The aim of this research work is to study and characterize precipitates in a structural microalloyed steel by transmission electron microscopy and analysis by high resolution (HRTEM). Microalloyed steel with titanium was produced by casting in an electrical induction oven of 25 Kg. capacity. Carbon content in steel was less than 0.1 % and carbon content from 0.035 to 0.06%. Steel was processed thermomechanically at an starting temperature of 1150°C with a thickness reduction of 80% at a finishing temperature of 850°C. Steel mechanical properties were yield strength = 324 MPa and...
Characterization of Precipitates in Structural Niobium Microalloyed Steels by Transmission Electron Microscopy and Analysis by High Resolution (HRTEM): L. Béjar-Gómez; A. Medina-Flores; A. Bedolla-Jacuinde; M. Saavedra-Magaña; Universidad Michoacana de San Nicolás de Hidalgo

The aim of this research work is to study and characterize precipitates in structural microalloyed steels by transmission electron microscopy and analysis by high resolution (HRTEM). Microalloyed steels with niobium were produced by casting in an electrical induction oven of 25 Kgs. capacity. Carbon content in steels was less than 0.1% and niobium content from 0.03% to 0.06%. Steels were processed thermomechanically at an starting temperature of 1150°C with a thickness reduction of 80% at a finishing temperature of 850°C. Steels mechanical properties were yield strength from 460 MPa to 480 MPa and tensile strength from 460 MPa to 480 MPa. This work shows what precipitates are present in steel, the type of precipitates and their morphology. Analysis by transmission electron microscopy of high resolution (HRTEM) was applied to chemical analysis of precipitate region and of the matrix. Spectroscopy of dispersive energy was applied too (STEM-EDS). Particles of precipitates of NbC were found with a cubic morphology and size from 80 to 120 nm, circular morphology and size from 20 to 80 nm, polygonal morphology and size from 10 to 80 nm.

Analysis of Microstructure and Precipitates in Hot Rolled Low Carbon Steel Sheet by CSP: Yonggang Liu; Mengzi Zhao; Wenlin Wu; Guang Chen; Jianping Zhang; Shihuai Su; Nanjing University of Science and Technology; Technological Center of Maanshan Iron and Steel Company Limited

Microstructure and precipitates in hot rolled low carbon steel sheet by CSP were investigated in this paper. It is pointed out the precipitates in low carbon by CSP are different with that by traditional hot rolling. The bainites were found in CSP hot rolled steel sheet by TEM testing and these bainites could maintain in the sheets even after batch annealing. The selected area electron diffraction analyzing indicated that there were many C6N and FeN phases precipitated in hot rolled steel sheet and no AIN grains precipitated. The nitrides forming can limit AIN grains precipitating during the batch annealing processing, and this could do harm to the texture pipeline along γ orientation line forming with formed properties.

Evaluation of Turbulence Models in the Numerical Simulations of Fluid Flow in Different Configurations of Tundishes: Roberto P. Tavares; Henrique V. Oliveira; Thiago A. Avila; Marc C. Leão; Thiago R. N. Campos; Federal University of Minas Gerais

Continuous casting is the most important process for solidification of steels. In this process, the fluid flow pattern in the tundish and in the mould have significant effect on product quality. Problems associated to fluid flow in the tundish include surface turbulence, short-circuits, formation of dead zones and vortexing. During grade changes, mixing in the tundish plays a significant role in determining the length of the intermixed slab. All these flow aspects can be studied by means of mathematical and physical models. In the last years, numerical simulation of fluid flow has become a very popular tool in the analysis of the performance of continuous casting tundishes. In setting-up these numerical simulations, special care should be taken in choosing the appropriate mesh distribution, the interpolation scheme, the adequate location of the inlet boundary and the turbulence model. In the present paper, turbulent fluid flow in different configurations of tundishes was simulated. Different turbulence models were used in the simulations. Mixing curves during grade changes were predicted and compared to results obtained in physical models. The performance of the different turbulence models were evaluated. For the tundishes that have been studied, the performances of the different turbulence models tested in the present work were similar. There is no evidence that any of the models provided sustained improvement when compared to the well-established standard k-epsilon model. All turbulence models tested presented limitations in simulating flows under low turbulent Reynolds numbers.
its smelting process the arsenic bearing concentrates smelted in the TC unit allows a very high volatilization of arsenic, the CN smelter staff started a feasibility technical study to process an arsenic bearing concentrate directly in the TC unit, and in that way to process the concentrates with low arsenic content in the FSF. Accordingly, the CN smelter prepared a laboratory scale test program to evaluate the effect of smelting concentrates with high arsenic content >3% As. The promising results of these tests done at the Tohoku University facilities, allowed a large scale test planning to determine the arsenic fractional distribution in the process units involved in the smelting-converting-refining circuit of the CN smelter. For this purpose, the 7000 t of concentrates with > 3% As were processed in the 2500 tpd TC unit. The obtained results confirmed the stabilization of the arsenic content in the 70% Cu white metal.

2:45 PM Keynote
Energy Saving Activities at Onsan Smelter: Jong-Shin Chiang; Sung-Hwan Yu; Seung-Ho Shin; ‘LS-Nikko Copper Inc.
Onsan smelter has tried to do various activities for saving operation cost. With several expansion projects, Onsan smelter has aimed at not only quantitative growth but also qualitative growth through efforts improving operation equipment and processes. The activities to reduce operation cost have been one of those efforts. Especially, energy cost of operation costs has been a main target to be reduced. The activities to save energy have been carried out in two ways. One is to recover and utilize waste heat as much as possible and another is to replace existing equipment and processes with more energy-efficient ones. This paper reviews recent improvements and future plans in energy saving activities at Onsan smelter.

3:10 PM Break

3:25 PM Keynote
Recent Advances in Tin Smelting Using Top Submerged Lance Technology: Jose Antonio Ore Rivera; ‘MINSUR S.A.
Top Submerged Lance (TSL) smelting technology is currently used in a wide range of applications in the non ferrous and waste product treatment industries. The use of TSL technology for tin concentrates smelting has been successfully applied at the Minsur Tin Smelter and Refinery at Pisco, Peru. The process is based on the air-cooled top entry submerged Sirosmelt lance, developed by Dr. John Lloyd at the CSIRO division of Mineral and Process Engineering in the 1970’s. Advantages of the process include flexibility to operate the lance, main burner of the Sirosmelt furnace, with different levels of combustion stoichiometry which allows us to get from highly reducing to highly oxidising atmospheres in the smelting reactor according to the type of feed we are processing, ability to utilize cheap energy sources such as natural gas, low capital cost and an environmentally friendly operation. This presentation summarises the application of the Submerged Sirosmelt technology for smelting tin concentrates and a variety of tin containing materials like iron dross, copper dross, tin residues, low tin/antimony slags by applying recent metallurgical developments at the Minsur smelter. The impact of new feed conditions and level of impurities on reactor performance with features of process and operation control are described. As a result of these recent advances in tin smelting using TSL technology, the Minsur Tin Smelter and Refinery improved its overall tin recovery, substantially reduced tin inventories and became the largest tin smelter in the world, currently producing more than 40,000 metric tones of refined tin per year.

3:50 PM Keynote
M-DICE: An Impurity Distribution Model for Codelco-Norte Smelter: Alex Moyano; Carlos Caballero; Claudio Pizarro; Jonkion Font; ‘FCN, Codelco-Chile; ‘IM2 SA Filial Codelco-Chile; ‘GHT, Codelco-Chile; ‘Institute of Multidisciplinary Research for Advanced Materials, Tohoku University; ‘IM2 SA Filial Codelco-Chile
Due to very demanding environmental rules, and to the incrementing impurities contents in the processed concentrates, the Codelco Norte (CN) smelter permanently faces new demands for planning the production program with the present environmental rule fulfillment. Accordingly, the CN smelter along with IM2, developed an impurity distribution simulation model, M-DICE, which predicts the impurities behavior in each of the process units of a smelter complex under different process configurations. The M-DICE development which was based on a mass balance for all the process units involved in the smelter complex, included as a first stage, the gathering of operational data for the process units, including temperature, oxygen enriched air, matte grade, etc, then a thermodynamic evaluation for deriving the fractional distribution among the condensed phases (mattes/white metal/copper/slag) and the gas phase for each of the process units. At present, M-DICE is at its last stage of development, and is expected to be a suitable tool for the environmental and process managements of the CN smelter of Codelco-Chile.

4:15 PM
Arsenic and Antimony Removal from a Complex Blister Copper: Alex Moyano; Roberto Mac-Kay; Hector Henao; Kimio Itagaki; Jonkion Font; Claudio Pizarro; ‘FCN, Codelco-Chile; ‘GHT, Codelco-Chile; ‘Institute of Multidisciplinary Research for Advanced Materials, Tohoku University; ‘IM2 SA Filial Codelco-Chile

For the near future, the Codelco Norte (CN) smelter considers to process concentrates from the Chuquicamata and the Alejandro Hales (former Mansa Mina) mines, the last with high arsenic and antimony content of 6% and 0.6%, respectively, which will be producing a complex blister copper with high impurities contents, higher than the present values produced at the smelter. To know both the metallurgical, and anodic copper quality implications when a complex blister copper is processed in the refining process of the CN smelter, the Codelco and IM2 “task force” did a positively evaluation of the refining test when a complex blister copper is refined with the addition of alkaline fluxes. The promising results of these tests done at laboratory scale in the Tohoku University facilities, allowed a large scale test planning to validate the lab scale results in 3 refining furnaces of 250 t capacity of the CN smelter. The obtained results demonstrate the industrial technical feasibility to process a complex blister copper in the refining furnace producing an anodic copper quality suitable for the electrolytic process, by controlling the process parameters of fluxes dosage and copper oxidation degree.

4:40 PM
Mathematical and Physical Model for the Teniente Converter Fluid Dynamics: Marco Rosales; Alex Moyano; Alvaro Valencia; Ramón Fuentes; Roberto Mac-Kay; ‘IM2 SA Filial Codelco-Chile; ‘FCN, Codelco-Chile; ‘Universidad de Chile

Thru a physical and mathematical modeling the behavior of the three-dimensional waving, and the movement of the gases at the Teniente Converter was studied. The mathematical model considers the condensed phases of white metal and slags, along the gas phase, and include the k-e model for the turbulence description. Both the physical model and the mathematical model allow a conclusion that from the fluid dynamic stand point the Teniente Converter is suitable to process clearly 3000 tpd of concentrates. Also, both models are suitable to predict the slag fluid dynamics and its spacial distribution inside the converter, and the splashing in the tuyere zone as well.

5:05 PM
Characteristics and Roasting of Zinc Sulfide Concentrates in Fluid Bed: Boyan S. Boyanov; Nikolay K. Kolev; University of Plovdiv; ‘KCM SA

The hydrometallurgical technology for zinc production in Bulgaria is characterized by the use of considerable quantities of imported zinc concentrates (from 18 countries) and several kinds of Bulgarian ones which are quite different in chemical, phase and granulometric compositions. Today eighteen components are under control in the zinc concentrates, which by nature are a polymetallic raw material. In order to avoid difficulties in the process of roasting and leaching, a significant part of these components should be in concentrations lower than certain maximum values. In this connection, several sulfide zinc concentrates (Bulgarian and imported ones) were investigated by chemical analysis, DTA, TGA, X-ray diffraction analysis, sieve analysis. Providing optimal mixing proportions can be successfully done by using the PC software we have written, which calculate mixtures of different raw materials. The main base contains data about the content of 18 components in more than 340 concentrates from all over the world. The accomplishment of optimal mixing of concentrates and providing a stable mix composition for a long period of time is a task of primary importance in the technological process control in zinc hydrometallurgy.
2:45 PM  
**Formation Mechanism and Control of Corner Transverse Cracks of CC Nb-Containing Slabs: Guosen Zhu; Zhiyuan Zhu; Shougang Group**

Research on the formation mechanism and control of corner transverse cracks was carried out. The optical microscope and SEM were applied to analyze the characteristics of cracks. It is found that the cracks occur at the relatively lower temperature due to unbending strain and have almost nothing to do with the mold cooling and powder. The keys to prevent corner transverse cracks are to optimize the corner temperature of slab and maintain the good state of casting machine. Increasing casting speed and decreasing the cooling water flux at the corner in the unbending segments, resulting in mild cooling, were applied during investigation to control corner temperature above the upper limit temperature of the No.3 brittlement zone of Nb-contained steel tested by Gleeble-1500 system. As a result, corner transverse cracks were minimized, but centerline segregation got worse. And then increasing the cooling water flux at the corner (intensive cooling) was applied to make corner temperature below the lower limit temperature of the No.3 brittlement zone. Great diminution of both corner transverse cracks and centerline segregation was achieved finally.

3:10 PM  
**Break**

3:25 PM  
**How to Reduce Costs in Steelmaking with CaC$_2$: Javier Santiago; Electrometalúrgica Andina S.A.I.C.**

In the searching of reducing costs, steelmakers always try to test different products and operations. In the aluminum killed steels the use of aluminum, some times, increase the costs of steel. Several tests have been made in an argentinean steel plant during the furnace tapping. The target was to reduce the aluminum consumption and to find if the calcium carbide deoxidizes the steel. The results were satisfactory and it could decrease the aluminum consumption allowing to lower the cost of deoxidation of the steel. During the steel making there are different points of addition of calcium carbide. Why calcium carbide replace the aluminum? The answer is because it is a great deoxidant. Based on the primary reaction: CaC$_2$ + 3O $\rightarrow$ CaO + 2CO we can see than one molar of calcium carbide reacts with three moles of oxygen. But so that happen the contact between carbide and steel should be strong. It is for that reason that the addition point is very important. In this presentation, the data, observations and results collected during the period of trials in an argentinean steel plant are shown and compared with the usual practice. Also, this paper discusses an alternative to the aluminum use for the deoxidation of steel.

3:50 PM  
**Improving Steel Ladle Performance at Bhilai Steel Plant, India: Rakesh Kumar Singh; Laxman Tiwari; Bansi Dhar Chatturaj; D. R. Dinda; Research and Development Centre for Iron and Steel, SAIL; Bhilai Steel Plant, SAIL**

Steel Ladle in Bhilai Steel Plant, SAIL, India, passes through VAD & LF-RH route, and this exposes refractory lining to a severe operating conditions. Ladles are lined with in-house manufactured MgO-C refractories. Lining life used to be 35 heats, out of which 18-20 heats were through VAD/LF-RH, hence, ladle availability had become a constraint. Laboratory studies were carried out to optimize composition and granulometry. Granulometry was developed by adopting Andearsen packing model. A suitable plasticiser was identified to eliminate inconsistency caused due to variation in resin quality and weather condition. It reduced variation in green bulk density from 6 to 1.3%. Abrasion and slag erosion studies were conducted, which shows that with increase of carbon, abrasion resistance decreases and corrosion resistance improves. Based on these studies, graphite in slag zone was increased from 10 to 12.5% and in metal zone it was reduced to 7.5%. Different process parameters of brick making were optimized to make MgO-
C bricks of maximum bulk density with reduced coke porosity. Modified bricks have bulk density of 2.99-3.02 g/cc and coke porosity of 9.5-10.5%. Further, shape of the bricks were changed from side arch to mini keys and thickness was increased from 80 to 100 mm. Mini key bricks are pressed from sides, thus eliminating variation in thickness which is critical dimension for dry joints. These modifications improved average lining life of steel ladles to 62 heats, which includes 30-35 secondary heats. Maximum life obtained is 87 heats.

4:15 PM
Usage of Aluminum Dross for Slag Treatment in Secondary Steelmaking to Decrease Amount of Reducible Oxides in Ladle Furnace: Ahmet Geveci; Onur Aydemir; METU; ERDEMIR

In this study it is aimed to assess the plant analytical data from steelmaking shop (120t) which appeared during efforts to decrease the effect of carry-over slag (basic oxygen furnace slag) that can not be prevented to leak during tapping of steel in the ladles. While the amount changes, carry-over slag that escaped to ladle consists of appreciable amount of reducible oxides (FeO and MnO) which act as oxygen source for steel bath. Rather than using synthetic slag by skimming ladle slag after tapping from converters (because of high heat loss), it is aimed to refine existing slag by using aluminum dross, containing 30-35% metallic aluminum, which is a non-recoverable process outcome (discard) for most of the aluminum factories. Slag reduction behavior will be worked out considering parameters such as reaction time, initial amount of total Fe (excluding metallic iron) +MnO (determined by X-Ray diffractometer), amount of reducing agent and reducing effect of soluble aluminum in steel bath, while obtaining an optimal slag composition which promotes higher desulfurization capacity and inclusion removal for liquid steel. Starting with a 10% initial reducible oxide amount before ladle furnace operation, it is reduced to 4-5% by slag refining process using aluminum dross that is affected by parameters given above.

4:40 PM
New Operational Practices for Finer Control of End Blow Phosphorus in BOF: P. K. Tripathy1; A. K. Das1; Tata Steel

Consistent production of low phosphorus steel (≤ 0.015%) from high hot metal phosphorus (≥ 0.220%) in BOF steelmaking is a technologically challenging task. The problem gets compounded if steel is to be tapped at high temperature (≥1700°C). This paper deals with the continuing efforts and experiences of producing low phosphorus steel through various measures e.g. modification of slag chemistry and slag volume, use of six hole lance, bottom stirring during the blow etc. Of late, optimization of slag chilling process near the blow end has given good results, which has enabled better control of phosphorus in high temperature heats for flat products. This is followed by an extensive datamining study on vessel de-phosphorization performance which showed turn down carbon below a certain level adversely influences end-blow phosphorus.

New, Improved and Existing Technologies: Electrochemistry

Wednesday PM
August 30, 2006
Room: Boardroom West
Location: Catamaran Resort Hotel

1:30 PM Keynote
Corrosion Behavior of Lead-Alloy Anodes in Metal Winning: Michael Stelter1; Pavel Salykov2; TU Bergakademie Freiberg

Lead alloys are a typical material for anodes in technical electrowinning processes. The lifetime of those anodes differs from 2 years to more than 5 years in tankhouse practice depending on the type of alloy, the mechanical damaging and last but not least the chemical corrosion in the electrolyte. Different types of alloys, such as PbSb, PbCa, PbAg, PbSnCa or PbAgCa have been developed and used in the past, their rate of corrosion being more or less a philosophic discussion. Comparable investigations on the corrosion behavior in dependence of the concentrations of alloying metals, the grain structure and the mechanical and thermal treatment during production have not been conducted before. In the last years the Institute for Nonferrous Metallurgy and Purest Materials of the TU Bergakademie Freiberg investigated the corrosion behavior of the typical lead alloys for metal electrowinning under comparable conditions. Correlations between different alloys, mechanical treatments like rolling or thermal treatment like annealing to the rate of corrosion were made, leading to the conclusion that grain structure and grain size are of eminent importance for the rate of corrosion in technical electrolytes. From these results new and optimized lead alloy anodes can be produced with an increase in life time of the factor 3 - 5. The optimized lifetime in terms of corrosion stability can not protect from mechanical damaging in tankhouse practice, but with a careful practice the increase in lifetime can save a lot of money and problems.

1:55 PM Invited
Electrochemical Behaviors of Silicon Monoxide as an Anode Material for Lithium Secondary Batteries: Jae-Hun Kim1; Chru Kyung Lee2; Hun-Joon Sohn2; Seoul National University; Kumoh National Institute of Technology

Rechargeable lithium-ion batteries provide one of the best energy densities and have become very common with their prices continuing to decline. The future prospect of the rechargeable battery industry is bright as the global demand for the lithium-ion cells that are commonly used in portable electronic devices such as laptops, mobile phones and personal digital assistants is growing consistently. Lithium metal is an attractive anode material for lithium secondary batteries since it has a large theoretical capacity of 3860 mAh/g. However, it has not been used in practical battery systems because of low performance in cycling and safety problems. As alternative electrodes, carbonaceous materials have been applied to commercial lithium-ion batteries with the maximum theoretical capacity of 372 mAh/g for graphite due to their good cycleability, low cost and relative safety. For recent years, many researchers have focused on finding alternative anode materials such as Li-alloying type materials, which show higher gravimetric and volumetric capacities than those of graphite. Among these Li-alloy anode materials, silicon monoxide (SiO) appears as promising anode materials because of its large capacity and long cycle life. The chemical states and microstructure of electrochemically liathed SiO electrodes for lithium secondary batteries have been analyzed by solid-state nuclear magnetic resonance (NMR) and high resolution transmission electron microscopy (HRTEM). The analyses were performed on the electrodes at various voltage steps during the first cycle and a reaction model for SiO with lithium was suggested.

2:20 PM
Electrochemical Studies of the Intermetallic Inert Anodes in Molten Salts: Xiaobing Yang1; University of Leeds

The present work is focused on developing intermetallic inert anodes for aluminum electrolysis. The anode alloy based on Al-Ti-Cu system was prepared by casting and then protected by oxides coating. The results of the theoretical calculations on phase equilibria and experimental studies of anode in the molten cryolite are presented. Behavior of corrosion and the passivation under anodic condition were characterized using microscopic technique and cyclic voltammetry. Optimal conditions of the anode passivation were determined.

2:45 PM Keynote
Ionic Liquid Electrochemical Processing of Reactive Metals: James Vaughan1; David Dreisinger2; University of British Columbia

Ionic liquids can be used as solvent for the electro-plating, winning and refining of metals. Of particular interest is the possibility of processing reactive metals such as aluminum, magnesium and titanium that cannot be deposited from aqueous solutions. The electrowinning of aluminium from AlCl3; ionic liquid mixtures has been carried out at a laboratory scale with the advantages of low temperature and low energy consumption compared with conventional Hall-Héroult smelting. Similar benefits have been recognized for the refining of aluminum. Imidazolium ionic liquids are promising due to their relatively high ionic conductivity and cation stability. The less studied and less expensive phosphonium ionic liquids systems may provide a
viable alternative to imidazolium ionic liquids for certain applications. New information regarding the physical properties and electrochemical behaviour of phosphonium ionic liquid systems is presented. The advantages and disadvantages of select systems are discussed.

3:10 PM Break

3:25 PM Keynote
Electrochemical Modeling of Electrowinning Performance: Michael L. Free; 1University of Utah

Electrowinning is directly impacted by many parameters that include electrolyte composition, voltage, current density, contact resistance, temperature, electrode spacing, and fluid flow as well as many other interrelated factors. The effects of these parameters are primarily related to thermodynamics, mass transport, and electrochemical kinetics. In this study thermodynamic, mass transport, and electrochemical kinetic equations are simultaneously solved to determine the effects of such parameters on electrowinning current efficiency, power consumption, electrodeposition morphology, and electrodeposit distribution. Modeling predictions will be compared with experimental results.

3:50 PM Invited
Atmospheric Pressure Plasma Process and Applications: Peter Kong; 1Idaho National Laboratory

Plasma is a sufficiently ionized gas with significant energy content. The presence of charged species in plasma makes it a conductor of electricity. Although there are free charges and ambipolar pairs in plasma, overall negative and positive charges compensate each other. Therefore, plasmas are electrically neutral, a property which is known as quasi-neutrality. There are two main types of plasmas, namely atmospheric pressure plasmas and low pressure plasmas. Under atmospheric pressure plasmas there are two distinct categories. The first is thermal plasma in which electron temperatures \( T_e \) \( \approx \) heavy particle temperatures \( T_p \). Examples of thermal plasmas are those produced in high intensity arc, plasma torches, or in high intensity, high frequency discharges. The second is the atmospheric non-thermal plasma (ANTP). The ANTP has very high \( T_e \) while the \( T_p \), remains ambient. ANTP has very low degree of ionizations and the density of charge species is very low. The electrons and ions never achieve local thermodynamic equilibrium. For this reason the gas temperature is at room temperatures. However, ANTP is extremely effective to produce activated species (free radicals) and is very reactive. Atmospheric pressure plasmas have a wide potential to develop industrial processes. These plasmas have seen applications in extractive metallurgy; metal recovery; novel nano-material synthesis; refractory and wear resistant coatings deposition; chemical synthesis; energy conversion; industrial, medical, and nuclear waste destruction; engine combustion enhancement; and exhaust gas pollutants clean up. This paper will present an over view of atmospheric pressure plasma process applications and systems in these areas.

4:15 PM Invited
The Effect of Anode Composition on the Passivation of Commercial Copper Electrorefining Anodes: Michael S. Moats; 1J. Brent Hiskey; 2University of Utah; 3University of Arizona

As commercial copper electrorefineries look to expand their capacities by increasing their operating current density, the likelihood of anode passivation intensifies. To improve the industry’s understanding of the passivation phenomena, the role of anode composition was evaluated. While previous studies have focused on studying one impurity element at a time, this study was compared with experimental results.

4:40 PM
The Conductivity Measurement of Scandium Doped Barium Zirconate for Fuel Cell Application: Sasuna Imashuku; 1Tetsuya Uda; 1Yasuhiro Awakura; 1Kyoto University

Doped barium cerates exhibit good protonic conduction in water containing atmosphere at elevated temperatures and have been expected for the use of a fuel cell electrolyte. However, since the barium cerates decompose into barium carbonate and barium hydroxide in the presence of \( \text{CO}_2 \) and \( \text{H}_2\text{O} \), it is difficult to apply the barium cerates for fuel cells. In contrast, barium zirconate is much more stable in the same atmosphere than barium cerate. In addition, yttrium doped barium zirconate is known to have the highest conductivity among various doped barium zirconates, the conductivity of which is almost comparable to that of doped barium cerate. However, very recently Yamaguchi et al. have discovered that barium zirconate lost its stability when yttrium is dopod. In this study, we investigate the effect of dopant on the stability and conductivity of barium zirconate. Especially, we had an interest in scandium doped barium zirconate. In general, \( \text{Zr} \) site in barium zirconate is substituted for the doped trivalent cation. The ionic radius of scandium is almost the same as that of zirconium (\( \text{Zr}^{3+}:0.072 \text{ nm}, \text{Sc}^{3+}:0.0745 \text{ nm} \) for six-fold coordination). But ionic radius of yttrium is bigger than that of zirconium (\( \text{Y}^{3+}:0.0900 \text{ nm} \)). Therefore, there is possibility that Sc doped barium zirconate is more stable than Y doped barium zirconate. We present the results of AC impedance spectroscopy measurement for Sc doped barium zirconate and its stability examined by TG-DTA in a humidified atmosphere containing \( \text{CO}_2 \).

5:05 PM
Improvement of Zinc Production Process at the Chelyabinsk Zinc Electrolytic Plant to Produce High-Grade Zinc: L. A. Kazanbayev; 1P. A. Kozlov; 1Chelyabinsk Zinc Plant

The Chelyabinsk zinc electrolytic plant was put into operation in 1935. The capacity of zinc production has been increased over the recent years from 100,000 to 180,000 tpy and starting from 2004 the plant has produced zinc of SHG grade attested at the London Metal Exchange. All production circuits at the plant have been modernized, advanced technologies introduced and the existing processes improved: 1) distributed oxygen feeding in the zinc concentrate roasting process, 2) use of a flocculant of Magnafloc type in the calcine leaching process with an improved method for flocculant feeding, 3) use of an activator (antimony trioxide) in the process of solution purification to remove cobalt and nickel, 4) an innovative zinc electrolysis complex commissioned, including automatic cathode stripping for Jumbo cathodes, 5) technology developed for production of zinc-aluminum, zinc-nickel and zinc-antimony alloys, and 6) problems associated with treatment of wastewater and off-gas from sulfuric acid plant have been resolved.
by a co-precipitation method from the aluminum dross and the waste MgCl2 solution discharged in an aluminum regeneration process. Slight amounts of SiO2, Al2O3, Fe2O3 and so on remain in the reaction product as an impurity component. Interlayer distance of the obtained hydrotalcite is about 0.3nm. Hydrotalcite changes to Mg-Al oxide by the calcination at 773K for 3h, and then hydrotalcite is formed again by a rehydration operation after calcination. The toxic metal ions are removed from aqueous solution by the anion exchange reaction in the pH region where toxic metal ions exist as the anionic species like AsO2-, HAsO42-, CrO42-, and SeO32-. The exchange amount is considerably concerned with the valence of anionic species and the size of anionic species. The removal of toxic metal ions were investigated from the engineering aspects such as the low concentration limit to be removed, the amount of hydrotalcite to be used for the perfect removal of toxic metal ions and so on.

1:55 PM
A Novel Green Technique to Recovery Titanium Compounds from Molten Slag under the Dynamic Oxidation Condition: Zhang Li; 1Northeastern University

A novel green technology to recovery Titanium compounds from Ti-bearing blast furnace slag under the dynamic oxidation condition was developed and tested. Air was blown into the molten slag as oxygen resource through a lance during the dynamic oxidation process, in which six important results were found: (1) the TiC, (Ti2O3), Fe and (FeO) in the slag were oxidized, (2) the temperature of slag temperature rapidly increased, (3) the viscosity of slag decreased, (4) the coalescence, growth and drop of the metallic Fe droplets in the molten slag were carried out under an air agitation condition, (5) the dispersed Ti components were selectively enriched into the perovskite phase, and the perovskite phase could be selectively precipitate and grow. And also, the perovskite phase can be separated by the dressing method. The oxidation of molten slag gives off a large amount of heat, which helps chemical reactions proceed, improve the rate of chemical reactions, and promote the precipitation and growth of the perovskite phase. The features of the technique are clean, low-cost and a great capacity to deal with a large quantity of slag. It was confirmed by experiments that the precipitation of the perovskite (CaTiO3) in molten slag is obviously affected by operation factors such as temperature, chemical composition, heat-treatment, additives and so on. The precipitating kinetics and mechanism of the perovskite phase from molten slag during the dynamic oxidation processes were also investigated.

2:20 PM
Sampling of Fine Shredder Residues (FSR) and Characterization Oriented to Physical Separations: Pierre-François Baroel; 1David Bastin; Claude Bodson; Jean Frenay; 1University of Liège; 1Comet Traitements

EU legislations impose ambitious recycling targets for various consumer goods. End-of-Life Vehicles (ELVs), scrap iron and various proportions of Waste Electrical and Electronic Equipment (WEEE) are processed by shredding plants which recover most of the metals but produce 20 to 25 wt.% of Shredder Residues (SR) which are landfilled. Energy issues for the coarse fraction of SR are now largely studied. However, below 2 mm, the calorific value falls off drastically. These Fine Shredder Residues (FSR) represent up to 55 wt.% of the total SR. To meet European objectives other alternatives to landfilling must be considered for the FSR. The present paper describes a study carried out to characterise the FSR and investigate ways to process them and produce marketable products. Applying Gy’s theory, a sampling procedure was conducted over two years to statistically quantify the variability of the physical and chemical properties of FSR produced by a Belgian post-shredding treatment plant. Macroscopic characterisation has led to the identification of four material categories which could be separated according to their physical properties: ferrous metals (more or less oxidized), non-ferrous metals, an organic fraction (plastics, rubber, textiles, foams, wood) and a minerals fraction (glass, ceramic, concrete). The entrainment of small metallic particles within the pores of organic fragments will affect the quality of the separations.

2:45 PM
Processing of Man-Made Metal-Containing Raw Materials in DC Electric Furnaces: G. S. Nas; 1Valery M. Paresky; 1Gintsvetmet

Technology for treating man-made metal-containing raw materials in DC electric furnaces with polarization of the bottom phase (PDF furnaces) has been developed and proven on a semi-commercial scale. PDF furnaces permit processing of man-made raw materials, i.e. current and accumulated intermediate products with rather high contents of valuable metals (i.e. slags, sludge, residues, Waels slag, etc.), as well as secondary raw materials and virtually any type of waste using an environmentally safe technique based on sublimation of volatile metals and transfer of non-volatile metals and sulfur into the bottom phase in the furnace. Processes developed on the basis of the use of PDF furnaces make it possible to take advantage on a full commercial scale of electrolysis of molten materials, including electrochemical reduction of metals, intensification of their settling into the bottom phase and sublimation of volatile components, as well as to significantly improve recoveries of nonferrous metals, resolve the problem of excessive accretion formation in slagging processes and substantially improve the environmental situation. The low-grade discard obtained can be utilized in the construction industry, in particular, slag can be added to the limestone feed for cement manufacture.

3:10 PM Break

3:25 PM
Recycling of Mo Containing Acid by Ammonia Gas Neutralization: Jong Jin Pak; Yeung Ho Park; Wan Yi Kim; Jung Yong Ahn; Duck-Yong Hwang; Dong Hyuk Shin; 1Hanyang University

In manufacturing tungsten filament coils at lamp industries, a very fine tungsten wire is coiled around molybdenum mandrel wires to form so-called a coiled coil. The formed coiled coil is then heat-treated and cut to a size, and immersed in a solution of mixed nitric acid and sulfuric acid which dissolves the molybdenum mandrel leaving the coiled tungsten. In this “spent” acid solution, molybdenum is usually dissolved in amount of 80 to 90 g/ liter of acid solution. The volume of spent acid generated from a typical manufacturing company in Korea ranges from 300 to 600 liters (containing 25 to 50 kg molybdenum) per day. In the past, it has been a common practice in these companies to neutralize the spent acid with sodium hydroxide and discharge it into waste water system. The loss of molybdenum in this manner is economically significant, and the discharge of nitrate and sulfate ions and heavy metals like molybdenum into the nation’s rivers is undesirable from the environmental view. Furthermore, this disposal method became illegal by the environmental protection law enforced in Korea since 2003. The present work reports the commercialization of a recycling process of spent acid to recover molybdenum. The process consists of ammonia gas neutralization of acid, crystallization and filtration of ammonium molybdate, roasting and hydrogen reduction of molybdic oxide to produce a commercial grade molybdenum metal powder. The mother liquor, residual solution after the filtration of ammonium molybdate, can be utilized to produce fertilizers.

3:50 PM
Pyrolysis of Mixed Plastic Wastes into Alternative Fuel Oil – Pyrolysis Process (300 & 3,000 Ton/Yr) Developed at Korea Institute of Energy Research: Kyong-Hwan Lee; Dae-Hyun Shin; Sang-Gu Jeon; Kwang-Ho Kim; Nam-Sun Noh; 1Korea Institute of Energy Research

The recycling of plastic wastes consisting of elements of C, H and O mainly is one of important issues being faced in all the countries of the world. In recycling methods, pyrolysis that can recover fuel oil and hydrocarbon feedstock is accepted as an effective method of utilization of waste plastics with a great interest both economically and environmentally. Pyrolysis in the absence of oxygen involves the breaking down of the larger molecules into smaller molecular weight hydrocarbons that may be gasoline, kerosene, diesel and heavy oils. KIER (Korea Institute of Energy Research) has developed a 300 ton/yr pyrolysis plant that is capable of converting plastic wastes into alternative fuel oils such as gasoline, kerosene, light oils and heavy gas oils. In the present, commercial plant of 3,000 ton/yr is under installing at Korea R & D Company incorporated in our study. In this paper, the characteristics of the pyrolytic process developed in KIER will be described. In this process, basic unit concepts consist of preliquefaction, thermal cracking and vacuum distillation. Main characteristics are recirculation system of high temperature cracked reactant into preliquefaction reactor to melt solid reactant fast and
circulation reaction system of reactant by using both CSTR and Plug reactor to obtain high cracking efficiency in the cracking reactor. Also, this process guarantees the pyrolytic operation near atmospheric pressure, continuous production of fuel oils, continuous feed and discharge of solid residue and reliable operational stability, in order to improve the economic aspect of this plant.

4:15 PM
Clorination Applied to the Separation of Metals: Fabiola J. Alvarez; Georgina De Micco; Daniel M. Pasquevich; Ana E. Bohé; Centro Atómico Bariloche; Centro Atómico Bariloche/Universidad Nacional de Cuyo; Centro Atómico Bariloche/Consejo Nacional de Investigaciones Científicas y Técnicas; Centro Atómico Bariloche/Consejo Nacional de Investigaciones Científicas y Técnicas/Universidad Nacional del Comahue

The National Commission of Atomic Energy is investigating a suitable physicochemical process for the conditioning of spent nuclear fuel of research reactors of the Al-UxSi type. A possible way of processing is through dry chlorination of the cladding with the purpose of selective separation of the aluminium from the remaining elements such as Fe, Ni, Zn, Cu, etc. transforming them into volatile chlorides. Some important advantages of this method are the thermal stability of the chlorides that allow easy separation of the halides by physical methods and the low volume of radioactive waste generated. The interactions in the following systems were studied in the range of temperature between 150°C-500°C: AIA6061, Al-Fe, Al-Ni, Al-Cu, Al-Zn, Cu-Zn and the pure metals. We found that the reactivity was different depending if the elements were alloyed or separated. The separation factors of the systems under study were determined. Nickel is perfectly separated from aluminium for all temperatures, whereas good conditions for copper separation were achieved below 400°C. In the case of iron, complete isolation was never attained, however decreasing temperature to 150°C is possible to obtain aluminium chloride with less content of iron. The separation of zinc from the product was also difficult. It was detected that zinc chloride volatilization decreases when other chlorides were present, for example copper chlorides. In the Cu-Zn alloy, zinc chlorides remained in the condensed product due to interactions with copper. The samples were characterized by energy dispersive spectrometry (EDS), scanning electron microscopy (SEM), x-ray diffraction (XRD), Mössbauer spectroscopy (MS) and x-ray fluorescence spectrometry (XRF). The chemical composition was determined by atomic absorption, spectrophotometry and gravimetry.

4:40 PM
The CMI NESA Pyrolysis: An Attractive Process for the Treatment of Sewage and Industrial Sludges and By-Products: Paul Dominique Oudenne; CMI NESA

For many years, CMI NESA has gained considerable experience in a field of alternative thermal processes by which useful products result in addition to the destruction of the raw wastes. The CMI NESA pyrolysis process has been extensively applied to a wide range of sewage and industrial sludges and residues. The paper describes in details the development works carried out at pilot stage as well as the key parameters of the process. Some of the industrial realisations are briefly described, the most recent one being the erection of a sludge pyrolyser on predried sludges at 90% dryness of a temperature of 1200°C for a total firing time of 38 minutes (from cold to cold) under industrial conditions. According to the results, the addition of TSW appeared to improve liquid phase development with better physical properties compared to those of standard composition for the firing regime involved. The results indicated a prospect for using the waste as a co-flux in floor tile formulations.

5:05 PM
Using De-Watering Sieve Waste of Borax to Enhance the Properties of Floor Tile: S. Kurama; A. Kara; H. Kurama; Andolu University; Osmangazi University

There are various studies published in the relevant literatures on the use of borates in tile production, where borax waste has been mainly used in place of feldspathic minerals and the results showed that borate migration to the surface was the commonly encountered problem. In the present study, dewatering sieve waste (TSW) of Etibor Kirka Borax Company (Turkey) was used for use in a commercial floor tile formulation in proportions up to 20% as a partial substitution for Na-feldspars. A total of four formulations were prepared with 0.5, 1, 1.5 and 2 wt % TSW incorporation and shaped by dry pressing. The obtained samples were single fast-fired at a peak temperature of 1200°C for a total firing time of 38 minutes (from cold to cold) under industrial conditions. According to the results, the addition of TSW appeared to improve liquid phase development with better physical properties compared to those of standard composition for the firing regime involved. The results indicated a prospect for using the waste as a co-flux in floor tile formulations.
Technical Program

2:20 PM Invited
Economic Benefits of Mineral Extraction from Geothermal Brines: 
Gordon Bloomquist; 'Washington State University Energy Program

The economic benefits of the co-production of minerals from geothermal brines far exceeds the potential revenue stream from the sale of marketable by-products such as silica, zinc, manganese, lithium and a number of rare earths. Extraction of silica can avoid scaling problems often associated with many geothermal power projects and may allow for additional power production through the use of bottoming cycles or the use of the brine in direct use applications now impractical due to scaling problems. An additional benefit of silica removal is the opportunity to use the geothermal brine as a source of water for enhanced evaporative cooling—a technique that can significantly improve the summer power output from binary power plants employing air cooling for condensing the working fluid.

2:45 PM Invited
Geothermal Brines – Problem or Resource: Mark Patterson; 'Advanced Ceramics Research

Hydrothermal brines are extracted from significant depths below the surface and arrive at the surface at elevated pressure and temperature. The exact chemistry and conditions of these brines depends upon the rock formations through which the water travels, but many of the brines are rich in dissolved minerals. At pressure and temperature the minerals remain in solution but in order to extract heat from the brines, they are cooled and many of the minerals precipitate causing problems. Where precipitation is a problem in the downstream processing, the brines are maintained at a high enough temperature and pressure so as to avoid precipitation and injected back into the geothermal formation. This results in a significant loss in potential energy that could be recovered from the geothermal brines. If left to precipitate in an uncontrolled manner, many of the minerals will precipitate as gels, in a high surface area form which is difficult to extract from the liquor and which can cause problems. If the brines are seeded or the precipitation conditions are changed the precipitated minerals can be separated more easily and also can be altered to be made into more valuable particulates. Some of the specific chemistries will be discussed with reference to known geothermal brines.

3:10 PM Break

3:25 PM Invited

The excitement of recovery of minerals from geothermal brines has many positive angles. The economics of certain geothermal site is improved if a revenue is arrived from a sellable commodity with the geothermal power. The use of cleaner geothermal brines also improves the capable use of the brine before reinjection. We will review the opportunities for recovery of different minerals and the markets for them.

3:50 PM
Investigation of the Effects of Interstitial Filling Ratios on the Dry Grinding Kinetics of K-Feldspar: Halil Ipek; 'Osmanagazi University

In this study the effects of interstitial ratios on k-feldspar samples were investigated. K-feldspar samples were taken from Egypt using dry batch grinding conditions and a kinetic model. Three different mono size fractions (-3550+2360, -850+600 and -300+212 µm) were ground separately for 0.5, 1, 4, and 8 minutes and at four different interstitial ratios (125%, 100%, 75% and 50%) using a Bond mill with a mixture of five ball sizes. The mill utilized was a size of 30.5 cm diameters, with 30.5 cm length, providing a total mill volume of 22272 cm³. The mill has a total mass consisting of 22648 g. steel ball mixtures of 38.10, 31.75, 25.40, 19.05 and 12.70mm diameters, occupying 22% of mill volume. The mill rotates at a speed of 70 rpm. The weights of the feed charges were 3815.5, 3052.4, 2289.3, and 1526.2 g for 125%, 100%, 75% and 50% filling of the interstices of the balls respectively. The mineral used in all tests was three different mono sized feed fractions of k-feldspar with a specific gravity measured by a pycnometer, is averaged as 2.61 over eleven measurements, Mohs hardness, measured by a hardness pen, is 6 and also work indexes (Wf) is 11.14 kWh/t. Chemical analyses show that k-feldspar contains 66.52% SiO₂, 18.86% Al₂O₃, 2.53% Na₂O, 12.66% K₂O. T. The specific rate of breakage (S) was determined from the top size fractions at different grinding times that were mentioned above and the model parameters were compared.

4:15 PM
Preliminary Characterization, Liberation, and Dressing of Sands from Michoacan, Mexico: R. Escudero; Francisco J. Tavares; Ricardo Morales; 'Metallurgical Research Institute

The interest of studying Michoacan’s beach sands is increasing mainly because of the different mineralogical species contained (ilmenite, zircon, rutile, magnetite, among others). In this communication, preliminary studies to characterize these sands are focused to know the characteristics, liberation and dressing of the different mineralogical species. Although, the most applied mineral dressing to treat these kind of sands, that contain magnetic species (i.e., ilmenite, magnetite), is a combination of gravity separation and magnetic separation, it could be of a great deal of benefit to apply the information regarding the surface properties of the sands’ components, in order to study the application of flotation technologies to separate selectively those species with commercial value.

4:40 PM
Characterization of Ilmenite Ore Samples from Dankoli in North Western Nigeria: Adelana Adetunji; ‘Obafemi Awolowo University

Ilmenite ore samples obtained from Dankoli in Zamfara, North Western Nigeria has been characterized using Energy Dispersive X-ray fluorescence (EDXRF) technique, X-ray diffraction (XRD) technique and the Neutron Activation Analysis (NAA) technique. The major constituents in the ore were quantitatively found to be TiO₂ and Fe₂O₃ in concentrations of about 60wt% and 31wt% respectively. These occur in the forms of magnesium ilmenite (Fe, Mg)O·TiO₂, pure ilmenite (Fe-Ti-O₃), and barium copper yttrium oxide (Ba₂Cu₃YO₆·56) minerals. Other constituents impurities in minor or trace quantities include MnO, Na₂O, CaO, Mg, Zn, Cu, Ni, Co, Pb, Br, Al, Rb, Y, Th and U.

5:05 PM
The Development of Artificial Marble Made of Dolomite in Malaysia: Kamarudin Hussin; Shamsul Baharun Jamaludin; Che Mohd Ruazidi; Ghazali Mohd Sobri Idris; Mohd Nazry Soilih; Mohabattul Zaman; Khaizul Nazar Ismail; ‘Northern Malaysia University

Dolomite and limestone are one of the major mineral resources in Malaysia. Artificial marble was made of dolomite as a main raw material and epoxy as a binder. Perls is one of the major producers of dolomite in Malaysia that can produce large deposit of high-purity dolomite. Dolomite has been used as filler in road construction and by this new invention, it can value added the dolomite itself and thus it can be used in many applications such as in construction industry and decorative products. Besides from its excellent physical strength, this artificial marble allows the creation of many shape and form. It is a non-porous, stainless and colorful. Converting dolomite into such usable construction material would serve two purposes: producing a new product of tiles and value added to dolomite mineral in Malaysia.

New, Improved and Existing Technologies: Materials Processing I

Wednesday PM
August 30, 2006
Location: Catamaran Resort Hotel

1:30 PM Invited
Recent Development in Sonoprocessing of Materials: Mamoru Kawanbara; Jian Yang; Takashi Kubo; ‘Nagoya University

In a new field of Sonoprocessing of Materials in which ultrasonic is applied to materials processing operations, many innovative technologies can
be created. The technologies are based on the fact that a high-power sound can transmit through any continuous elastic medium with less attenuation, particularly in liquid. This allows us to externally control the system of concern by using the acoustic radiation force or the cavitation phenomena which can be induced by the sound. These functions may eliminate gravitational and/or atmospheric constraints which are often encountered in conventional operations for producing clean and advanced materials. The radiation force acting on fine suspending objects in a fluid can be utilized for eliminating or rearranging/orienting the objects in the fluid. Acoustically induced cavitation phenomena in liquid can be utilized as an effective dynamic means to control interfacial phenomena as well as micro- and macro-mixing of liquid. Sonoechemical and thermal effects in cavitation multi-bubble can be also useful in a waste water treatment. This paper outlines the recent development in the field of sonoprocessing of materials. Cold model experiments in some vessels have been performed to simulate ultrasonic operations such as inclusion removal from liquid, degassing of melt, emulsification of two liquid phases, solidification processing, and decomposition of chemical species in waste water. High speed visual imaging is carried out for better understanding of the cavitation phenomena as well as the followed microjets during the processing.

1:55 PM
Elaboration of Iron Based Hydrogen Accumulating Alloys: Vassil Kopaleishvili; Irakli Kashakhashvili; Lamara Kereselidze; Nugzar Khidasheli; 1Georgian Technical University

The bainitic Fe-C-Si alloys with optimum content of retained austenite serve as “containers” for storing of hydrogen. Both the vacancies offcc lattice and the possibility of forming hydrides of silicon and other alloying elements will be used. The idea is based on our scientific hypothesis. There is the silicon threshold (Si20.5%) in “Fe-Si” system and Fe-C bainitic alloys, above which it causes self-organized phenomena: sudden increase of hydrogen solubility and amount of retained austenite in the alloy after \(\gamma\rightarrow\beta\)-transformation, formation of two supersaturated solid solutions \(\alpha\rightarrow\gamma\rightarrow\beta\rightarrow\gamma\rightarrow\beta\rightarrow\gamma\) renaturation and its reverse process. Rapprochement of iron atoms when Si>0.50%, causes appearance of new covalent forces where uncompensated electrons of 3D-subshell are involved and it provokes synergetic phenomena. They “free” silicon atoms from the previous bonds. After that silicon itself becomes a getter of hydrogen using vacancies of 3Pd-subshell and it results in sudden increase of hydrogen solubility in metal. Simultaneously sudden decrease of iron activity takes place. That in its turn “releases” the carbon. Thus, its redistribution, controlling the bainitic transformation, is hastened. It stipulates for creation of “brittle bainite”\(\beta\tau(\alpha(C,H)+\gamma(C,H))\) after \(\gamma\rightarrow\beta\)-transformation. While weathering of metal, “rejuvenating”, hydrogen diffuses in “islets” of retained austenite and “relaxed bainite”\(\beta(\beta(\alpha(C)+\gamma(C,H)+H))\) is obtained. When heating austenite \(\gamma(C,H)\) is obtained, and after cooling “brittle bainite” is obtained, etc. Presented scientific hypothesis explains the available experimental facts (“rejuvenation” and its reverse process, graphitization, weldability, forming of flakes, reaching high strength, etc.) in a new manner, as well as, gives real opportunity for creating of new trends in many fields, e.g. iron based HAA. Provisional data having been obtained are encouraging.

2:20 PM
Molecule Polarization State for Refractive Indices Material Compensation Film Thickness: Chia-Fu Chang; Chia-Hi Chan; Zou-Ni Wan; 1Kun Shan University of Technology

We revise applicability of the theory of self-organized criticality (SOC) to the process of magnetic relaxation in type-II superconductors. It is demonstrated that the driving parameter of self-organization of vortices is the energy barrier for flux creep and not the current density. Power spectrum of the magnetic noise due to vortex avalanches is calculated and is predicted to vary with time during relaxation. We propose that the time dependent barrier for magnetic moment reversal yields a natural explanation to the time-logarithmic decay of the magnetization. Interactions between particles as well as shape and crystalline magnetic anisotropies define a new energy scale that controls the magnetic irreversibility. Introducing this energy scale yields a self-consistent explanation of the experimental data.

2:45 PM Invited
Recent Advances in Powder Metallurgy Technology: Kalathur S. Narasimhan; 1Hoeganaes Corporation

Powder Metallurgy is a net shape process with close dimensional tolerances. The average American car has 43 pounds of powder metal parts. Recent advances in high-density processes, alloy development and sintering techniques foster further growth of Powder Metallurgy in automotive applications. This presentation will review some of these advances.

3:10 PM Break

3:25 PM Invited
Energy Reduction in Ore Communion through Microwave: Ashish Kumar; V. V. RamaRao; Balachandran P. Kamath; K. P. Ray; 1K. R. Kini; 1Hindustan Zinc Limited; 2Society for Applied Microwave Electronics Engineering and Research, IIT Campus

Communion is an essential mineral processing operation to liberate the minerals from the ore. This however, is an energy intensive step in mineral processing industries. This work highlights the possibility of saving in grinding energy for ore comminution reducing work index of the ore by effective utilization of microwave energy. This reduced work index results in increased throughput of the grinding circuit in mineral beneficiation plant in order not to shift the product size. The fundamental principle behind this application remains the ability of microwave to heat individual phases within the ore matrix. The constituents of the ore typically having different thermal and mechanical properties develop stress of sufficient magnitude to create intergranular and transgranular fractures during heating and subsequent quenching of the ore. The experiments conducted with the ore samples of Zawar Mines and Rampura Agucha Mine of Hindustan Zinc Limited, India (A member of Vedanta Resources Plc) reflect a substantial up-shift in cumulative weight percentage passing in finer sieve fractions under quenched conditions. Further, the experiments carried out on Rampura Agucha ore reveal 20-30% reduction in work index, which result in decreased milling time or saving in grinding energy. The simulation studies estimates a 2-4% increase in plant throughput. Moreover, preliminary flotation studies indicated a significant increment in total metal recovery and concentrate grade for the desired grade and recovery values respectively. This paper is a technical note on the laboratory investigations carried out at Central Research and Development Laboratory of Hindustan Zinc Limited. Results have been encouraging to progress the work further. It is also proposed to carry out modeling work for simulation so as to predict the changes in minerals.

3:50 PM
Some Aspect of Duplex PACVD Hard Coating onto Tools for Hot Work Application: Vojtech Leskoskvi; 1Institute of Metals and Technology

The tribological load is the load of forging tools by relative motions between the plastically deformed work piece and the die. In comparison to many other forming processes hot die forging has an especially disadvantageous tribosystem. The advantages of the application of hard coatings, which are well known for cutting tools, are to a much lesser extend explored for casting, extrusion, moulding and forging tools. Increasing the lifetime of these tools is an important task in surface engineering because of complex loading conditions and often complicated tool geometry. The plasma-assisted chemical vapour deposition (PACVD) technique is well suited to deposit hard coatings on large dies and moulds. The aim of this study is to present and discuss results obtained on duplex PACVD hard coating in industrial application like hot forging of automotive parts. A new generation of vacuum melted and remelted (VMR) hot-work tool steels has been developed, which can reach a hardness of 58 HRC, and has a fracture toughness at this hardness equivalent to that of standard hot work tool steels at 45 HRC. This offer one of two advantages: the steels can be used at the higher hardness to provide resistance to wear or deformation, or, when used at hardness of 47 – 49 HRC for hot forging, to provide temper resistance, the nitriding behaviour and the adhesive wear resistance. The results, which will be presented, are from preliminary investigation. Experimental results indicate that introduction of a proper duplex PACVD hard coating will lead to an improved wear resistance and a longer lifetime of the hot forging dies. Furthermore, by using hard low-friction coating excellent anti-sticking properties can be obtained. At this
stage of investigation it is also necessary carrying out pilot trials to determine wear resistance and tool life in practice. These tests are currently underway.

4:15 PM  
Hydrogen-Absorption Properties of Rare Earth - Transition Metal Compounds: Teruo Tanabe1; Jun’ichiro Kadono2; Satoru Yamamoto3; 1Kyoto University; 2Kyoto Municipal Institute

The hydrogen-absorbing materials are expected to have the following properties at moderate conditions: (a) a large capacity of hydrogen absorption, (b) the absorption rate of hydrogen is large and (c) hydrogen-absorbed materials can easily desorb hydrogen. Thus the three concepts of capacity, rate and reversibility seem to be indispensable to clarify the mechanism of hydrogen absorption by the materials. In this work, the amount of absorbed hydrogen, the absorption rate and the reversibility of hydrogen absorption-desorption reaction were measured for binary R-M systems (R = Y, La, Ce; M = Co, Rh, Ir, Ni, Pd, Pt). These experimental results were discussed by the following three physical properties that were calculated by the extended Hückel method, i.e. the density of states unoccupied by electrons, the cohesive energy and the energy fluctuation. The major results are as follows: (a) the amount of absorbed hydrogen increases with the density of states in the energy range between -9 and -4 eV, (b) the R-M compounds of which energy fluctuations are large show a large value of rate of hydrogen absorption, and (c) when the cohesive energy is large, the compound has a tendency not to easily desorb hydrogen, i.e. its reversibility is poor.

4:40 PM  
Structural and Electrochemical Properties of Layered LiMn0.5Ni0.3Co0.2O2 Positive Material Synthesized by Co-Precipitation Method: Chen Yu; Chen Baizhen; 1Central South University

Lithium-ion secondary batteries are important power source for portable electronics, such as mobile phones, cameras and laptop computers. In addition, they are also considered as one of the most attractive power source for electric vehicles in the future. As global battery manufacturers seek to improve their products and cathode materials play a tremendously important role in lithium ion secondary battery performance, various lithium transition metal dioxides have been synthesized and investigated as cathode materials in the last ten years. Although LiNiO2 and LiMnO2 were once regarded as promising alternative materials to LiCoO2 due to their low cost and acceptable environmental effect, they both have severe problems related to structural instability and electrochemical properties. Recently, in order to overcome these disadvantages, many groups have focused on one-to-one-to-one solid state mixture of LiMnO2/LiNiO2, and LiCoO2, i.e LiMn1/3Ni1/3Co1/3O2. In this paper, we synthesized LiMn0.5Ni0.3Co0.2O2 by co-precipitation and solid state reaction method. XRD analysis confirmed that the structures of the synthesized materials are layered (space group R3m). Electrochemical properties were investigated by charge/discharge cycling, cyclic voltammetry, and A.C. impedance methods. The synthesis strategies and electrochemical performance will be discussed in detail.

5:05 PM  
Synthesis of MmNi5 by Combined Mechanical Alloying-Low Temperature Heating Process: Marcelo Ricardo Esquivel1; Julio José Andrade Gamboa2; Fabiana Cristina Gennari3; Gabriel Meyer3; 1Consejo Nacional de Investigaciones Científicas y Técnicas; 2Comisión Nacional de Energía Atómica

The synthesis of MmNi5 from their constituents using either mechanical alloying or a combined mechanical alloy and low temperature heating process has not been studied in detail. The first method present is a very simple procedure and low cost. Nevertheless, a remarkable decreasing on milling time is obtained if the starting materials are short time milled and heated at low temperatures (600°C). Experimental set up involves samples preparation in glove box and milling in Ar using a Uni-Ball-II apparatus. Samples were extracted at different milling times and analyzed by X-ray diffraction (XRD), scanning electron microscopy (SEM) and differential scanning calorimetry (DSC). The first technique was used to determine the identity of products and to analyze the changes of the crystallite size during milling. The second technique was used to observe the changes in morphology and size of the particles. From this study, the stages occurring during milling were identified and characterized. Differential scanning calorimetry was used to determine the temperature of formation of MmNi5 from samples milled at different times. Rietveld refinements were performed on experimental diffractograms to quantify the relative amount of the MmNi5 formed. The material produced by both synthesis mechanisms possesses the adequate microstructure for interaction with hydrogen. Then, the possibility of avoiding high temperature synthesis methods justify the effort of this study to obtain MmNi5. These results would facilitate the upgrade from laboratory to industrial scale and augments the scientific knowledge. These objectives aimed the elaboration of this work.

New, Improved and Existing Technologies: Non-Ferrous Processing III

Wednesday PM  
August 30, 2006  
Room: Toucan  
Location: Catamaran Resort Hotel

1:30 PM  Keynote  
SOM Process for Titanium Production Directly from Titanium Oxide: Uday Bhanu Pal1; Marko Suput2; Guoshen Ye3; Rachel De Lucas; Adam C. Powell1; 1Boston University; 2Massachusetts Institute of Technology

Titanium is a high-strength, low-density metal nearly immune to corrosion. The high cost of smelting and processing the ore prohibits its use in many applications. Applying the solid oxide membrane (SOM) process to titanium production will eliminate the need for multiple steps, as it only requires a single step. This more energy efficient approach will generate an enormous reduction in the cost of CP billet, ingot, and possibly also for the powder used to make titanium alloys. In our experiment, a steel crucible contains MgF2-CaF2-TiO2 flux. A titanium rod is partially immersed in the flux and serves as the cathode. An oxygen ion-conducting one-end closed YSZ tube containing a liquid metal serves as the anode. When the electrical potential between the anode and cathode is higher than the dissociation potential of titanium oxide, titanium ions are reduced at the cathode. The oxygen ions pass through the YSZ tube and are oxidized at the liquid metal anode. Flux samples were collected immediately after electrolysis and analyzed with Induction Coupled Plasma Mass Spectroscopy (ICP-MS) to calculate the Faraday efficiency. After the experiment, a cross section of the titanium deposit on the cathode rod was examined using SEM and its chemical composition was analyzed using EDS. The EDS results showed that pure titanium was deposited.

1:55 PM  
Magnesium Extraction from Magnesium Oxide Using SOM Process: Uday Bhanu Pal1; Rachel De Lucas; Guoshen Ye; Marko Suput; 1Boston University

As meeting the anticipated future energy demand with fossil fuels becomes less likely, scientists have started to shift focus to other energy sources such as hydrogen. A key problem to solve before a hydrogen economy can be implemented is hydrogen storage. A solution that has great promise is the use of magnesium hydride (MgH2), which can be reacted at low temperatures with water to produce hydrogen gas. If this storage medium is to be implemented on a large scale, it is important to develop a high efficiency process for recycling the huge amount of Mg(OH)2 byproduct back into magnesium metal for reuse. The solid oxide membrane (SOM) process is an emerging technology for this recycling process. In the SOM process, MgF2-CaF2-MgO flux at 1150°C is contained in a stainless steel crucible that also works as the cathode. An oxygen ion-conducting one-end closed YSZ tube containing a liquid metal anode is partially immersed in the flux. When the electrical potential between the electrodes is higher than the dissociation potential of MgO, magnesium ions are reduced at the cathode. The oxygen ions pass through the YSZ tube and are oxidized at the liquid metal anode. The magnesium vapor generated at the cathode is collected in the condenser as high purity magnesium. SOM experiments have been conducted with different liquid metal anodes and without reducing agents. Flux samples were
collected after electrolysis and analyzed to calculate the Faraday efficiency.

2:20 PM
Removal of Lead and Antimony from Liquid Copper by Cu₄O or CuCl-Based Fluxes between 1423 K and 1573 K: 1. Yang Cai1; 2. Xing-Hong Du2; 3. Hirokyuki Matsura3; 4. Tasuku Hamano1; 5. Fumitaka Tsukihashi1; 6. University of Tokyo; 7. Northeastern University

The partition ratios of lead and antimony between liquid copper and MgO saturated Cu₄O-CaO-SiO₂ flux and their removal rate by using CuCl-based flux were measured between 1423 K and 1573 K. For Cu₄O-CaO-MgO flux, the partition ratio of Pb was not affected by the CaO content at 1573 K, while that of Sb increased with increasing CaO content. The maximum value was 160 at the CaO content of 15.4 mass%. For Cu₄O-CaO-SiO₂-MgO flux, two liquid phases of calcium silicate rich phase and CuO rich phase were observed at 1573 K. The partition ratios of Pb and Sb between calcium silicate phase and liquid copper depend on the (mass%CaO)/(mass%SiO₂) ratio. When the (mass%CaO)/(mass%SiO₂) ratio increased, the partition ratio of Pb decreased and that of Sb increased. For CuCl-based flux, the removal of Sb was difficult by CuCl flux at 1423 K, and the removal ratio was approximately 20% for 75 minutes. However, the addition of Na₂CO₃ or CaO to CuCl flux was effective to remove Sb from liquid copper, and the removal rate was relatively large at 1423 K. The removal ratio of Sb from liquid copper was about 99.8% for 30 minutes by CuCl-Na₂CO₃ flux, and that of Sb was 99.9% for 15 minutes by CuCl-CaO flux.

2:45 PM
Slag Solidification with Water-Cooled Probe Technique: Mieke Campforts1; Karel Verscheure1; Frederik Verhaeghe1; Eddy Bodny1; Bart Blanpain2; Patrick Wollants1; K.U.Leuven

Solidification of slags is a domain of increasing importance for the metallurgical industry. With respect to freeze lining formation in pyrometallurgical reactors an industrial zinc-fuming slag has been investigated experimentally using a water-cooled probe technique. With this technique, a layer of solidified slag is formed on a water-cooled probe that is submerged into a liquid slag bath. The influence of submerging time, temperature of the slag bath and convection in the slag bath is being investigated. The solidified layers are analyzed with light microscopy, electron microscopy, electron microprobe and X-ray diffraction. The results demonstrate that the experimental technique is useful for interpretation of freeze lining formation in pyrometallurgical reactors and promising for measurement of CCT-diagrams of slags.

3:10 PM Break

3:25 PM Keynote

The Extractive Metallurgy of Beryllium: Current and Future Technologies: Edgar E. Vidal1; Donald J. Kaczynski2; Colorado School of Mines; 3. Brush Wellman, Inc.

Beryllium metal and alloys have been crucial in the advancement of technologies in space exploration, transportation, national defense, communications, energy, safety and medicine, to name a few. Beryllium is one-third lighter than aluminum and six times stiffer than steel, with unique thermal properties. Demand for this metal is expected to continue to increase as new technologies emerge, hence its efficient and safe extraction needs to be addressed. Current extraction technologies are very complex and energy intensive, but at the same time yield excellent quality metal. In order to develop new or improve current extraction methods, a detailed analysis of current and past extraction technologies must be made. This work intends to compile and interpret most of the research, development and industrial practices used in the production of beryllium, and open the field for innovative extraction methods.

3:50 PM

Heavy minerals containing rare earth elements were recovered from beach sand of Korean Yellow Sea. The physical separation techniques such as gravity, magnetic and electrostatic separation were examined to establish the optimized process for recovery of them. The beach sand of Korean Yellow Sea contained abundant ilmenite, zircon and rutile with different particle size and mineralogical features. Most of magnetic minerals composed of ilmenite and marginal rare earth minerals such as monazite and rutile were recovered by magnetic separation. The separation factors for constitutional minerals of beach sand were also established according to the different magnetic and electrostatic responses of them.

4:15 PM
Processing of Man-Made Raw Materials as a Significant Source of Resources and One of the Main Ways for Development of the Russian Nonferrous Metals Industry: Andrey V. Tarasov1; A. D. Besser2; 1. Gintsvetmet

The insufficient scientific and technical level of a number of operations in the nonferrous metals industry encourages development of new processes and equipment, including smelting in liquid bath, flame-type sparged smelting unit for combined processes, electrothermal process with the use of alternating current (PDF furnace), electrothermal processing of complex raw materials and intermediate products at nonferrous metallurgical plants, etc. One of the most important aspects for development of new processes and equipment in the Gintsvetmet Institute is their environmental safety. Special attention is paid to environmental protection measures, which is also of important economic and social significance. This refers also to a complete extent to processing of reserves of man-made raw materials and wastes available at the existing operations with the use of innovative techniques ensuring not only resource conservation and environmental protection, but also abatement of negative impact on the nature due to accumulated industrial and domestic waste, reclamation of the land used for waste disposal and recycling of nonferrous metals. Technologies and equipment developed in the Gintsvetmet Institute and based on electrothermal processes determine the prospects for ensuring more integrated usage of ores and man-made raw materials.

4:40 PM
Autoclave Processes for Mineral Processing: Andrey V. Tarasov1; E. M. Timoshenko2; 1. Gintsvetmet

Autoclave technology can be effectively used for liberation of complex mineral raw materials to transfer valuable constituents into solution for their subsequent recovery or to refine feed material in order to remove deleterious impurities, e.g. arsenic. The high efficiency of autoclave processes is attributed to the fact that they are suitable for processing of refractory raw materials, have low capital costs, high productivity, ensure integrated utilization of the feed materials, produce innovative saleable products, completely eliminate any air emissions, provide low-waste or waste-less technology, mechanization and automation of production processes. In the immediate future, it might be expected that autoclave processes will find use on commercial scale for production of heavy non-ferrous metals in combination with other processes (hydrometallurgical, upgrading, sorption and solvent extraction, electrolytic, etc.) to ensure: 1) integrated processing of refractory ores and concentrates (pyrrhotite, zinc, copper-zinc, lead-zinc, nickel-cobalt, copper, pyrite) and 2) production of metallic powders of base metals as commercial products (copper, cobalt, nickel, etc.), composites on their bases, final products and saleable salts. Processing technologies incorporating autoclave processes, especially at the stage of liberation (chemical upgrading) of raw materials are characterized generally by high overall recoveries of valuable constituents significantly exceeding recoveries common for conventional pyrometallurgical processes (for some elements by several tens of percent).
Thermo and Physicochemical Principles: Non-Ferrous Processing: Recycling and Recovery

Wednesday PM
August 30, 2006
Room: Russeau East
Location: Catamaran Resort Hotel

1:30 PM Keynote
Recovery of Metals from Steelmaking Dust by Selective Chlorination
- Evaporation Process: Hirotsuki Matsuura; Fumiyaka Tsukihashi; University of Tokyo
Approximately 0.5 Mt of steelmaking dusts containing large amount of metals such as zinc and lead have been generated from converter and electric arc furnace (EAF) annually in Japan. Treatment of these dusts has become an important issue from the viewpoint of the environmental protection and recycling of variable resources. Recently, a new recovery process of these metals has been developed, in which the metals in the dusts react with waste polyvinyl chloride to form metal chlorides. Zinc and lead oxides are converted to chlorides, while iron oxide is stable at high oxygen and chlorine partial pressures. Since vapor pressures of zinc and lead chlorides are enough high for those chlorides to be recovered by vaporization, these metals could be selectively recovered from these dusts. In addition, not only metal chlorides but also oxochlorides may form at such highly oxidizing atmosphere. Therefore, it is important to clarify the physicochemical properties and behaviors of zinc, lead and those chlorides. In the present study, the kinetics of chlorination of ZnO, PbO and ZnFe₂O₄ mainly contained in the converter and EAF dusts were investigated at 1023 to 1273K with Ar-O₂-Cl₂ gas. Based on these results, the selective chlorination - evaporation process of zinc and lead from the mixture of ZnO-PbO-ZnFe₂O₄-Fe₂O₃ were examined and the high efficiency of selectivity has been represented.

1:55 PM
A Study on the Characteristics of Ceramic Support Manufactured by Spent Foundry Sand/Loess: Seung-Whee Rhee; Kyonggi University
Spent foundry sand from cast iron industry mixed with loess is used to manufacture a ceramic support to recycle spent foundry sands. In Korea spent foundry sand is generated more than 700 thousands ton/year and it has a trend to increase. Since spent foundry sands consist mostly of sand including binding agents and residue, it has been treated by landfill. Hence, it is necessary to recycle spent foundry sands as ceramic supports because sands are permeable media. And loess which has highly adsorptive and reactive properties has been used as support materials. In this study, spent foundry sands mixed with loess are used to manufacture ceramic supports. Characteristics of ceramic support made by spent foundry sand-loess mixtures are investigated by bulk density, porosity, durability, and compressive strength. Also, the effect of water content, elevated temperature time, sintering temperature, and period of time is estimated to obtain the optimal condition to manufacture ceramic supports. Bulk density of ceramic supports is almost not dependent of elevated temperature time, sintering temperature and period of time. Porosity and compressive strength of ceramic supports are dependent of water content. Porosity is increased with increasing water content but compressive strength is decreased with increasing water content. Porosity and compressive strength of ceramic supports are increased with increasing elevated temperature time. Porosity is increased with increasing sintering temperature up to 900° and is decreased with increasing sintering temperature over 900°. Compressive strength is increased with increasing sintering temperature and is increased sharply over 1000°.

2:20 PM
Characterization of Electric Arc Furnace Slag as Construction Material: Kwang-Suk You; Nam-II Um; Gi-Chun Han; Ji-Whan Ahn; Korea Institute of Geoscience and Mineral Resources
This paper describes the characteristics of electric arc furnace slag (EAF slag) for recycling as aggregate of concrete. The chemical composition and leaching concentration of heavy metals and soundness of EAF slag and compressive strength of mortar with various replacement ratio of sand were investigated. As results, leaching of heavy metals and soundness of EAF slag satisfied Korean environmental limit and Korean Industrial Standard for aggregates. The compressive strength of mortar increased as the replacement ratio of EAF slag for sand increased, which is due to the hydrates formed by reaction of slag.
reaction.

4:15 PM
The Fundamental and Frontier on Resource Recycling of Nonferrous Metals: Guo Xueyi1; Central South University

The nonferrous metal industry is facing the resource depletion, energy crisis and environmental deterioration. The resource recycling is a correct way to promote the nonferrous metal industry development towards sustainable. To realize the resource recycling, the technical support is most important. In this paper, the techniques barrier for nonferrous metal resource recycling are summarized, the fundamental on resource recycling of nonferrous metals are proposed.

4:40 PM
Evaluation of Efficiency in Zinc Recovery from Waste Materials: S. M. Taghavi1; M. Halali2; Sharif University of Technology

In this report, the efficacy of different factors such as temperature of reaction, time of reaction and depth of bed are investigated to recovery of zinc oxide from zinc ore concentration residues in a fluidized bed furnace. Under optimum conditions, there was more than 93.5% zinc oxide in products.

5:05 PM
Processing of the Ni- and Cr-Bearing Oxidized Scarring Granulates with Liquid Cast Iron: Vladyslav M. Sokolov1; Veronika Gorbenko2; Irina Vinnik3; Yevgeniy Zhydkov4; National Academy of Sciences; National Technical University

The cost effective and environmentally friendly recycling technology was developed and tested. It enables utilization of the fine waste containing nickel and chromium oxides. The novel approach is based on the intimate interaction between powdery oxidized waste and liquid cast iron for arranging the optimal conditions for reduction of oxides. Moreover the thermodynamic evaluation demonstrates higher reduction efficiency of carbon and silicon dissolved in iron than of the same elements in a form of separate phases. The considered process partially provides itself by energy since the reaction of reduction of the chromium oxide by silicon dissolved in liquid iron has exothermal character. The technology advantages were derived by the experiments on the Ni-bearing scarring granulates. This waste is generated during electric discharge machining of Ni-base superalloys. The mechanism of its formation is considered in details. The waste can be efficiently introduced into liquid iron since it has a form of fine natural agglomerates. The trials demonstrated that visible generation of flue dust was virtually absent during the processing operations. The mostly complete extraction of Ni into different phases was received. The sufficient reclamation of Cr was gotten at the same time. The industrial application of the technology has shown the noticeable advantages in comparison with the current functioning approaches for processing the Ni-containing metal fines.

Thermo and Physicochemical Principles:
Steel Making:
Casting

Wednesday PM  Room: Russeau Suite
August 30, 2006  Location: Catamaran Resort Hotel

1:30 PM  Keynote
A New Era for Steel Production?: Lauri Elias K. Holappa1; Sheniqiang Wang2; Helsinki University of Technology

The aim of the metallurgical process development is, nowadays, to search for the shortest, most economical, more environmentally friendly and sustainable route to convert raw materials to finished products. Recent progress in steelmaking processes BOF and EAF - has also motivated to search for more advanced casting technologies to shorten process route. Continuous casting, which became industrially feasible in the 1960s, is now a mainstream technology with over 90% share of the world steel casting. After
in the conventional casting system, while these phenomena are remarkably suppressed using swirling motion in the immersion nozzle, which leads to very calm and uniform flow pattern at the outlets of the immersion nozzle, in the mold and on the meniscus in the mold. 2. For the case of billet continuous casting mold; a) Uniform velocity distribution can be obtained within a very short distance from the outlet of the nozzle. b) Heat and mass transfer near the meniscus can be remarkably activated compared with a conventional straight type immersion nozzle without swirl. 3. Suppression of uneven flow developed flowing through the sliding gate by a swirling blade. 4. Formation of fine bubble through centrifugal force of swirling flow. As a result, remarkable progress on the quality and production of continuous casting products has been observed in practical application.

3:10 PM  Break

3:25 PM  Keynote

A Tundish to Mold Model for Grade Change during Ladle Change-Over in Continuous Casting: Varadarajan Seshadri; Carlos Antonio da Silva; Itavahn Alves da Silva; Versiane Albis Leão; Vanderson Eney de Matos; Dimas Bahiense Moreira; Vinicius de Oliveira Cravo; ¹Universidade Federal de Minas Gerais; ²Universidade Federal de Ouro Preto; ³Companhia Siderúrgica de Tubarão

The increase in production of continuous casting machines requires long ladle sequences without interruption. Very often the production schedule is required to accommodate a variety of steel grades. In such cases downgrading may be inevitable. Models must be made available to study the alternatives that would make possible mixing of steels in the tundish but minimizing the losses due to downgrading the plates. Physical modeling was used to evaluate the influence of variables such as internal geometry of the tundish, presence of turbulence inhibitors, depth of ladle valve, weight of steel in the tundish, steel throughput upon the tundish transition curve. Expressions for minimum residence time and transition period have been determined. Mixing-transition is allowed to continue inside the liquid pool in the mold and the final solute distribution in a given cross section is captured by a solidification model. The result is a map of the transition in the final product.

3:50 PM

A Numerical Model of Solidification of a Massive Casting from Malleable Cast-Iron: Frantisek Kavicka; Jaromir Heger; Jana Dobrovská; Karel Strásky; Bohumıl Sekanina; Josef Stetina; ¹Brno University of Technology; ²ALSTOM Power Technology; ³Technical University of Ostrava

A numerical model of the temperature field associated with solidifying castings aims to achieve two general goals: directed solidification (as the primary condition for a healthy casting), and optimization of the technology of casting together with the preservation of optimum utility properties of the product. A specific goal of this model is the selection and optimization of the method of cooling to shorten the solidification time to obtain a spherical graphite structure with good nodular properties, and with a sufficient density of graphite spheres (cells). The speed of cooling during solidification and cooling in the mould is therefore a significant quantity influencing the formation of the structure. The achievement of these goals depends on the ability to analyze and, successively, to control the effect of the main factors which characterize the solidification process or accompany it. The analysis of the quantities is focused on determining the causes of the formation of the heterogeneous temperature field during casting, considering the phase and structural changes. It is also focused on the thermokinetics of the formation of shrinkage porosities and cavities and on the prediction of their formation. This leads to the optimization of the shape and sizes of the risers, the method of insulation, the treatment of the level. The model is applicable to various shapes of castings. The software is capable of analyzing the temperature field of the actual casting, as well as the temperature field of the mould and cores, including the dependence of their material.

4:15 PM  Keynote

Mathematical Description of Flows in Continuous Casting Machine of Steel: Pascal Gardin; Jean-François Domgin; ¹Arcelor

The aim of the proposed paper is to improve the simulation possibilities of an existing CFD-code by further development especially with regard to unsteady flow behavior in continuous casting mould of steel, including bubble dynamic evolution in the reactor. For CFD validation of oscillation prediction, unsteady calculations with realisable k-e model were performed in a billet caster with rectangular section. Self sustained and regular oscillations were obtained. Calculated flapping frequency is very close to what is mentioned in literature. For slab caster configuration, oscillation is influenced both by lower roll, which creates very small frequency oscillation (0.012 Hz for Arcelor water model), and upper roll, which creates slightly higher frequency oscillation (0.05 Hz for Arcelor water model). The two rolls interact and it is possible to detect both frequencies in the nozzle jet region. Numerical results are in good agreement with measurements for fluctuating velocity spectra and provide explanation for interaction of rolls. However, highest peaks of velocity fluctuations are not well detected by CFD. This is due to intrinsic limitation of unsteady k-e model, which cannot reproduce velocity disturbance coming from small and energetic turbulent eddies. Nevertheless, it is established that there is no need to use Large Eddy Simulation Model, which can be thought to be the most appropriate turbulence model for unsteady calculations, but requires larger computing time (one order of magnitude larger).

4:40 PM

Investigation of a Hard Substance that Adheres to Foot Rollers of Caster: Junfeng Shen; Huapeng Niu; ¹China University of Geosciences, Beijing

A hard solid substance, which adheres to moving foot rollers of a caster, causes the bloom surface to be seriously scratched. Based on the compositional investigation and microstructural analysis of the hard substance, this paper supports the viewpoint that the accumulation of oxide iron sheets from the bloom oxidation and slag film from the melting powder is a result of poor lubrication. The accumulated iron sheets and slag is partial remelted and then sintered into a solid, which clings to the foot rollers resulting them unhandy turn, and the bloom surface getting scratched.
Trioxide

Improved Method for the Purification of Technical Grade Molybdenum

Yasuhiro Awakura

Chromium Solution

Yasuhiro Awakura; Kyoto University

Aqueous and Electrochemical Processing

Thursday AM

8:00 AM Keynote

Applied Metallurgical Process Testing and Plant Optimization with Design of Experimentation Software

Corby G. Anderson; Montana Tech of the University of Montana

Laboratory and plant testing, interpretation and the application of metallurgical technologies can be tedious, time consuming and costly. This paper outlines the use of proven statistical design of experimentation software for rapid optimization of laboratory testing and operating plants with limited representative sample utilization. This results in less costly required testing, a more thorough understanding of results and the ability to simultaneously optimize several variables and outcomes at once. At the Center for Advanced Mineral and Metallurgical Processing, this testing methodology has been used successfully in many metallurgical development and plant optimization projects thereby confirming its real world utility and application. Accordingly, several applied examples in flotation and hydrometallurgy will be outlined in this paper.

8:25 AM

Alternating Pulsed Electrolysis for Fe-Cr Alloy Coatings Using Trivalent Chromium Solution

Shunsuke Yagi; Kuniki Murase; Tetsuji Hirota; Yasuhiro Awakura; Kyoto University

A novel Fe-Cr plating using an aqueous solution containing only Cr(III) ions as a metal component was investigated for an anti-corrosion surface modification process by an alternating pulsed electrolysis. In the most widely used pulsed electrolysis, the plating current is interrupted periodically. In the present process proposed, however, anodic potential was applied instead of current interruption. During the anodic polarization of the pulsed electrolysis, iron substrate immersed in the Cr(III) solution was dissolved, providing iron ions in the vicinity of the substrate. Then, Fe-Cr alloy was electrodeposited by subsequent cathodic polarization. Repeating this sequence of process, Fe-Cr alloy layer was developed on the substrate using a solution containing a single metal salt Cr(SO$_4$)$_2$, which can make the waste solution treatment easier. Anodic and cathodic polarizations, anodic and cathodic potentiostats were optimized to obtain a uniform Fe-Cr alloy layer. With decreasing anodic polarization time $t_a$ and anodic potential $E_a$, the amount of deposited Cr decreased, resulting in crack-free surfaces. A bright, flat, and crack-free Fe-Cr alloy layer of 1 µm thickness with composition gradient was obtained within 20 minutes on an iron substrate under an optimized condition using Cr(III) solution containing Cr$_2$(SO$_4$)$_3$, KCl, NH$_4$Cl, NH$_4$Br, H$_2$BO$_3$, and HCOOK. The composition at the surface was determined to be 80% Fe and 20% Cr by X-ray photoelectron spectroscopy, and the Cr composition gradually decreased in the direction of the thickness.

8:50 AM

Improved Method for the Purification of Technical Grade Molybdenum Trioxide

Raj Pal Singh

ADM crystallization used as an NH$_3$ source. Results indicated that leaching of MoO$_3$ with HCl is possible only when used at about 1N concentration. At high concentration of HCl, MoO$_3$ had very high solubility (7.5 to 40 g/L Mo). The most suitable conditions for HCl leaching were obtained at a slightly elevated temperature of 80°C. Using about 1N HCl at 80°C, K in the leached solid decreased to about 110 ppm, a value typically obtained in purified MoO$_3$ in 3.5 - 4.0 M HNO$_3$ + 0.5 – 1.0 M NH$_4$NO$_3$ media. The Mo losses under these conditions were 0.8-0.9 g/L Mo.

9:15 AM

Organic Entrainment Reduction at the Phelps Dodge Tyrone SXEW Plant

Martin Brueggemann; Gerald Gerleeve; Philippa Killian; Patrick Lopez; Randy Devinney; Phelps Dodge Mining Company

The Tyrene copper solution extraction/electrowinning plant was the first such facility built by Phelps Dodge Mining Company in 1984. Over the next 20 years, the aqueous flow rate capacity of the plant has been expanded from the original design of 8,000 gpm to 34,000 gpm to meet production goals in the face of declining copper grades in the leach solutions. The ability to process higher aqueous flow rates through existing equipment comes at the expense of increased organic loss through entrainment to raffinate. These losses of organic (diluent and extraction reagents) can account for 10% or more of the plant’s total operating costs. With the recent dramatic price increase of petroleum-based products, these operating costs due to losses are sure to increase. This paper will discuss recent improvements at the Tyrene SXEW plant that have resulted in a 40% reduction of organic losses. These improvements include picket fence modifications, new fence materials, organic recovery systems, and operational practices.

9:40 AM Break

9:55 AM Invited

Tankhouse Optimization by METTOP GmbH

Iris Filzwieser; Andreas Filzwieser; Josef Pölzl; Andreas Anzinger; Stefan Wallner; METTOP GmbH; Montanwerke Brixlegg AG; TECENSOL S.R.O.

The secondary copper producer, Montanwerke Brixlegg AG (Austria), produces 73 000 tonnes of cathodic copper per year using ISA tankhouse technology. METTOP GmbH (Austria) evaluated the different anode qualities from the plant with relation to the current efficiency and specific energy consumption. Parameters including the chemical and physical anode quality, current and current density distribution at each cathode, voltage, and distance between each cathode and anode were examined. In addition, the temperature, chemical analysis, and conductivity of the electrolyte was determined for each investigated cell, as well as the anode weight, anode scrap, cathode sheet, and short circuits. Metallographic analysis was also performed on selected dendrites. The investigations resulted in specific improvements in the tankhouse process including the level of anode impurities, and future projects are planned for further tankhouse optimization.

10:20 AM

Sonochemical Synthesis of Zeolite Na-A from Metakaolinite

Wantae Kim; Heeyoung Shin; Sangbae Kim; Korea Institute of Geoscience and Mineral Resources

Ultrasonic stimulation of constituent suspension (metakaolinite/NaOH) can improve the rate of synthetic reaction for zeolite Na-A. Zeolite Na-A can be synthesized from the suspension by sonication treatment at comparatively shorter exposing time than conventional heating treatment. The main effect of ultrasound for the production of zeolite Na-A in the present heterogeneous solid/liquid reaction is intense stirring the solid and liquid substances to produce relatively narrow-sized zeolite Na-A particles with higher CEC value.

10:45 AM

Effect of Rare Earth Metals on Corrosion Resistance of Mg Metal

Toshio Takenaka; Takami Ono; Yuji Narazaki; Masahiro Kawakami; Toyohashi University of Technology

The corrosion resistance of Mg metal containing rare earth metals (REs) was investigated, and the effect of REs was discussed. Mg metal containing RE was prepared by addition of RE in melted Mg metal at 950-1000K under a high purity Ar atmosphere. The corrosion resistance of the specimen was
assessed by the immersion test in 3mass%-NaCl solution at room temperature. To clarify the effect of REs, conversion coating in a solution of Mg(NO$_3$)$_2$ and/or RE(NO$_3$)$_3$ was carried out, and the change in the corrosion resistance of Mg was also investigated. The corrosion resistance of Mg was improved exceedingly by adding a small amount of RE, and became almost the same as that of a commercial Mg alloy, AZ31, under the suitable condition. The corrosion resistance of Mg was also improved by the conversion coating with the solution including both Mg(NO$_3$)$_2$ and RE(NO$_3$)$_3$. This result suggests that the mixed oxide film from Mg and RE on a Mg surface gives good corrosion resistance to Mg metal. Direct electrodeposition of Mg containing REs was also tried in this study. The potentiostatic electrolysis was performed in a dehydrated NaCl-KCl-MgCl$_2$ mixture (16:33.51 mole) containing RECl$_3$ at 943K. The RE content in the electrodeposited could be controlled by the electrolytic condition, and Mg metal containing the suitable amount of REs for corrosion protection was easily obtained.

11:10 AM

This paper described the studies on the recent development of China electrolyzed-Mn industry. Since 1994, China has grown into one of the largest countries in the world for its electrolyzed-Mn production and producing capacity, and at the same time, the production technology is greatly improved. According the statistics of 2004, China has electrolyzed-Mn producers of more than 140, with total annual production capacity being over 900 kt, and practical annual production of 492 kt. China electrolyzed-Mn technology in industrial production, including leaching technology, Fe and heavy metal removing technology and technology in Mn-electrolysis, post-production treatment, environment protection and equipment techniques, has been much improved. This paper also described the major technological process, technical requirements on the production and technical index and quality control of the products. Reactions for each major cathode – anode process have been expatiated based on the thermodynamic analysis.

11:35 AM
Studies on the Industrial Production Test of Zn-MnO$_2$ Simultaneous Leaching, Impurity Removal, and the Electrolytic Process: Wilson Zhang; Guangming Mei; Zhiqian Zhong; ‘Central South University’

This paper described a new technique in the industrial production test process of Zn-MnO$_2$ simultaneous leaching, impurity removal and the simultaneous electrolysis, and the related technical requirements and obtained results. This study has obtained higher technical index and higher quality of products. Reactions for each major technological process have been expatiated based on the thermodynamic analysis.

8:25 AM
A New Advanced CFD Model for Flash Smelting and Converting Processes: Juha Järvi; Tapio Ahokainen; ‘Outokumpu Research Oy’; ‘Outokumpu Technology Oy’

Development of commercial modeling software and increasingly efficient computers have brought a CFD tool for a more comprehensive investigation of the flash smelting and flash converting processes. Nowadays CFD modeling can be used for design purposes in many cases, but some relevant physical and chemical phenomena are still missing from commercial CFD packages. Therefore Outokumpu has developed several subroutines to describe these phenomena in flash smelting process. Sub-models of copper concentrate and matte combustion, particle-particle-wall interaction and more accurate radiation properties of gas-particle suspension are needed to provide reliability to numerical simulation of flash smelting and converting processes. Several basic combustion phenomena can be modeled with Fluent, but own models for combustion of particles must be included in case of special feed materials. Mathematical models for copper concentrate and solid matte combustion have been developed during last decade. Model calculates the temperature and the composition of particles and is based on experimental research work in laboratory scale furnaces with validated kinetic parameters and temperature measurements of reacting particles. Inside and near the concentrate burner standard particle tracking methods do not include particle-particle interaction and particle-wall interaction is too simplified to describe collisions of the particles with distribution cone. Therefore additional models for particle-particle and particle-wall interactions have been implemented. For thermal radiation, models for emissivity of gas mixture and calculation of particle absorption and scattering coefficients have been developed. In addition, enhanced radiation model can be used in simulation of off-gas cooling in waste-heat boilers of flash smelting processes.

8:50 AM
Method for Optimising Current Efficiency by Repairing Permanent Cathodes: Joachim Lemke; ‘Norddeutsche Affinerie AG’

The stainless steel sheets of permanent cathodes at Norddeutsche Affinerie (NA) were damaged by corrosion after nearly 11 years in operation. The necessary raising of the strength for stripping the copper had increased the deformation of the stainless steel blades. Current efficiency declined. After investigating the possibilities, like buying new cathodes or treating the steel surface, i.e. by sliding, a repair process was developed whereby the stainless steel sheet was exchanged. Special laser technology for cutting used blades and welding new stainless steel sheets underneath the used hanger bar was applied because the energy input into steel is the lowest of all welding methods. The new stainless steel sheet was welded with the rolling line in a horizontal direction. The achieved flatness of the repaired cathode blades amounted to less than 4mm per meter. During 11 months NA repaired nearly 36,000 permanent cathodes and put them back into operation. Repair costs were much lower than the costs of buying new ones and current efficiency increased again to more than 96% with a current density of 340 A/m$^2$.

9:15 AM
Efficient and Portable Mathematical Models for Simulating Heat Transfer in Electric Furnaces for Sulphide Smelting: Yuhua Pan; Shouyi Sun; Sharif Jahanshahi; ‘CSIRO Minerals’

Generic mathematical (computer) models have been developed for simulating heat transfer in two types of slag resistance heating electric furnaces for sulphide smelting: i) six-electrode-in-line rectangular furnaces and ii) three-electrode circular furnaces. The models are based on three-dimensional steady-state heat transfer of conduction, convection and radiation. Solidification of liquid slag into solid slag by water cooling units, for use as freeze lining of furnace walls, is also considered in the models. The developed models are capable of providing predictions with reasonable accuracy for electric furnaces on 1) temperatures in slag, matte, cooling water, freeze lining and other solid regions as well as temperatures at various fluid/solid interfaces, 2) freeze lining thickness, 3) furnace smelting rate, and 4) furnace heat loss rate. These computer models are built into executable application programs that are very efficient, with execution time less than one second, and can be easily portable to most computing platforms. This
The technical program describes, as an example, the modelling results on heat transfer in six-electrode furnaces. The major modelling results show that in six-electrode furnaces uniform electric power inputs to the electrodes likely lead to low-temperature regions close to slag and matte ends of the furnaces, and the power input and the formation of air gaps between freeze lining and cooling units have significant influences on the thickness of freeze lining maintained by the cooling units.

9:40 AM Break

9:55 AM Keynote

Furnace Lining Analysis and Design by Mathematical and Physicochemical Modelling: Roberto Parra; Luis Felipe Verdeja; María Florentina Barbés; Christian Goñi; University of Concepcion; North Catholic University

The wear and corrosion phenomena in the furnace lining of the ferrous and non ferrous pyrometallurgical processes are complex problems where chemical, interfacial and mechanical phenomena are presents. The characteristics of the processes determine the conditions to which these materials are submitted, where the thermal conditions reached during the operation is one of the most important parameter. Assuming that all the degradation phenomena are thermal activated, the rate of the different steps of the wear mechanism will depend on the thermal field in the lining.

In view to apply the independent physicochemical knowledge of degradation mechanisms to the analysis and design of furnace lining the methodology of the Nodal Wear Model (NWM) was done. It combines the mathematical modelling of the heat transfer in the lining with the physicochemical control equation for the wear-corrosion phenomena. The NWM has been applied to different examples: theoretical analysis, laboratory scale test and industrial applications. We present in this paper the theoretical background of the model with some applications.

10:20 AM Invited

Mathematical Model for the Fragmentation of Copper Matte Particles Oxidized under Flash Converting Conditions: Manuel Perez-Tello; Irma Maria Madrid-Ortega; Hong Yong Sohn; University of Sonora; University of Utah

A mathematical model to represent the expansion and fragmentation of copper matte particles oxidized under flash converting conditions is presented. The model assumes the particles to be initially nonporous, have a constant mass prior to fragmentation, and travel at a constant velocity throughout the reaction chamber. The model requires the specification of five parameters: the particle expansion rate, a fragmentation diameter factor, a fragmentation size distribution parameter, and the fractions of the finest and the coarsest particles in the feed that undergo fragmentation. The model predictions show good agreement with experimental data collected in a laboratory flash converting furnace over a wide range of experimental conditions. The evolution of the size distribution of the particles along the reactor length was computed, and the model parameters were correlated with the experimental operating variables. Model predictions indicate that particle residence time is an important factor in the generation of dust. The presence of two maxima in the particle density function may be attributed to turbulent conditions prevailing in the furnace, which causes particles to follow very different trajectories within the furnace even if they are injected at the same location.

10:45 AM Invited

Thermal Transportation Properties of Copper Flash Smelting Flue Dust: Elli V. Nurminen; Helsinki University of Technology

Fouling of heat recovery process equipment may significantly decrease their heat transfer efficiency. In Copper Flash Smelting process flue dust tends to form build-ups in the heat recovery boiler. Thermal transportation properties of copper flash smelting flue dust and its components have been studied. The effects of porosity and temperature on thermal transportation properties have been determined. The results indicate that dust and its components are effective thermal insulators and build-up layers in the boiler are likely to decrease greatly the heat transfer efficiency of the boiler. Decreasing dust layer porosity has a strong increasing effect on thermal conductivity. The results may be used in CFD-modelling and optimisation of the process.

11:10 AM

Sampling Campaigns for the Characterization of Flash Smelting Combustion of Copper Concentrates: Roberto Parra; Roberto Parra; Angeles American Chile; University of Concepcion

In a long term program for the optimization of the Outokumpu Flash Smelting Furnace of Chagres Smelter many different subprograms are being developed. One of them is the development of a sampling method that can allow the direct diagnostic of the quality of the copper concentrates combustion. We present in this paper three types of sampling devices used in a ten months continuous sampling campaigns. The results allow identifying the distribution of sulfur elimination and magnetite formation in the flame for different type of concentrates and operational conditions. The analyses with the appropriate mathematical modelling of the combustion propose some consideration to correct the classic criteria in the preparation of the charge for the smelting of copper concentrates based only on the mass and energy balance from the chemical and mineralogy composition of the concentrates.

11:35 AM

Prediction of Combustion Phenomena in Flash Smelting Furnace for Production Enhancement Using a Mathematical Model: Yukihito Sasaki; Yoshiaki Morii; Yasumasu Hattori; Akihiko Tanabe; Sumitomo Metal Mining Company, LTD.

The Sumitomo Toyo Smelter and Refinery has planned an expansion program for the increase of the production capacity of electrolytic copper to 450,000 tpy in 2007. Regarding the flash smelting furnace, a drastic increase of smelting capacity to 3,950 tpd of concentrate from 2,350 tpd in 2003 was needed to achieve the plan. It was necessary to examine the performance of the Sumitomo-type concentrate burner when the feed rate was so greatly increased. The authors developed a mathematical model to describe the combustion phenomena in the Toyo flash smelting furnace. This model was constructed incorporating fluid flow, heat and mass transfer, and the chemical reactions of copper concentrate and auxiliary fuel. Copper concentrate was regarded to consist of mainly chalcopyrite (CuFeS2). The reaction of CuFeS2 was assumed to consist of two steps, namely the decomposition of CuFeS2 and the oxidation of the resulting pyrite (FeS) and sulfur (S). The combustion phenomena in the furnace at the increased rate was predicted using the model. It was found that the Sumitomo-type burner had the smelting enhancement ability by increasing oxygen-content in the reaction air and spreading the concentrate cloud more widely in the furnace. The former improved the reactivity of the concentrate particles and the latter contributed to providing sufficient time for the concentrate reaction. By combining the expertise of the smelting team and the calculation results, the Toyo Smelter has stably increased the smelting capacity of concentrate to 3,250 tpd to date and the further improvements are still ongoing.

International Symposium on Sulfide Smelting: Analysis and Optimizations II

Thursday AM: Room: Cockatoo
August 31, 2006 Location: Catamaran Resort Hotel

8:00 AM

Graphite Reduction of Molten Nickel Matte/Oxysulfide/Slag: Part I: Slag and Oxysulfide Reduction: Jin Liu; Torstein Utigard; Inco Ltd; University of Toronto

To improve value metals recovery, a new operating concept for the Inco flash furnace was investigated, in which the flash furnace coke addition practice would aim at establishing a reducing barrier on the surface of the molten bath. The descending partially oxidized sulfide mineral particles would reach the supernatant coke layer prior to the formation of slag. The key for success depends on the effectiveness of the coke layer to produce a sulfur deficient matte while maintaining furnace production capacity.
The mechanism and rate of carbon reduction of the phases formed in the flash flame, i.e., sulphide (matte) and oxy-sulphide was investigated by means of crucible graphite reduction test work. The objective of these tests was to measure the rate of solid graphite reduction of matte, oxy-sulphide, slag, and matte-slag mixture at different temperatures. These tests were expected to permit understanding and explaining the reduction mechanism of each material by comparing the respective reaction rates, product reaction gas compositions, reduced material assays, and other relevant parameters. Direct visual inspection of the test crucibles would provide additional information.

8:25 AM

**Graphite Reduction of Molten Nickel Matte/Oxysulphide/Slag: Part II: Nickel Matte and Slag+Matte Reduction**

*Jin Liu*; Torstein Arnfinn Utigard; Inco Ltd; University of Toronto

The mechanism and rate of carbon reduction of each of the phases that are formed in the flash flame, i.e., sulphide (matte) and oxy-sulphide, was investigated. Graphite-slag reduction was conducted for comparison purposes. The objective of these tests was to measure the rate of solid graphite reduction of respectively matte, oxysulphide, slag, and matte+slag mixture at different temperatures. More in particular, these tests were expected to permit understanding and explaining the reduction mechanism of each material by comparing the respective reaction rates, product reaction gas compositions and CO/CO2 ratios, reduced material assays, activation energies, and other relevant parameters. Direct visual inspection of the test crucibles would provide additional information.

8:50 AM

**A Study of Freeze Layers in Smelting Furnaces**

*Fernando J. Guevara*; Gord A. Irons; Steel Research Centre, McMaster University

Many smelting and slag-cleaning furnaces operate with cooling systems designed to freeze a slag layer over the refractory to protect it. Flow and heat transfer conditions associated with the freeze layer and mushy zone are poorly understood. These phenomena were simulated with a small-scale room temperature, 2-dimensional model, using an aqueous solution of calcium chloride to simulate the slag. Reasonable similarity with conditions encountered with copper and nickel melting systems was achieved (Pr = 50 and Ra = 10^6, in the laminar-turbulent transition). Measurements of the freeze layer development and velocities were made with the Particle Image Velocimetry (PIV) technique. Direct Numerical Simulations (DNS) were also made of the unsteady fluid flow and heat transfer problem. It was found that the solidification process is well-described using an improved model for high molecular viscosity in the mushy zone. Solid front growth, isothermal profiles, velocity profiles and heat transfer through the walls showed good agreement between the PIV and DNS results. Experimental and numerical velocity profiles close to the freeze layer show a parabolic behaviour in the vertical velocity profile which is completely different from the calculation of heat transfer using a sharp interface model. The reason for this is attributed to the effects of the mushy zone with a high viscosity and high shear stresses acting on that area.

9:15 AM

**Real-Time Monitoring and Performance Analysis of Furnace Tapblocks**

*Lowy Gunnewiek*; Hatch Ltd.

An advanced real-time monitoring and performance prediction system, generally referred to as a “tapblock diagnostic system” has been developed to assist furnace operators manage the operation and maintenance of their tapblocks. Using cooling water flow and temperature measurements from the tapblock, the system performs numerous functions in real-time, including: establishing the reliability of the data being measured, tapblock performance relative to a predefined operating envelope, and diagnostics to inform the furnace operators of why instrumentation may be faulty, if maintenance is required, or why performance is degrading with time. A state indicator in the form of a green, yellow and red light system is used to inform operators of the tapblock’s performance and “health” status. A green light means all is good, yellow a warning that care must be taken, and red indicating that tapping must not commence or should be stopped immediately. In some operations, a red light triggers the entire furnace operation to be stopped. Additional features of the system are the ability to send messages to those who need to know the status of the tapblock but are not necessarily involved with daily hands-on operations, and a database for storing all measured and calculated data. The development of this system has given operators of high intensity smelting furnaces an enhanced understanding of a tapblock’s overall functioning, and thus the ability to better manage the safety and performance of its operation.

9:40 AM

**Break**

9:55 AM

**Keynote**

**Analysis of Behaviour in Flash Furnace Burner Concentrate Chutes**

*Peter Koh*; *Francis R. Jorgensen*; Barry J. Elliot; CSIRO Minerals; BHP Billiton

The velocity solid charge attains when dropping down concentrate chutes is an important boundary condition when developing mathematical models of flash furnace burners and reaction shafts. In this work an experimental rig was developed to measure the velocity attained when nickel concentrate was dropped down a vertical pipe 3 m long. The velocity measurements showed that the nickel concentrate did not fall as individual particles. The measured values of the velocity approached but did not attain those calculated for solid bodies, the disparity being attributed to friction at the pipe wall and fluid drag losses. After falling 3 m velocities between 5-6 m/s were attained. The analysis was extended and applied to understanding the intermittent problem of puffing which sometimes occurs from the top of the concentrate chute. Flow back up the chute is the net result of two opposing pressures, namely that developed by (a) the process air entering through the velocity control device, and (b) the solids falling down the concentrate chute. Flow back up the chute occurs when the former exceeds the latter. The process air pressures in the burner were obtained from CFD simulations of a full burner. Variables considered included air speed through the velocity control device, drop height and furnace draft. The analysis was useful in highlighting the operating conditions which were conducive to puffing and establishing procedures to minimise its occurrence.

10:20 AM

**Invited**

**Copper ISASMELT – Dealing with Impurities**

*Gerardo Raul Alvear*; Simon P. Hunt; Xstrata Technology

The ability to efficiently remove impurities contained in concentrates is a key point to consider when selecting copper smelting technology for new plants or modernisation projects. Volatilisation of impurities such as As and Sb should occur as early as possible in the process, and preferably in the smelting furnace, so that they do not impact on downstream unit operations. The ISASMELT process has been demonstrated to remove impurities efficiently, through high levels of volatilisation. This behaviour is promoted by attributes of the process such as the strong bath agitation, the flexible nature of the process design, allowing the operator to choose the optimal matte grade for impurity partitioning, and the positive effect of the moisture content in the feed. This paper presents the distribution of minor elements in the copper ISASMELT furnace for a number of existing plant scenarios. Then, based on plant results and thermodynamic considerations, the potential application of ISASMELT technology for processing complex concentrates is also discussed.

10:45 AM

**Validation of the Olympic Dam Flash Furnace Burner and Reaction Shaft Model – Comparison of Model with Plant Measurements**

*Christopher B. Solnordal*; Frank Jorgensen; Andrew Campbell; CSIRO Minerals; BHP Billiton

A mathematical model was developed to simulate the performance of the reaction shaft at BHP-Billiton’s Olympic Dam copper flash smelter. In order to have confidence in the predictions of the mathematical model, validation was performed by comparing and reconciling the predictions from the model with the results from a campaign of sampling and plant measurements. The model was based on the computational code CFX 4.4 utilizing a combustion sub-model purpose-built by CSIRO. The combustion sub-model employed the concept of a composite particle which contained the three components of the solid charge: concentrate, flux and returned dust. Plant measurements were made and samples taken immediately below the burner and through a port halfway down the reaction shaft. Parameters measured included...
Technical Program

New, Improved and Existing Technologies: General Recycling and Waste Treatment II

Thursday AM Room: Kon Tiki Ballroom
August 31, 2006 Location: Catamaran Resort Hotel

8:00 AM
The Use of Blast Furnace Slags in “High Performance” Asphalt Mixes: A Laboratory Characterization: Marco Pasetto; Nicola Baldo; University of Padova

The possibility to reuse marginal materials (by-products) deriving from industrial activities, in the construction of road infrastructures, as total or partial substitution of the natural aggregates, happily conjugates demands for economic convenience and environmental sustainability. The paper presents the results of a laboratory study, conducted at the Experimental Road Laboratory of the University of Padova, aimed to verify the suitability of a particular typology of blast furnace slag to be recycled in the lithic skeleton of high-performance asphalt mixes (porous asphalt, high modulus mixes, stone mastic asphalt) for road and airport flexible pavements. The mixtures evaluated in the Marshall mix design as optimal, have been submitted to an articulated series of test to verify their mechanical performances (static and dynamic creep, stiffness modulus, indirect tensile strength). Finally, thanks to the use of a gyratory compactor, and the support of the Superpave methodology, it has been possible to analyze their volumetric behavior and to characterize the workability of the mixes. This study forms a part of a wider theoretical – experimental research being done at the University of Padova in order to improve the knowledge of the characteristics of succedaneum materials and check up their possible applications in the road and airport construction.

8:25 AM
Recycling of Platinum from Spent Catalysts: Dieter Offenthaler1; Jürgen Antrekowitsch; Stefan Konetschnik2; Christian Doppler Laboratory for Secondary Metallurgy of Nonferrous Metals; University of Leoben

Catalysts used in petroleum industry often contain valuable amounts of PGMs. The typical recycling route for those materials is the pyrometallurgical one, but this treatment way offers limited flexibility with respect to small charge weights. A new process, combining a pyrometallurgical pre-treatment step of the ceramic carriers with a hydrometallurgical leaching procedure overcomes this disadvantage. It not only allows the economical treatment of even very small charge weights, but also gives the possibility to maximize the PGM yield by individually adapting the process to the different charge materials. Due to an ingenious process design, where all leaching agents and effluents are recycled in a closed loop and therefore no waste water leaves the process, process operation becomes very economical. However, the temperature-time-regime in the pyrometallurgical pre-treatment step is of major importance for the success of the whole process. Therefore various investigations have been done to identify how the different process variables in the pyrometallurgical pre-treatment influence the subsequent leaching procedure. It turned out, that the adjustment of the correct phase-modification in the ceramic carrier materials during the pyrometallurgical treatment is the key factor of this process step. Although it is a troublesome issue to exactly adjust the correct phase modifications, it is the prerequisite to take advantage of the benefits of this new process concept.

8:50 AM
Separation of Individual Plastics from Mixtures by Gravity Separation Processes: Woo Zin Choi; Jae Myong Yoo; Eun Kyu Park2; University of Suwon

Plastics recycling has become an established national industry in Korea. However, it is still in its infant stage and experiences growing pains. In Korea, mixed plastic wastes generated from households after hand picking and/or mechanical sorting processes amount to 1,700,000 ton per year in 2005, and most of these waste are finally end up with landfill and/or incineration due to lack of separation technologies and economical reasons. These plastic wastes can not be used as raw materials for chemical and/or thermal recycling because of their high content of PVC (up to 4.0 wt.%). In the present work, gravity separation system has been developed to remove PVC from the mixed plastic waste and recover the individual plastics. The separation system mainly consists of air classification, crushing, feeding system at fixed rate and wet-type gravity separation system. The gravity system also consists of mixing, precleaning, separation, dewatering, recovery system, wastewater treatment system, etc. The main objective of this process to be developed is to achieve high separation efficiency of polyolefins (PE, PP, PS) with less than 0.3 wt.% PVC content and less than 10% moisture content in the final products. The system with a capacity of 0.5 ton per hour is developed and operational results are presented.

9:15 AM
Engineering Factors Affecting Removal of Toxic Materials with Inorganic Cation Exchanger: Norihiro Murayama; Junji Shibata; Kansai University

The hydrothermal syntheses of zeolites from coal fly ash were carried out using NaOH and KOH as an alkali source. The cation exchange capacity (CEC) and the ion exchange selectivity were investigated for the zeolites.
and substitution of all the FBRF’s nickel powder with it and, eventually, shut-down of the calcine reduction operation at the Severonickel. Annual economical impact of the process implementation exceeds US$ 2 ml.

11:10 AM

Study on the Zinc Reduction of Stainless Steelmaking Dust: Bing Peng1; Liyuan Chai2; Central South University

Stainless steelmaking dust is classified as a hazardous waste due to higher than acceptable heavy metal leachabilities such as zinc, lead, cadmium and chromium. In addition to being an environmental hazard, the flue dust is also an economical concern to stainless steelmakers as it contains large amounts of valuable alloying elements, especially for iron, chromium and nickel. A new technology of direct recycling of stainless steelmaking dust has been developed to recover the metals from the dust. But it was found that zinc was accumulated in the dust collection system in practical run of direct recycling. This study focuses on the effect of the operating parameters such as temperature, dust feed rate and the ratio of dust to CO on the reduction of zinc oxides in the dust. The mathematics model for the reduction process was set up based on the experimental research. According to the mathematics model, the temperature has obvious effect on the reduction of zinc. It is benefit to the process of zinc reduction to increase the temperature. But the temperature will not be the main factor for the reduction process after 1228°C. It will promote zinc reduction to decrease the dust feed rate and control the ratio of dust to CO. It was also found from the experiments that ZnFe2O4 in the dust could be decomposed at high temperature. Decomposing ZnFe2O4 in the dust increases the recovery of zinc from the dust distinctly.

11:35 AM

Aerated Autoclave Concrete from Flyash and Effect of Flyash Composition on the Properties of Concrete: Madhusudhamrao Vallabhaneni1; Vignan’s Engineering College

Flyash is a finely divided non combustible material obtained as a byproduct of coal combustion. It is a major waste and pollutent produced by coal based thermal power stations. This paper explores the possible end uses of flyash. The fabrication of insulating partitions, doors and sealing material is discussed in detail. The Aerated Autoclave Concrete (AAC) is developed for above mention uses. The compositional effect of flyash on the properties of AAC is also discussed in detailed. At the end it is proved that the proper utilization of flyash could reduced the power generation cost to one fourth of present.

New, Improved and Existing Technologies:
Non-Ferrous Processing IV

Thursday AM
August 31, 2006
Room: Toucan
Location: Catamaran Resort Hotel

8:00 AM Keynote
Innovative Prospects for Nonferrous Metals Production in Russia: Andrey V. Tarasov1; Gistsvetmet

The nonferrous metals industry has been a sector with one of the highest growth rates during the recent years. The prospects for the Russian metals industry during the period until 2010 are associated first of all with a growing domestic demand for its products. The technological level of the metallurgical operations in Russia is relatively low in comparison with industrially developed countries: the average energy requirement is higher by 20% to 30%; the amount of generated waste in the process of rolled products manufacture is twice as high; the average labor productivity is lower by 2.5 to 3.0 times; the overall negative environmental impact is twice as high. Improvement of the technological level of the nonferrous metals production under the conditions of market economy is possible by application of innovative technologies for the development of this sector. The main trends for development of the nonferrous metals sector are: 1) meeting of more stringent requirements to the quality of concentrates, 2) more complete recovery of associated elements as commercial-grade products,
The Effect of Formation Age on Manufacturing Process of Aragonite Precipitated Calcium Carbonate: Ji-Whan Ahn; Jung-Ah Kim; Jeong-Hwan Kim; Hwan Kim; ‘Korea Institute of Geoscience and Mineral Resources; ‘Seoul National University

Korea has about 68 hundred millions tons of limestone’s reserves, Nevertheless high-CaO limestone that is containing calcium oxide more than 52% within itself occupies only about 12% of them. Therefore security and effective development of limestone is promptly necessary. The best solution is manufacture of precipitated calcium carbonate (PCC). Synthesis of PCC using high-CaO, limestone makes a large profit such as efficient development of resources and curtailment of import dependence on PCC. The first step for this is selection of suitable limestone to synthesis of PCC. So in this study we decide on formation age to the first key point and investigate the effect of formation age on calcination, hydration and synthesis of aragonite. As a result, the yield of aragonite increases when more present limestone is used. The other side, activity and bulk density of quicklime or particle size of aragonite is not affected by formation age. But they have special value following each formation age. Also bulk density of quicklime and particle size of aragonite tends to increase with decrease of activity. This result is opposite to other experimentations. So suitable method for measuring activity of quicklime that will be used to manufacture of PCC is must established.

The Effect of Hydration Condition on Synthesis Characteristic of Aragonite Precipitated Calcium Carbonate: Jung-Ah Kim; Ji-Whan Ahn; Jeong-Hwan Kim; ‘Korea Institute of Geoscience and Mineral Resources

Precipitated Calcium Carbonate (PCC) is obtained by calcination, hydration and carbonation. So the change of each process condition decides particle size or morphology of PCC. Until now, studies about precipitated calcium carbonate have mainly focus on process manufacturing aimed matter, synthesis, The other side finding studies about calcination or hydration is so difficult. Therefore in this study, we investigate the effect of hydration condition on synthesis characteristics of aragonite PCC. Particle size of calcium hydroxide changes with variation of initial temperature of hydration. The higher initial temperature, the bigger particle size of calcium hydroxide used at synthesis. And particle size and yield of aragonite increase, when calcium hydroxide made at high temperature is used. But water/solid ratio or the total amount at the hydration time has no effect on manufacturing process of aragonite.

Production of Rare Earth Ferrosilicide Alloy: Yavuz Ali Topkaya; Ahmet Geveci; Ogulcan Turgay; ‘METU

Rare earth ferrosilicide is a versatile alloy mainly used to control the detrimental effects of sulfur in steel and to modify graphite structures in cast iron. The aim of this study was to determine the optimum conditions to make rare earth ferrosilicon alloy using a preconcentrate produced from a bastnaesite type of ore present in the Belyakhir-Eskilchir region of Turkey. This concentrate contained 23.5%REO; 41.37% CaF2; 10.69% BaSO4, 8.50% CaCO3, 4.18%Fe2O3, 2.83%Al2O3, 2.74% SiO2, 1.20% P2O5 and 5.25% Fe and 20-40% Si, with about 90% metal recovery.
Technical Program

11:10 AM Processes and Production of Sodium Pyroantimonite in China: Tianzuo Yang; Zhao-Feng Xie; Ming-Xi Jiang; Wei-Feng Liu; 'Central South University

Sodium pyroantimonite has a production history of 30 years in China. In this work, the production processes adopted in China, the operation conditions and the product qualities of Sodium pyroantimonite prepared by different preparation methods have been summarized and on the basis of comparing of the advantages and disadvantages for each process, the most advanced method-the air-oxidation method was introduced in detail. The production processes of sodium pyroantimonite mainly include the oxidation method of sodium nitrate, the oxidation method of oxydol, the potash salt method, and the air-oxidation method etc. The sodium nitrate oxidation method has the advantage of short and simple technological process. However low quality of sodium pyroantimonite and bringing about serious environmental pollution are the disadvantages and this method has been substituted by other methods. Sodium pyroantimonite can be directly prepared by the oxydol oxidation with the advantages of simple technological process, high grade quality of the product and little environmental pollution. High quality of sodium pyroantimonite can be also synthesized by the potash salt method, in which industrial antimony white, the oxydol, potassium hydroxide and sodium hydroxide are applied as the starting material. The disadvantages of the above two methods are high production cost and high requirements on the raw materials. The air-oxidation method with sodium hydroxide, stibinite/jameisonite, sodium sulfide, and sodium hydroxide as the raw material and air as the oxidant is a newly developed method and its advantages are low production cost and the complex raw material can be treated by this method.

Thermo and Physicochemical Principles: Alloys and Refining Processes

Thursday AM Room: Russeau West August 31, 2006 Location: Catamaran Resort Hotel

8:00 AM Keynote Thermal Properties of Bulk Glassy Alloys: Yoshihisa Waseda; Hiroyuki Shibata; Hiroichi Ohta; 'IMRAM, Tohoku University; 'Ibaraki University

Zr-based and Pd-based glassy alloys with particular composition, such as Zr75Al20Ni5 and Pd70Cu30P5 are well known to exhibit glass transition with a wide supercooled liquid region. The extremely high level of thermal stability of supercooled liquid state enables the production of bulk amorphous alloys. These bulk amorphous alloys allow us to investigate thermal properties and electrical resistivity of these alloys. The main purpose of this work is to determine values of thermal diffusivity (\(\alpha\)), electrical resistivity, specific heat (Cp) and thermal conductivity (\(\lambda\)) of Zr-based and Pd-based glassy alloys. Moreover, the glass-forming ability of these alloys was discussed on the basis of the obtained values. The thermal diffusivity values of the alloys were measured with a laser flash technique. The electrical resistivity of the alloys was measured by a direct current four probe technique. The specific heat of the alloys was measured by the heat flux type differential scanning calorimeter with a triple cell system. The thermal conductivity was determined from \(\lambda=\alpha Cp\). The thermal diffusivity values of the three alloys in the liquid state are summarized in the linear equations with positive temperature dependency. The lower the thermal diffusivity values of Zr-based and Pd-based alloys at liquidus temperature, the lower the critical cooling rate to obtain amorphous alloy becomes. Thermal properties and electrical resistivity of the alloys are systematically determined. The obtained values are valuable to discuss the glass-forming ability of Zr-based and Pd-based alloys.

8:25 AM The Calculation of Thermodynamical Properties and Phase Diagrams of Binary Alloys on the Basis of Chrome: M. I. Zinin; K. Yu. Shunyaev; 'College of Judea and Samaria; 'Ural’s Division of Russian Academy of Sciences

A model of an ideal associated solution is presented. This model takes into account the existence of complexes of various compositions, sizes and geometries and allows calculating thermodynamic properties and phase diagrams of binary alloys. This model has been used formerly to calculate thermodynamic parameters and the position of the liquidus line for binary eutectic systems and also those having a stable compound in the solid phase. In all the cases the model parameters were not adjusted rather estimated from melting temperatures of the components. The recent studies dealt with the influence of arbitrary-stoichiometry associates on the equilibrium thermodynamical properties of liquid alloys. The application of the model to eutectic systems and systems having an unlimited solubility in solid and liquid states close to liquidus has been considered. It was shown that if the difference in melting temperatures of the components was small, different types of fusibility diagrams were possible: eutectic diagrams, eutrigonal diagrams or diagrams with upper or lower azotrop points. Peritectic transformations could take place when the difference in melting temperatures of the components was large. The present work is devoted to calculation of phase diagrams and thermodynamic properties of binary systems on the basis of chrome.

8:50 AM Technology for Production of Aluminum Alloys: Andrey V. Tarasov; V. P. Shamshiev; 'Gintsvetmet; 'Kandalaksha Aluminum Smelter

An extensive range of aluminum-base alloys is produced, which feature low density (up to 2.8 g/cm³), high corrosion resistance, thermal and electric conductivity, heat resistance, strength and plasticity at low temperatures, as well as good light-reflecting properties. Aluminum alloys can contain along with aluminum as base metal also one or more of the five main alloying metals, i.e. copper, silicon, magnesium, zinc and manganese, as well as iron, chromium, titanium, nickel, cobalt, silver, lithium, vanadium, zirconium, tin, lead, cadmium, bismuth, etc. Alloying components are dissolved in liquid aluminum completely at sufficiently high temperatures. Casting aluminum alloys are used for manufacture of shaped castings. It is possible to use for this purpose both primary alloys manufactured by alloying of pure aluminum or standard-type secondary alloys manufactured from aluminum scrap. In some special cases castings of pure aluminum are also manufactured, primarily for chemical and food industries and electrical applications. In many industrial countries the proportion of casting aluminum alloys made of secondary raw materials is as high as 85% to 90%. Different types of units are used for smelting secondary aluminum raw materials.

9:15 AM Keynote B Removal in the Solidification Refining of Si with Si-Al Melt: Takeshi Yoshikawa; Kentaro Arimura; Kazuki Morita; 'University of Tokyo

Recently, the amount of solar cell production, especially that of poly-Si, increases significantly with a growing demand for clean energy. Solar grade silicon (SOG-Si), however, would be short of supply because of its dependence on a semiconductor industry. The development of an innovative low-cost mass production system for poly-Si is strongly needed, and the authors have been trying to develop the low temperature silicon refining process, “solidification refining of silicon with Si-Al melts at 1173 – 1273K” by taking advantage of thermodynamic instability of impurity elements at lower temperature. In the metallurgical refining of Si, the effective removal of B is a crucial matter. The difficulty in B removal is caused by its large segregation coefficient and its low vapor pressure in Si. In this work, we have investigated the B removal in the above-mentioned refining using the segregation effect and also the Ti adding effect. Segregation ratio of B between solid Si and Si-Al melt was measured by the temperature gradient zone melting technique and it indicated the B removal fraction would be as much as 90%. Ti addition to the melt was found to produce the TiB2 precipitation with soluble B and bring the effective B removal to its content of 1ppm.
High temperature aluminum alloy 8009 is rapidly solidified powder metallurgy aluminum-iron-vanadium-silicon alloy. This alloy in combination with hard oxide aluminum film has unique engineering properties which may recommend its use in compressors and impellers for aerospace applications.

Various anodizing processes (including Low Voltage DC+AC) for these tasks will be evaluated and normal chemical composition, physical properties, and macrostructures of 8XXX aluminum alloys will be presented.

10:20 AM
The Physical and Mathematical Model of Aluminum Refining Process in Reactor URO – 200: Mariola Saternus1; Jan Botor1; ‘Silesian University of Technology

In the metallurgy, quality of the liquid metal has the biggest influence on the quality of the final products. In the metallurgical industry, especially in aluminum production the refining process is an important technological stage. Today the most popular are refining reactors with impellers such as URO – 200, which can generate small gas bubbles. A rotary impeller makes the metal bath stirred well. There are two basic hydrodynamics parameters: the flow rate of refining gas and the mixing of refining gas (impeller rotation) that influence the generation of small gas bubble and their dispersion in metal. The paper presents the influence of the flow rate of refining gas on the hydrogen removal process from aluminium. The refining process of AlSi7Mg alloy with the use of URO – 200 is taken into account. The mathematical model of this process is presented. The equation needed for calculation of the final hydrogen concentration as a function of the equivalent bubble diameter and optimal refining time are done. This paper presents the physical model (the water one) of aluminium refining process and the gas dispersion. It should be noted that the gas flow rate is changing from 2.5 to 17.5 l/min and the impeller speed is changing from 0 to 400 rpm. Schemes of gas dispersion in liquid metal were compared with the model data.

10:45 AM
Using General Regular Solution Model to Obtain Analytic Express of Solution Excess Properties from the Ternary Alloy System: Tang Xiaoning1; Xie Gang1; ‘Kunming University of Science and Technology

A general regular solution model put forward in this paper defines a general interaction parameter that includes both composition and temperature dependence. On the basis of this model, analytic express of solution excess properties was obtained by least square fit using the composition and temperature relations in binary alloy phase diagram. After some solution excess properties analytic expresses of correlated binary alloy system obtained, the analytic express of ternary alloy system could be obtained by superposition of general geometrical model. The ternary alloy system Pb-Sn-Zn has been predicted in terms of this method and the result was very in agreement with actual measured value.

11:10 AM
The Importance of Coal and Coke Properties in the Production of High Silicon Alloys: Viktor Myrvenges1; Tor Lindstad1; ‘Norwegian University of Science and Technology

In the production of high silicon alloys utilization of carbonaceous materials like coal, coke, charcoal and woodchips are taking place. Primarily based on historical prices of charcoal compared to fossil reduction materials, the Norwegian Ferro alloy industry has been using mostly coal and coke as carbon source. The most important role of the carbonaceous material is to react with the SiO gas to produce SiC. The ability of the reduction materials to bind SiO gas can be measured and the value is recognized as the reactivity of the carbon source. This reactivity is one of the most important parameters in the smelting process in order to obtain a high yield of metal. The reactivity of the carbon materials is directly correlated to the material properties. In the present work three single seam unashed coals of different origin are investigated. It is known that the rank of the coal influences the SiO reactivity where low rank is beneficial. Coals of the same rank have however proven to have varying reactivity. In this article the microstructure of the coals and physical properties of the carbonized product are investigated and correlated with the measured reactivity. The reactivity measurements are carried out using the SINTEF SiO reactivity method and thermo-gravimetric apparatus with cubes of different sizes. Effective diffusivities, DE, and reaction rate constants, kc, were calculated from the experimental data.

Thermo and Physicochemical Principles: Experimental Measurements and Techniques

Thursday AM Room: Russeau East
August 31, 2006 Location: Catamaran Resort Hotel

8:00 AM
Distribution of Precious Metals (Au, Pt, Pd, Rh and Ru) between Copper Matte and Iron- Silicate Slag at 1573 K: Hector Mario Henao Zapata1; Katsunori Yamaguhi2; Shigeru Ueda3; ‘Tohoku University; ‘Iwate University

There is an increasing trend in the copper smelters to recycle electronic materials which contain relatively high concentration of precious metals. As a consequence, the amount of precious metals lost in the slag phase is increasing. To determine the portion of the precious metals chemically dissolved and that associated with the mechanically trapped matte in the slag will be a key factor to improve the recovery of those metals. Thus, an experimental study was carried out to determine the distribution of precious metals (Au, Pt, Pd, Rh, Ru) between the equilibrated copper matte and iron-silicate slag phases. The experiments were made in a magnesia crucible at 1573 K and a fixed partial pressure of SO2 of 0.1 atm for the matte grades between 40 and 70 mass% of copper. It was found that the distribution ratios (defined as mass% X in slag/mass% X in matte, where X represents the precious metal) are around 102 for Ru, 104 for Au, Pt and Pd and 105 for Rh. The distribution ratios show a tendency to increase when the grade of matte is increased. These results are compared with those obtained in a practical operation in the industry.

8:25 AM
Effect of Al2O3 or MgO Addition on Liquidus of FeO3-CaO Slag at 1250 and 1300°C: Hector Mario Henao Zapata1; Hiroyuki Ohno1; Kimio Itagaki1; ‘Tohoku University

The FeO3-CaO-CaO base slag at intermediate oxygen partial pressures is very often used in non-ferrous melting processes. This slag would also contain Al2O3 and MgO because these compounds are normal components in the ore and the refractory of a furnace. The objective of the present work is to determine the effect of Al2O3 or MgO addition on the liquidus temperatures of the plain FeO3-CaO-CaO slags in the atmosphere between intermediate pO2 of 105 and that of iron saturation at 1250 and 1300°C. The experiments were carried out at given mass%CaO/mass%SiO2 ratios of 1, 0.5 and at spinel-tridimite double saturation. The experimental results show that the effect of Al2O3 or MgO addition on the plain FeO3-CaO-CaO slag is not uniform and depends on the content of Al2O3 or MgO, the oxygen partial pressure and the mass%CaO/mass%SiO2 ratio. It is apparent that Al2O3 addition enlarges the spinel saturation area, but reduces the FeO3 saturation area when the crystal precipitated is wustite. MgO addition to the plain slag enlarges the spinel or wustite saturation area at all the oxygen partial pressures. The obtained phase diagrams will be useful in the metallurgical industry to assist in the selection of slag chemistry, operation condition and development of new processes.
Technical Program

8:50 AM  Thermoanalytical Study on the Oxidation of Sulfide Minerals at High Temperatures: Manuel Perez-Tello; Silvia Eugenia Perez-Fontes; Lizbeth Ofelia Prieto-Lopez; Francisco Brown; Felipe Castillon-Barraza; University of Sonora; Universidad Nacional Autonoma de Mexico

An experimental study on the oxidation of chalcocite (CuFeS2), pyrite (FeS2), chalcopyrite (CuFeS2) and covellite (CuS) particles was conducted by means of differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA) techniques. Oxygen concentration in the process gas was set to 40 and 70% by vol. and a heating rate of 40 C/min was used. Response variables included: the temperature of incipient reaction, the total exothermic heat of reaction, particle mass, morphology, and mineralogy of the reacted particles. Based on the experimental data and phase stability calculations, reaction mechanisms were proposed to represent the behavior of the particles during oxidation. The reactions mechanisms were verified by X-ray diffraction analyses of the oxidized particles, and by thermochemical and mass balance calculations to reproduce the DSC and TGA thermograms. Overall kinetic models were developed to represent the evolution of the exothermic heat of reaction for each mineral as a function of time. Experiments conducted with copper concentrate particles containing the minerals studied suggest that the reaction mechanisms for the individual minerals can be used to represent the oxidation behavior of the copper concentrate particles.

9:15 AM  Phase Relations and Activity of Iron Oxide in the FeO_CaO-SiO2 System at 1300-1400°C under Various Partial Pressures of Oxygen: Hector Mario Henao Zapata; Kimio Itagaki; Tohoku University

To provide the thermochemical data regarding the slag system, which are of importance for sulfide smelting and metallurgical processes but still lacking, an experimental study was carried out on the phase relations and activity of iron oxide in the FeO_CaO-SiO2 system at temperatures between 1300 and 1400°C and partial pressures of oxygen between 10^-1 and 10^3 atm. First, the solubility of CaO and SiO2 in the solid FeO were obtained and the tie lines connecting between the solid wustite (FeO) or magnetite (Fe3O4) and the liquid phase were determined. Secondly, iso-activity lines for FeO in the homogeneous liquid region were determined, based on the activity of iron in the Fe-Cr-cylindus in the equilibrium experiments. The activity coefficient of FeO in this region was also derived from the composition of the system and partial pressure of oxygen on these thermochemical quantities is discussed.

10:20 AM  Equilibrium Distribution of Selenium and Tellurium between Calcium Ferrite Slag and Alloys: Murray Johnston; Sharif Jahanshahi; Frank Lincoln; CSIRO Minerals; University of Western Australia

New measurements have been made on the equilibrium distribution coefficients of selenium and tellurium between slag and metal phases. The distribution of Se and Te was measured at temperatures between 1200 and 1400 °C, under controlled oxygen partial pressures (pO2) of 10^-11 to 10^-4 atm (air), in magnesia-saturated calcium ferrite slag and copper or silver alloys. The results demonstrate that up to pO2 of 10^-atm both minor elements exist in calcium ferrite slag in the –2 oxidation state. As conditions become more oxidising, Te undergoes a transition to the divalent oxide whereas Se does not. Increasing the temperature was found to enhance partitioning of the minor elements to the slag. The effect of slag composition was studied by conducting distribution experiments in Ca-ferrite slags of varying CaO content. It was found that increasing the lime content of the slag also enhanced partitioning of these elements to the slag phase, more significantly in the case of Se. Minor element capacities determined from the experimental results showed the Ca-ferrite slag to have a much greater holding capacity for Se than Te. In terms of activities, Se showed strong negative deviation from the ideal, while Te showed only slight positive deviation.

10:45 AM  Liquidus Temperatures in Calcium Ferrite Slags Equilibrated with Molten Copper at Fixed Oxygen Partial Pressures: Stanko Nikolic; Eugene Jak; Peter Charles Hayes; University of Queensland

Calcium ferrite slags are currently used in a number of copper-converting processes. Despite the industrial importance of this system the phase equilibria have not been fully investigated. Characterisation of this slag system is necessary to improve the control of process parameters, including fluxing and operating temperatures. Recently, a modified experimental method has been developed; this involves the rapid quenching of slag samples equilibrated at high temperatures with the resulting phase assemblages analysed using electron probe microanalysis (EPMA). In the present study experiments were completed under controlled temperatures and oxygen partial pressures. The investigated slags were supported during equilibration by a substrate of the primary phase field. This technique removes the limitations arising from the use of crucibles and facilitates rapid quenching of the melt. Samples were equilibrated at fixed oxygen partial pressures using CO/CO2 or H2/CO2 gas mixtures. The experiments were carried out at 1200°C and 1250°C (1473 K and 1523 K) and in the composition range 0-80 wt.% CuO, 0-25 wt.% CaO and 0-60 wt.% FeO. Liquidus and solidus data are reported for primary phase fields of spinel, lime, and dicalcium ferrite. The analysed compositions of liquids and solids are used to construct the phase diagram of CaO–FeO–CuO system in equilibria with metallic copper at fixed oxygen partial pressures.

11:10 AM  Measurement of the Physical Property of FenO-MgO-CaO-SiO2 System: Xi Dui; Chunfui Zhang; Honghui Tang; Central South University

In present work, the physical properties of molten FenO-MgO-CaO-SiO2 slags were measured. It is shown by the results that when the slag composition is as follows: MgO 8%-12%, CaO 2%-8%, FeSiO2 1.2-1.6, the viscosity of the slags decreases with the increase of temperature. When the FeSiO2 ratio and the MgO content are fixed, the melting temperature and viscosity decrease as CaO content increases, while the content of CaO exceeds 6%, its influence to viscosity weakens. When the MgO content is 11% and the CaO is 6%, the viscosity of the slag decreases markedly as the increase of Fe/SiO2 ratio. Its influence to viscosity is inconspicuous when the Fe/SiO2 ratio exceeds 1.5. The viscosity of slag will increases for the melting temperature of slag rises significantly as the content of Fe3O4 increases. The electrical conductivity rises when temperature increases at any slag content. When the CaO content is 6% and FeSiO2 is 1.2, with the increasing of MgO content, the electrical conductivity decreases as temperature is below 1290°C, but increases when temperature is above 1290°C. When the MgO content is 11% and the FeSiO2 ratio is 1.2, the electrical conductivity decreases with the increase of CaO content. When the CaO content is 6% and MgO content is 11%, the electrical conductivity increases as the of Fe/SiO2 ratio increases, while its influence weakens as the temperature increases continuously. The melting temperatures of molten FenO-MgO-CaO-SiO2 slags is below 1290°C at any slag content.
The Effect of Carbon Material Properties on the Reduction Kinetics of Manganese and Silicon from Slag to Metal: Gabriella M. Tranell; Sebn G. Gaal; Dechan Lou; Jaafar Safarrian; Leiv Kolbeinsen; Merete Tangstad; SINTEF Materials and Chemistry; Norwegian University of Science and Technology

In the manganese ferroalloys industry, there is increasing focus on the performance of different carbonaceous materials within the smelting processes. With a developing scarcity of traditional raw materials, new carbon sources are being identified for potential use in the processes. For this purpose, it is important to be able to predict the suitability of different materials in the process. Hence, the effects of both the physical and chemical properties of the carbon material on the reduction kinetics of manganese and silicon from slag to metal have been investigated using an advanced kinetic experimental series. Using this technique, the reaction patterns of SiO2-MnO containing slag droplets in contact with various solid carbon materials (graphites with different properties as well as coals and charcoal) at 1400 to 1600°C were studied in-situ. In addition, slag and metal reaction products from kinetic experimental series were analysed. From these results, differences in reactivity between various carbon materials and slags were demonstrated and explained. Mechanisms for both manganese and silicon reduction were proposed.

The Importance of the Slag Phase in Electric Smelting of PGM Containing Sulfide Concentrates: Hurman Eric; University of the Witwatersrand

In this review paper the effect of composition and temperature on electrical conductivity and viscosity of the slags encountered in ferromanganese smelting have been determined as a function of composition at 1500°C. The distribution results were employed to calculate the phosphorus capacities of the SiO2-Al2O3-CaO-MgO-MnO slags in equilibrium with the Mn-Fe-Si-C metal phase. The classical gas-slag-metal equilibrium-queenching technique was employed using CO gas atmosphere and graphite crucibles to saturate the metal phase with respect to carbon. The phosphorus distribution ratio increased from 0.045 to 0.375 when the slag basicity increased from 0.63 to 1.16. As expected, the distribution ratio decreased from 0.4 to 0.105 when silica increased from 37.4% to 45.8% in the slag phase. Empirical relationships are being developed to express the phosphorus distribution ratios and phosphide capacities of the above slags.

The flow of slag is discussed together with furnace geometry, stirring action, buoyancy and electromagnetic effects. The action of the electric furnace as a settler is emphasized. A discussion on the design and production capacity of the furnace is provided which are based on considerations derived mainly from slag properties.

Tracking Chromium Behaviour in Submerged Arc Furnace for Ferrochrome Production: Yanping Xiao; Yongxiang Tang; Lauri Elias K. Holappa; Delft University of Technology; Helsinki University of Technology

In submerged-arc furnace for smelting chromium ores into ferrochrome, there exist large temperature gradients and wide distributions of mineralogy and compositions in the furnace, due to the complexity of feed structure and electrical-thermal-chemical interactions. This leads to various zones in the furnace and thus different reaction mechanisms. In the present paper, the behaviour of chromium in the submerged arc furnace is discussed in steps in various reaction zones of the production process, including chromite reduction with CO in solid state, structural changes of partially reduced chromite in the smelting zone and recovering chromium from slag to metal. In the gas-solid reaction zone, the reaction kinetics is presented and compared for both lump and pellet reduction. The reduction mechanism is discussed based on the experimental observations and analysis. In the smelting zone, the behaviour of partially reduced chromite is examined, and slag formation is addressed. The slag in FeCr process contains mainly Al2O3, MgO, SiO2, CaO and Cr2O3, featured by chromium with both divalent and trivalent oxidation state. The role of slag for chromium recovery is very important, and thus the relevant thermodynamic properties of FeCr slag are summarized. In addition, the factors influencing the slag/metal reaction and the chromium recovery are described. A concept of process model is established based on the process fundamentals and experimental data, which is aimed to improve the process understanding and performance.

Selective Separation of Rare Earths from Titaniferous Ores during the Production of High-Grade Synthetic Rutile: Jeya Kumari; Animesh Jha; University of Leeds

The demand for titania pigments and the shortage of higher-grade titaniferous ores worldwide has encouraged new techniques for the beneficiation of lesser grade titaniferous ores. The presence of zircon and monazite in ore also increase the chlorine gas consumption in FBCR (Fluidised bed chlorine reactor) and contribute to a larger volume of hazardous waste, which must be neutralised before being disposed off. In view of the problems described for lanthanide and actinide trace impurities in titaniferous ores, an alternative route, for processing difficult ores, is discussed. In the new process, the ore is roasted with sodium carbonate below 950°C to promote the formation of water soluble ferric and insoluble sodium titanate phases. In this investigation, the roasting process and the ensuing hydrometallurgical leaching steps have been analysed in context of selective separation of lanthanide and actinide minerals from the main minerals. Evidences for the selective separation are presented based on the chemical (XRD, XRF) and microstructural analysis (SEM, EDX, EPMA) of roasted mass and the leached product. The paper highlights the various thermodynamic aspects of reaction equilibrium in the Fe-Ti-O-Na system, and the effect of Eh-pH diagram in the determination of pH required for the better removal of iron and sodium. Two different types of Ti ores, namely ilmenite and anatase, their crystal structure and the phase transformation will also be explained on the basis of wet chemical analysis, XRF, XRD, EPMA and SEM-EDX studies. The method developed examines the technological feasibility of the selective separation process.

Reduction Behaviour of Chromite in the Presence of a Hydrocarbon Gas: Maria de Campos; Hurman Eric; Hatch South Africa; University of the Witwatersrand

The pre-reduction behaviour of chromite particles in methane-argon and methane-hydrogen gas mixtures was investigated between 1050°C
and 1250°C. Loose bed of chromite particles were reacted in a vertical tube furnace under a pre-set gas mixture for predetermined time intervals. Metallisation results were obtained for the Cr and Fe components by chemically analysing the reaction products. SEM-EDAX techniques and X-ray diffraction were employed to elucidate the reduction mechanism. It was found that higher reduction kinetics and higher Cr:Fe ratios in the metal phase could be achieved when hydrocarbon gas was used in comparison to classical carbothermic reduction at a given temperature. The reduction rate was generally bulk gas mass transfer controlled to the reaction site for initial stages which then was followed by ionic diffusion rate control. It is proposed that methane did not partake directly in the reduction but cracked, presenting the reaction site with hydrogen gas and atomic carbon, which was able to immediately react at the immediate area of reduction regenerating CO and H₂ and thus maintaining a low partial pressure of oxygen at the reaction site.

10:45 AM
Prereduction of Chromite Agglomerates: Serdar Kucukkaragoz; Harman Eric; University of the Witwatersrand
The kinetics of pre-reduction of chromite by carbon was studied under argon atmosphere at temperatures between 1000°C and 1300°C. The compacted and agglomerated specimens were reacted by using a TGA system. The mixing characteristics and the degree of compaction of the chromite and coke particles were the main parameters influencing the reduction kinetics. The reduction rate increased with temperature reaching 81% reduction at 1300°C. Metallization started around chromite particles at 1100°C. The particles were surrounded by the metallic phase at approximately 40% reduction level obtained at 1200°C. At 1300°C, the reduction proceeded with a high rate during initial stages and with a low rate at final stages. The reduction was found to proceed in the sequence of Fe²⁺ to Fe⁰ to metallic Fe and Cr⁶⁺ to metallic Cr with the formation of carbides.

11:10 AM
Carbothermic and Magnesiothermic Reduction of Titanium Dioxide - A Thermodynamic Analysis: Donabandhu Gosh; Jadavpur University
The stability diagram of the ternary system Ti-C-O is drawn in the present work for four temperatures, 1473 K, 1573 K, 1673 K and 1873 K, showing the stability fields of TiC, Ti, TiO, Ti₃O₅ and TiO₂. An analysis of the system reveals that it is not possible to produce Ti in a carbon-saturated system; instead, the stable product is TiC. However, Ti can be an equilibrium product in a carbon-unsaturated system at prohibitively low values of p₂C, and pO₂; for example, at 1873 K, these limiting values are: p₂C = 10⁻⁶ atm and pO₂ = 10⁻¹⁵ atm, which, when exceeded, produce TiC and TiO₂ respectively. The magnesiothermic reduction is examined through the stability diagram (log p₂C vs. 1/T) of the system Ti-Mg-O, drawn for a number of P,MgO values, presenting the pairwise stability fields such as Mg(l) + Ti(s), MgO(s) + Ti(s), etc. The diagram shows that magnesiothermic reduction of TiO₂ to Ti is possible only at T < 1641 K with p,MgO = 1 atm and only at T < 1569 K with p,MgO = 0.5 atm. An experimental scheme for Mg vapor reduction of TiO₂ is proposed in which an argon stream is passed over a Mg(l) evaporator at temperature T₁ (say, 1234 K); the resulting Ar-Mg mixture at 1 atm is subsequently blown over a bed of TiO₂ at temperature T₂. A thermodynamic analysis establishes that complete reduction to Ti is possible and that the best results are obtained when T₁ = T₂.

8:00 AM  Keynote
Experiences in Physicochemical Modelling of Oxygen Converter Process (BOF): Heikki Kusti Jalkanen; Helsinki University of Technology
BOF is a highly complex metallurgical process comprising a number of simultaneous chemical reactions proceeding in several reaction environments in connection with complicated heat and mass transport procedure in the reactor. It is obvious that even a simplified model describing the chemical and thermal progress of the process requires combination of thermodynamic and mass transfer phenomena. The basic characteristics of the process to be taken in to account in simulation of BOF are: 1) Thermodynamic affinities of oxidation reactions control the oxygen distribution between oxidising elements; 2) Intensity of agitation in the iron bath controls the concentration of impurity elements at superficial regions of iron bath where the primary oxidation reactions proceed; 3) Heat from highly exothermic oxidation reactions is consumed in heating up the fluid phases in the reactor, heating up and melting the solid charge and lost by radiation and conduction during and between the blow. Oxygen converter simulator CONSIM-5 simulates the chemical and thermal evolution of the process on the base of the above mentioned three groups of phenomena combined with parameters assessed against or obtained from actual BOF practice. Simulation program basic chemical reaction and mass transfer models and several submodels for “secondary” phenomena taking place during a blow. The basic chemical, thermal and transport phenomena and problems involved in the simulation of BOF-process is analysed and discussed independently as well as in connection with experience from simulation of actual converter blow using CONSIM-simulator.

8:25 AM
Reduction Behavior of BOF Slag: Sung-Mo Jung; Young-Ju Do; Pohang University of Science and Technology
In the first part of this research, experiments were carried out on a system with artificially prepared slags in a graphite crucible, in order to examine the possibility of recycling BOF slags produced in the steelmaking process. More than 80% of FeO and P₂O₅ was reduced within 20 minutes and the FeO reduction rate was greater than that of P₂O₅. Reduction began after more than 60% of FeO was reduced. Increasing slag basicity enhanced the reduction of FeO and P₂O₅. Temperature also improved slag reduction. The overall reduction rate was controlled by the chemical reaction at the slag/carbon interface. The reduction rates of FeO and P₂O₅ were second and first order with respect to their respective contents. Most of the reduced phosphorous is believed to vaporize in the form of P₂ gas. In the second part of this work, BOF slag was reduced by dissolved carbon in iron for examining its smelting reduction. The reduction reactions of FeO and P₂O₅ proceed steadily and the reaction rate of FeO was almost similar to that of P₂O₅. P₂O₅ reduction began after more than 60% of FeO was reduced. Increasing slag basicity enhanced the reduction of FeO and P₂O₅. Temperature also improved slag reduction. The overall reduction rate was controlled by the chemical reaction at the slag/carbon interface. The reduction rates of FeO and P₂O₅ were second and first order with respect to their respective contents. Most of the reduced phosphorous is believed to vaporize in the form of P₂ gas. In the second part of this work, BOF slag was reduced by dissolved carbon in iron for examining its smelting reduction. The reduction reactions of FeO and P₂O₅ proceed steadily and the reaction rate of FeO was almost similar to that of P₂O₅. P₂O₅ reduction began after more than 60% of FeO was reduced. Increasing slag basicity enhanced the reduction of FeO and P₂O₅. Temperature also improved slag reduction. The overall reduction rate was controlled by the chemical reaction at the slag/carbon interface. The reduction rates of FeO and P₂O₅ were second and first order with respect to their respective contents.
CO Bubble Bursting and Splash and the Subsequent Generation of Electric Arc Furnace (EAF) Dust: Bahador Abdedi Tari; Andrew Kykho; Neil Gray; 1University of Melbourne

The use of electric arc furnaces (EAFs) in steelmaking has increased dramatically over the past twenty years due to the widespread availability of recycled metal scrap. There are environmental concerns associated with the use of EAFs such as hazardous dust and fume emissions given that 15-25 kg of hazardous dust is generated for every tonne of steel produced. The generation mechanisms of EAF dust have not been extensively researched and thus are not very well understood. This project is investigating the generation of EAF dust as a result of bursting of CO bubbles, resulting from decarburization processes, on the melt surface and the subsequent ejection and carry-over of metal/slag droplets. This has been identified as the prevalent dust generation mechanism in EAFs as well as in steelmaking converters such as BOFs. The bubble bursting phenomena has been predominantly studied in low temperature and single phase systems. This project entails carrying out both low and high temperature single bubble bursting experiments to determine the similarities between the two systems, ascertain the effects of bath properties such as viscosity and surface tension on the dynamics of the bubble bursting phenomena and the subsequent splash and identify the critical bubble size which produces the maximum number of ejections.

9:40 AM Break

9:55 AM

Physical Modeling of a RH Degasser to Study Decarburization Rate: Roberto P. Tavares; Tiago J. P. Belarmino; Alysson T. P. Almeida; Jairo A. Alvarenga; 1Federal University of Minas Gerais

Steels with low concentrations of nitrogen, hydrogen and carbon have in large demand lately. The RH process is a secondary refining process that can simultaneously attain significant levels of removal of these interstitial elements from liquid steel. In the RH process, the melt circulation rate plays a very important role in determining the productivity of the equipment, since it affects the decarburization rate. In the present work, a physical model of a RH degasser in a 1:5 scale of an industrial reactor has been built and used in the study of the circulation rate and of the kinetics of decarburization. The effects of the following parameters have been analyzed: -gas flow rate; -configurations of the nozzles used in the injection of the gas. Different number, diameter and location of the nozzles have been tested in the experiments; -diameters of the upleg and downleg snorkels. The decarburization reaction of liquid steel was simulated using a reaction involving CO2 and caustic solutions. The concentration of CO2 in the solution was evaluated using pH measurements. The experimental results indicated that the kinetics of decarburization can be described by a first order equation. Based on the results, it was possible to determine the contributions of the decarburizations in the upleg and in the vacuum vessel.

10:20 AM

Design of Steel for High Speed Machining: Mani Subramanian; 1McMaster University

The tooling for high speed machining is well advanced but the steel design for high speed machining has lagged behind. The paper examines the design of steel in order to control the sliding tribology for high speed machining under dry machining conditions. In high speed machining of steel, accelerated chemical wear of the tool occurs once atomic contact is established at the tool-chip interface, resulting in poor tool life even with high performance tools such as cubic boron nitride. Recent research has confirmed the occurrence of nanocrystalline grains in the interfacial layer of the chip at the tool-chip contact. The volume percentage of grain boundary is increased significantly (10 to 30%) as the nanocrystalline grain size is decreased well below 30 nm. The solubility of tool material into the nanocrystalline grain boundary is two or three orders of magnitude greater than in the crystalline lattice. Further the kinetics of diffusion in the grain boundary is seven or eight orders of magnitude greater than in the crystalline lattice. The accelerated chemical wear is caused by enhanced nanocrystalline grain boundary diffusion occurring in the interfacial layer at the tool-chip contact. Significant improvement in tool life could be achieved in machining of steel by engineering glassy oxide inclusions designed to self-lubricate the tool-chip interface in-situ at higher cutting speeds. Thus the control of sliding tribological conditions at the tool-chip interface is key to suppress nanocrystalline layer formation at the tool-chip contact and hence prevent accelerated chemical tool wear.

10:45 AM

Elastic T-Stress Evaluation from FE Analysis for Mode (I) Loading in X52 Arc of Pipe Specimens: M. Hadi Melani; M. Benarous; A. Ghozl; Z. Azari; 1University of Chlef; University of Metz; 2University of Chlef; 3University of Chlef, Detached with the Ministry of Labour Public; 4University of Metz

This paper explores direct use of finite element analysis by CASTEM 2000 in order to determine the evolution of T-stress term for arc of pipe specimens with external surface crack. A simple method, called the stress difference method proposed by Yang (1999), is used to compute the elastic T-stress in mode I at a crack tip. The different crack geometries and length-to-thickness ratio on T-stress and stress-intensity factor (SIF) are examined. The revisited stress difference method is shown to be an accurate and robust scheme for evaluating T-stress in arc of pipe.
Advance Registration Form

August 27-31, 2006
Catamaran Resort
San Diego, California, USA

Advance Registration Deadline: August 7, 2006
Register online, by fax or by mail.

(Forms received past the deadline will be processed at the on-site fee. Payment must accompany form.)

Please print or type:

Salutation □ Dr. □ Prof. □ Mr. □ Mrs. □ Ms.

Last Name ___________________________________ First Name ___________________________ Middle _____________

Employer ___________________________________________________ Job Title _______________________

Address is □ Business □ Home Street/P.O. Box __________________________

City _____________________________________ State/Province __________________________

Zip/Postal Code ___________________________ Country ___________________________________

Telephone ______________________________________ Fax __________________________

E-mail ________________________________________________________________________________

Name of Guest (if applicable) (Guests do not receive admission to technical sessions.) ______________________________________

Registration Fees:

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<td>Student**</td>
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(Students must attach a copy of school identification card.)

*Fee includes technical sessions, exhibit, welcoming and closing receptions, coffee breaks, banquet, and proceedings on CD-ROM.

**Fee includes technical sessions, exhibit, welcoming and closing receptions, and coffee breaks.

Additional Post-Conference Proceedings:
One copy of the proceedings in CD-ROM format is provided to those paying the member, author, or nonmember registration fee. Additional copies of the CD and a two-volume hardcopy version of the proceedings are also available for purchase, plus shipping and handling. Contact TMS to determine shipping and handling charges and to arrange for delivery of books after the symposium. Proceedings will also be available for purchase at the conference.

Additional Copies of Proceedings:

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<tr>
<td>Two-Vol. Hardcopy</td>
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Optional Meal Plan:
Meal plan must be ordered in advance; meals will be served on the Catamaran Resort lawn, beach side.

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<tr>
<td>□ Other (specify)</td>
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TOTAL FEES: $ __________

Payment Options:

☐ Check payable to TMS in U.S. dollars drawn on a U.S. bank
☐ Visa ☐ MasterCard ☐ American Express ☐ Diners Club

Card Number __________________________
Expiration Date _______________________

Cardholder Name (Please print.) __________________________
Cardholder Signature _______________________

Refund Policy:
Written requests for refunds due to cancellations must be received by TMS no later than August 7, 2006. A $75 processing fee is charged for registration cancellations. No refunds are processed after the above deadline.

Questions?
Telephone TMS Meeting Services at (800) 759-4TMS or (724) 776-9000, ext. 243, or e-mail mtgserv@tms.org.
Register before August 7 to save up to $100!
Resort Reservation Form

August 27-31, 2006
Catamaran Resort
San Diego, California, USA

Reservation Deadline: Tuesday, July 25, 2006

Please print or type:

Last Name ______________________________________
First Name _______________________________________________________

Employer __________________________________________________________________________________________________

Street/P.O. Box _____________________________________________________________________________________________

City _________________________________________
State/Province _________________________________________________

Zip/Postal Code _____________________________________
Country _________________________________________________

Telephone ____________________________________________
Fax _________________________________________________

Complete this form and return by mail or fax to:

The Catamaran Resort Hotel
Attention: Reservations Department
3999 Mission Boulevard
San Diego, CA 92109
Fax: (858) 488-8386

Arrival Date ________________________________
Departure Date _______________________________

Please note: check-in time is 4 p.m. Check-out time is noon.

Reservations must be guaranteed by personal check or credit card for the cost of room and tax for one night. Cancellations must be made at least 24 hours prior to arrival to avoid billing for one night.

Symposium rate applies for reservations three days prior to and after the official meeting dates. Requests for reservation dates prior to and after the symposium will be accepted on a space-available basis only.

Payment Options:

☐ Check

Credit Card ☐ Visa ☐ MasterCard

Card Number ____________________________________________ Expiration Date __________________

Cardholder Name (Please print.) ________________________________________________________________

Cardholder Signature ________________________________________________________________

Check one:

☐ Catamaran Resort (symposium headquarters hotel)
☐ Single/Double - $150 ☐ Triple - $170 ☐ Quad - $190

☐ Bahia Hotel (transportation available to Catamaran Resort)
☐ Single/Double - $150 ☐ Triple - $170 ☐ Quad - $190

Room Tax - 10.5%

Special Requests (subject to availability):

________________________________________________________________________________________
________________________________________________________________________________________
________________________________________________________________________________________

Pick one:

☐ Catamaran Resort (symposium headquarters hotel)
☐ Single/Double - $150 ☐ Triple - $170 ☐ Quad - $190

☐ Bahia Hotel (transportation available to Catamaran Resort)
☐ Single/Double - $150 ☐ Triple - $170 ☐ Quad - $190

Room Tax - 10.5%

Please print or type:

Last Name ______________________________________
First Name _______________________________________________________

Employer __________________________________________________________________________________________________

Street/P.O. Box _____________________________________________________________________________________________

City _________________________________________
State/Province _________________________________________________

Zip/Postal Code _____________________________________
Country _________________________________________________

Telephone ____________________________________________
Fax _________________________________________________

Special Requests (subject to availability):

________________________________________________________________________________________
________________________________________________________________________________________
________________________________________________________________________________________

Payment Options:

☐ Check

Credit Card ☐ Visa ☐ MasterCard

Card Number ____________________________________________ Expiration Date __________________

Cardholder Name (Please print.) ________________________________________________________________

Cardholder Signature ________________________________________________________________

www.tms.org/Sohn2006.html
Deadline for resort reservations is July 25.
**Tour Registration Form**

**SOHN International SYMPOSIUM**

on Advanced Processing of Metals and Materials: Principles, Technologies and Industrial Practice

**August 27-31, 2006**

**Catamaran Resort**

San Diego, California, USA

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**Deadline: August 5, 2006**

Payment in U.S. funds must accompany form for processing to be completed.

**FAX**  Fax this form to (619) 275-4012, Attention The Meeting Manager. (Requires credit card payment)

**MAIL**  Mail this form with payment to The Meeting Manager, 2437 Morena Blvd., Suite 300, San Diego, CA 92110

**Please Note:**
1) Tour requests cannot be accepted by phone.
2) A confirmation of your order will be e-mailed to the e-mail address provided on this form.
3) Checks should be made payable to The Meeting Manager.
4) Tour registrations will be reserved under the name of the person listed on this form.
5) This form may be duplicated.
6) Tours will depart promptly from the lobby of the Catamaran Resort.

**Questions?**  Call Zorianna Horn at (619) 275-0181.

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<th>DATE</th>
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<td>Lifestyle La Jolla</td>
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<td>Tuesday, August 29</td>
<td>9 a.m. to 1 p.m.</td>
<td>Coronado Charm</td>
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<td>Wednesday, August 30</td>
<td>9 a.m. to 1 p.m.</td>
<td>Midway Aircraft Carrier</td>
<td>$47</td>
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Add $2 surcharge if paying by credit card.

Total Amount Charged to Credit Card Listed Below

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**Please print legibly below:**

Participant’s Full Name

Telephone ______________________ Fax ______________________ Mobile ______________________

E-mail ______________________

Method of Payment  □ Visa  □ MasterCard  □ American Express

Card Number ______________________ Expiration Date ______________________

Cardholder Name (Please print.) ____________________________________________________________

Cardholder Signature ____________________________________________________________

☐ Please indicate if you need additional assistance to fully participate in the tour program. 
You will be contacted by The Meeting Manager to make arrangements to meet your specific needs.
Tour registration deadline is August 5.
Corporate Sponsorship Form

August 27-31, 2006
Catamaran Resort
San Diego, California, USA

Mail or fax this form with payment to:
TMS, Cindy Wilson
184 Thorn Hill Road
Warrendale, PA 15086-7514
Fax: (724) 776-3770

Date ___________________ Contact Name _________________________________________________________

Company Name ________________________________________________________________________________

Mailing Address _______________________________________________________________________________________

City ______________________________________ State/Province _____________________________________________

Zip/Postal Code ______________________________________ Country _____________________________________________

Telephone ___________________ Fax _________________________

E-mail ___________________________________________________________________________________________

Sponsorship Level: □ Corporate Gold □ Corporate Silver □ Welcoming Reception □ Closing Reception
                                             Payment $__________

Method of Payment:

Credit Card □ Visa □ MasterCard □ American Express
Card Number ___________________________________________ Expiration Date _________________________

Cardholder Name (Please print.) ____________________________________________

Cardholder Signature ________________________________________________________________

If the cardholder’s mailing address is different than the address above, please complete the following:

Mailing Address ________________________________________________________________________________

City ______________________________________ State/Province _____________________________________________

Zip/Postal Code ______________________________________ Country _____________________________________________


□ Wire transfer ordered to:
PNC Bank, NA, Cranberry Township, PA USA
ABA Number 043000096, SWIFT Code: PNCC US33
TMS account number 10 186 207 12
Please reference “Sohn Symposium.”

A letter acknowledging your contribution and benefits to be received will be mailed to you.

Questions? Contact Cindy Wilson at TMS at telephone (724) 776-9000, ext. 231, or e-mail wilson@tms.org.
Secure your sponsorship today by mailing or faxing this form to TMS.

Our Gracious Corporate Sponsors to Date:

- Ausmelt
- Flogen Technologies Inc.
- Korea Institute of Geoscience and Mineral Resources
- Korea Zinc Co. Ltd.
- LS-Nikko Copper
- Outokumpu Technology
- Posco
- Umicore Precious Metals Refining
- Xstrata Technology
Who We Are

The Minerals, Metals & Materials Society (TMS) is the professional organization encompassing the entire range of materials in science and engineering, from minerals processing and primary metals production to basic research and the advanced applications of materials. The Society’s broad technical focus covers light metals; electronic, magnetic and photonic materials; extraction and processing; structural materials; and materials processing and manufacturing.

Our Members

Included among TMS professional members are metallurgical and materials engineers, scientists, researchers, educators and administrators who work in industry, government and academia, as well as students. They hail from more than 70 countries on six continents.

Our Mission

The mission of TMS is to promote the global science and engineering professions concerned with minerals, metals and materials. The Society works to accomplish its mission by providing technical learning and networking opportunities through interdisciplinary and specialty meetings; short courses; publications, including five journals and proceedings; and its Web site.

To learn more, visit www.tms.org.

Telephone: (724) 776-9000 / (800) 759-4TMS
Fax: (724) 776-3770
E-mail: tmsgeneral@tms.org

www.tms.org/Sohn2006.html