Commercialization of NanoMaterials 2006: Keynote: The National Nanotechnology Initiative

Tuesday AM Room: Ballroom 1&2
September 19, 2006 Location: Hilton Pittsburgh

8:30 AM Keynote
The National Nanotechnology Initiative: Engine for Innovation and Competitiveness: *Celia Merzbacher*[1]; [1]Executive Office of the President

The National Nanotechnology Initiative has invested over $5 billion in research and development since 2001 and plans to spend over $1.3 billion in 2007. The Federal government's broad investment in basic research at the nanoscale is a critical element of the innovation process. Other components include small and large businesses, entrepreneurs, State and local economic development organizations, and the investor community. Infrastructure, education, and workforce preparation are also important to the maintaining a healthy environment for research and technology development. Along with investment in the development of nanotechnology applications, it is necessary to do research that enables the assessment and management of potential risks. Finally, the NNI has an important role to communicate with industry, policymakers, and the public about the real potential of nanotechnology to benefit various sectors of the economy, the environment, and our quality of life.

Commercialization of NanoMaterials 2006: Functional Materials 1

Tuesday AM Room: Ballroom 3
September 19, 2006 Location: Hilton Pittsburgh

Session Chair: Toni Grobstein Marechaux, Strategic Analysis Inc

9:45 AM Invited
Nanotechnology in Hard Disk Drives: *Robert D. Hempstead*[1]; [1]Seagate Technology, Inc.

Over the past 50 years, areal densities in hard disk drives have increased by 30 million times to $120X10^9$ bits per square inch, from dimensional scaling of read and write heads and the spacing between them. This scaling has reached the point were the dimensions of critical features are now on the nanometer scale. This talk will feature the advanced fabrication techniques used in the research and manufacturing of heads and disks for hard disk drives of today and the future. Some of these techniques, such as photolithography, have been adapted from the semiconductor industry while others, such as lapping, have been adapted from more conventional industries but are controlled to achieve nanometer resolution. As the dimensions of magnetic materials used in these devices are reduced to the nanometer scale, their magnetic properties no longer behave as in the bulk.

10:10 AM Invited
Nanotechnology in Wireless Communications: *Papu Maniar*[1]; [1]Motorola

Wireless communications with its ability to provide mobile access to information and entertainment has revolutionized individual's reach to always being connected anywhere, anytime, and to anything. Mobile devices to capture, store, process, and communicate are at the heart of this seamless mobility. As an ensemble of useful functionality continues to migrate into these mobile devices, nanotechnology provides an opportunity for future innovations. Nanotechnology impacts all areas of mobile devices from displays, electronics, camera, antennas, storage, biometrics, housing, battery power, and user interface. Nano- materials, processes, structure integration, manufacturing, physical and functional characterization are exciting areas of research. Motorola is actively pursuing nanotechnology development and commercialization to enrich the user experience of seamless mobility. Commercializing nanotechnology innovations into products faces many challenges which are being overcome with creative organizational setups and well thought out strategic and operational partnerships.

10:35 AM Invited
Nano-Enabled Integrated Sensor Technology: *David Lambeth*[1]; [1]Carnegie Mellon University

Through the support of the Air Force Office of Sponsored Research (AFOSR) and National Institute for Occupational Safety and Health (NIOSH) we have launched a multi-disciplined team effort in developing integrated, single chip, multi-modal nano-sensor technology. These potentially low-cost, high-performance systems are CMOS-MEMS based allowing the possibility for combined physical, chemical and, perhaps, biological sensing all on a single integrated circuit chip. As MEMS based physical sensors are far better developed, we have focused on chemical sensor issues based upon the semiconductive regioregular polythiophene polymer system as the receptor chemistry. These materials have unique chemical and nanostructures which strongly influence their sensitivity to various volatile organic compound (VOC) vapors. Multiple regioregular polythiophene polymers, with a variety of side chains, end groups and secondary polymer chains, have been synthesized and studied for their electrical, sensing, and nano-structure properties. The ordering of nanowire morphologies, the electronic mobility, and the sensing properties are found to depend upon the polymer chemistry, molecular weight and the deposition solvent evaporation rate. GXID measurements revealed that the nanowire structure is

π-π stacking of the polymer chain. A custom inkjet system is used to selectively deposit the individual polymers onto selected circuit elements in an array of transduction electrodes. The sensors have demonstrated sensitivity and selectivity for the detection and discrimination across a number of VOCs. The sensing electrical responses are dependent both on the physical nano-structure, as well as the chemical structure, of the polymers. These same materials have also been studied as gravimetric MEMS structures.

11:00 AM Invited

Development of Nanomaterials for Infrared Detectors: *Gail Brown*[1]; [1]United States Air Force Research Laboratory

Nanostructured semiconductor materials, such as quantum wells, superlattices and quantum dots, have been under development for the past twenty years. Some of these materials are now on the market in commercial infrared cameras. Other materials are still in the research phase. A brief overview on how these nanomaterials can be used for infrared detection and the types of materials involved will be given. The current status of commercialization will be reviewed and opportunities for what is still emerging will be explored.

11:25 AM Invited

Polymerized Crystalline Colloidal Array Photonic Crystals for Chemical Sensing and Optoelectronics: *Sanford A. Asher*[1]; [1]University of Pittsburgh

We have developed a novel class of smart optical materials based on soft materials which are responsive to their environment and which can be actuated chemically or photonically. Highly charged, monodisperse colloidal particles will self assemble in water into crystalline colloidal arrays (CCA), which are either body centered or face centered cubic structures. We have developed smart materials from these self-assembled structures, which utilize the highly efficient Bragg diffraction of light from the CCA periodicity. We polymerized these CCA into acrylamide hydrogels. These CCA-embedded hydrogels show the rich volume phase transition phenomena characteristic of these soft materials. These materials act as frequency agile optical filters. We have functionalized these hydrogels with dyes and photochromic molecules, as well as with molecular recognition agents which cause the hydrogel to change volume in response to either photons, or the presence of specific analytes (eg Pb^{2+}, glucose etc). The resulting volume changes alter the array spacing, which causes the diffracted light wavelength to shift, or causes the diffraction efficiency to change. We will discuss the volume phase transition properties of these arrays and also describe the use of these arrays and also describe the use of these arrays as chemical sensors, novel ns optical switching materials as well as optical memory devices.

Commercialization of NanoMaterials 2006: Coatings 1

Tuesday AM Room: Ballroom 4
September 19, 2006 Location: Hilton Pittsburgh

Session Chair: Larry Friedman, Bayer Material Science

9:45 AM Invited

Materials Nanotechnology: PPG's Paths to Commercialization: *Truman Wilt*[1]; [1]PPG Industries, Inc.

Nanotechnology holds the potential to impact many areas of the materials industrial sector. The key is the ability to drive these technologies to commercial fruition. PPG Industries is a global leader in coatings and specialty products and services, with revenues of over $10 billion in 2005. Key business areas include coatings, glass and performance glazings, fiberglass, chemicals, and optical products. PPG has been a pioneer in nano thin film coatings with production scale physical and chemical vapor deposition capability, and introduced the world's first low emissivity glass product, Sungate® 100, in 1983. New and improved functionalities have continued to be developed for glass, including products for solar control, antennae, heating, self-cleaning, color styling, and electrochromic capability. In 2002, PPG delivered CeramiClear®, the first nanocomposite automotive clearcoat, to the market, providing unmatched mar and scratch resistance to maintain improved appearance over the life of the vehicle. PPG prides itself on the ability to apply novel technologies to create commercially viable products and services to meet market needs. This presentation will discuss some of PPG's nano-enabled product areas, from a historical perspective, and describe the key elements to enable commercial success. These include an effective innovation process, partnership and collaboration opportunities, and a proactive approach to environmental, health, and safety issues. We believe effective collaborative efforts between academia, small business, and large industry will be critical moving ahead and, as a founding member of the Pennsylvania NanoMaterials Commercialization Center, our goal will be to foster that model.

10:10 AM Invited

Nano Materials in Printed Electronics: *Bill Faulkner*[1]; [1]Cima Nanotech

The Global Electronics Industry is seeking next generation manufacturing methods to produce cheaper, smaller, and more flexible components. Industry leaders are ramping up significant development projects to eliminate the high capital costs, expensive processing, and environmentally damaging lithographic etching of electronics. Functionalized nano-materials are emerging a key component to meeting these goals. Printing technologies such as ink jet, gravure, flexo, and other graphic arts based systems are being optimized to achieve the higher resolution and operational demands of electronics. In many cases, the unique properties of nano materials are the necessary components in inks and coatings for these systems. The multi-billion dollar market opportunity includes components for flat panel displays, EMI shielding films, solar cells, printed thin film transistors, and RFID tags.Cima NanoTech is manufacturing & commercializing nano metal-based coatings and inks that enable self-assembling random patterns and direct printing of electronic circuits and films. The venture capital backed company is headquartered in St. Paul, Minnesota with R&D facilities in Caesarea, Israel, and toll manufacturing in Japan.

10:35 AM Invited

Synthesis and Characterization of Wear, Erosion, and Corrosion Resistant Multi Nano Layered Coatings: *Douglas E. Wolfe*[1]; Brian Borawski[1]; Brian M. Gabriel[1]; [1]Pennsylvania State University

It is well known that component life can be significantly enhanced by applying coatings for protection in wear, erosion, and corrosion environments. In the last two decades, significant improvements in coating equipment and processes have allowed deposition of multi nano layered coatings with significant improvements in hardness and thus wear resistance. Results will be presented on TiC/CrC, TiB2/TiC, and TiN-based multilayer coatings with varying individual layer thicknesses (100nm to 1200 nm). In addition, erosion of materials has become increasingly important for military aircraft as vortexes are formed during take-off and landing which often result in the incorporation of hard solid particles of sand, dust and ice which get ingested into engines. These hard particles impact compressor components at various angles resulting in severe erosion leading to decreased efficiency and performance. The mechanism of erosion due to solid particle impingement is very complex and poorly understood. No single coating material exists which offers erosion resistance properties at both high angle (55°-90°), as well as low angle (10-55°) hard particle (i.e.sand) impingement. Advances in multilayer coating design and structure methodology to over come these issues will be discussed. Select characterization of hardness, x-ray diffraction, scanning electron microscopy, scratch testing, fracture toughness, and erosion results will also be presented.

11:00 AM Invited

Innovating with Materials at the Nanoscale: A DuPont Perspective: *Krishna Doraiswamy*[1]; [1]DuPont

DuPont is an integrated science company with a long-standing commitment to materials-based innovation. Fundamental properties of materials (thermal, mechanical, electrical, optical, chemical) can be dramatically influenced by their nanostructure. The availability of modern tools for synthesis, measurement, characterization and modeling now permits the deliberate design of novel nano-structured materials. Such materials can deliver enhanced performance in existing applications, and can enable new applications and new business opportunities. DuPont is exploring how nano-scale science and engineering (NS&E) can add value in a number of applications, such as coatings, polymer nanocomposites, printable electronics, displays, sensors, membranes and functional surfaces. In these explorations, DuPont is guided by the belief that NS&E is not an end in itself, but enriches the options available to materials scientists to meet current and future market needs. DuPont is also committed to ensuring that any new nanomaterials are brought to market in conformance with its rigorous safety, health and environmental principles.

11:25 AM Invited

Nanotechnology at Air Products: From Strategy Development to Building Capabilities to Launch of a New Business: *Jeff DePinto*[1]; [1]Air Products

Air Products (www.airproducts.com; NYSE: APD), a Fortune 500 company headquartered in Allentown, Pennsylvania, serves customers in technology, energy, healthcare and industrial markets worldwide with a unique portfolio of products, services and solutions, providing atmospheric gases, process and specialty gases, performance materials and chemical intermediates. This talk will describe how Air Products developed a strategy around nanotechnology, built specific capabilities through both internal development and external partnerships, and launched a new business leveraging unique technology for dispersion of nanoparticles. The talk will describe specific applications of certain nanoparticles and the key role that dispersion technology plays in enabling the commercialization of new products enabled by nanomaterials.

Commercialization of NanoMaterials 2006: Commercialization Approaches

Tuesday AM Room: TBD
September 19, 2006 Location: Hilton Pittsburgh

Session Chair: Thomas Abraham, Innovative Research and Products, Inc.

9:45 AM Invited

Excellence in Technology Transfer—How to get a Nanomaterials Company off the Ground: *Neil Kane*[1]; [1]Advanced Diamond Technologies, Inc.

The issues associated with licensing a technology, setting up a proper governance structure, providing appropriate ownership for the founders and finding capital can be daunting even to experienced entrepreneurs. Clawing your way through the “valley of death” toward first customer revenues is particularly challenging for nanomaterials companies. In his talk Neil Kane, founder and president of Advanced Diamond Technologies (ADT) will discuss the path his company took to license the award winning Ultrananocrystalline Diamond™ (UNCD™) from Argonne National Laboratory and form a venture-backed startup. In particular the cultural issues that differentiate corporate settings versus research settings will be highlighted.

10:10 AM Invited

The Realities of Nanotech Commercialization in 2006 Sector by Sector: *James Hurd*[1]; [1]NanoScience Exchange

What is happening in nanotech commercialization today - as companies start to mature in the various sectors where nanotech is making an impact? What are the realities happening behind the scenes? What are the leading commercial successes? We’ll look at the companies impacting sectors such as tools, materials, electronics, energy, medical device and bio. Where are the exits and the financings coming from - acquisitions, IPO’s and private equity? It’s a historic yet unpredictable time - full of progress and full of disappointment. Time to stay tuned in or fall behind!

10:35 AM Invited

Nanotechnology: Creating Real Value for Commercialization: *Magnus Gittins*[1]; [1]Advance Nanotech

Advances in nano-scale imaging, synthesis and modelling over the past few decades are leading to an explosion of new nanomaterials. Nanotechnology is about more than nanometer size, it implies manipulation of nanostructures and design and control of nano-scale properties. Control of seemingly contradictory properties are possible with nanomaterials creating structures with unique properties for energy, medical, display, electronic, and sensor applications. For the first time in history, materials can be engineered from the bottoms up. The interactive and integrated nature of nanotechnology is leading to the creation of new value chains and the breaking and rebuilding of existing ones. Successful nanomaterials development requires a breadth of knowledge in materials, devices, medicine and control systems. The development of cost-efficient fabrication methods will lead to the adoption of nanomaterials. Bridging the Valley of Death, between scientific discovery and product development, is key to the future of nanotechnology.

11:00 AM Invited

A Needs-Based Assessment of Nanomaterials and the United States Measurement System: *Clare M. Allocca*[1]; [1]National Institute of Standards and Technology

The National Institute of Standards and Technology the U.S.'s National Measurement Institute and an agency of the U.S. Department of Commerce is engaged in an assessment of the state of the nation's measurement system (USMS). The USMS is the complex of all the firms and individuals in the U.S. that make or use measurements for an economic purpose as well as all the supporting institutions that help make those measurements valid, including instrument manufacturers, calibration laboratories, standards developing organizations, and accreditation bodies. The initial objective of the NIST USMS effort was to produce a needs-based assessment of the state of the USMS by June 2006. The focus of the assessment was on measurement problems that pose technical barriers to technological innovation, a major source of the nation's industrial competitiveness and economic well-being. The intended effect of the assessment report is to contribute to getting the nation's innovation-limiting measurement needs addressed in three ways: by allowing potential providers of solutions to specific measurement problems to be engaged and mobilized; by bringing the attention of stakeholders to systemic issues in the functioning of the U.S. measurement system as whole; and by serving as a catalyst for the identification of other needs and problems of the USMS. Report results will be reviewed, and implications for the world of nanomaterials will be explored. Identified measurement needs in the field of nanomaterials will be presented, as well as some potential resources for these measurements, including facilities at NIST such as the Center for Nanoscale Science and Technology (CNST).

11:25 AM Invited

Advanced Technology Commercialization and Economic Development: *Michael O'Halloran*[1]; [1]IDC Architects

Advanced technology, and nano-technology in particular, is receiving a great deal of attention for their potential to promote and assist with economic development. As American jobs move offshore, the interest mounts. Many hopes are pinned on the "Knowledge Based Economy". Unfortunately, the interest is also mounting outside America. Significant investment is being made within the US in R&D efforts directed toward development of new technologies that are one day hoped to produce the new products, new companies, new industries and new jobs for the new economy. The investments are being made by companies, venture capitalists and by the public (individuals and taxpayers). Investment objectives by corporations and venture capitalist are normally clear. Profits. Investment by individuals is often altruistic. The investment objective by taxpayers is a little fuzzy. Sometimes the goal is altruistic, but, more often that not, the public investment in research is "sold" based on the future of our children and the future economic viability of the region. This paper will look at the model for technology commercialization within the US. Comparisons will be made with the technology commercialization models of other countries. Examples of successful and unsuccessful approaches will be reviewed. Goals and objectives of economic development organizations will be examined relative to the goals and objectives of other organizations such as universities, corporations and venture capitalists. A model for relationships will be developed. Various international economic development strategies will be reviewed. Finally, a "Straw-man" model for advanced technology commercialization and economic development will be presented for consideration and comment.

Commercialization of NanoMaterials 2006: Keynote: Bayer MaterialScience

Tuesday PM Room: King's Garden
September 19, 2006 Location: Hilton Pittsburgh

12:00 PM Keynote

Nanotechnology at Bayer MaterialScience: *Robert Kumpf*[1]; [1]Bayer MaterialScience

An overview of the Bayer MaterialScience global approach to Nanotechnology will be presented with a focus on current and future products and technologies that are enabled by nanotechnology. The presentation will also address the role of nanotechnology in broader issues such as sustainability as well as the interface with the Pennsylvania NanoMaterials Commercialization Center.

Commercialization of NanoMaterials 2006: Perspectives of Commercialization Panel

Tuesday, 1:15 PM Room: Ballroom 1&2
September 19, 2006 Location: Hilton Pittsburgh

Panel Moderator: *S. Thomas Emerson*[1]; [1]Director, Donald H. Jones Center for Entrepreneurship, Carnegie Mellon University

Nanomaterials and NanoDynamics: *Keith A. Blakely*[1]; [1]Chief Executive Officer, NanoDynamics Inc
Abstract Not Available

Bridging the Gaps between Nanoscience and Commercialization: *Angus I. Kingon*[1]; [1]North Carolina State University
The huge investment in nanoscience and nanotechnology worldwide has resulted in equally large expectations regarding the creation of commercial value from the new knowledge and discoveries. Companies are recognizing that nanoscience and nanotechnology presents unique opportunities, but at the same time they are finding the path to commercialization to be more tortuous than expected. As part of a project to understand and improve this situation, the Center for Innovation Management Studies at NCSU have investigated the responses that large companies are taking to nanoscience, in order to understand some of the obstacles. A short synopsis of these will be presented. This will be followed by work that is being undertaken to bridge some of these obstacles. In particular, a short summary will be given of some action research that is being undertaken with funding from the National Science Foundation to develop new business processes for more rapidly commercializing upstream science, specifically nanoscience.

Nanomaterials and PPG: *James Trainham*[1]; [1]PPG Industries, Inc.
Abstract Not Available

NanoMaterials: Opportunities and Challenges for Aerospace: *Richard Vaia*[1]; [1]Air Force Research Laboratory
Ever since the Wright Brothers defied the skeptics of powered flight over a hundred years ago, scientists and engineers have been searching for innovative ways to build better aerospace systems. The innovations of 'Nano-science' are providing the foundation to not only revolutionize aerospace systems in the future, but to substantially enhance system capability and performance today. After a brief overview of the Air Force Research Laboratory's highest priority areas for transitioning 'Nano-science' into 'Nano-enhanced' technologies, examples of NanoMaterial innovations in the pipeline, such as nanocomposites, will be highlighted.

Commercialization of NanoMaterials 2006: Functional Materials 2

Tuesday PM Room: Ballroom 3
September 19, 2006 Location: Hilton Pittsburgh

Session Chair: Luis Fanor Vega, Alcoa

3:15 PM Invited
Applications of Semiconductor Nanomaterials in Biology and Biomedicine: *Lianhua Qu*[1]; [1]Crystaplex Corporation
Semiconductor nanomaterials promise a huge impact on the economy worldwide due to their unique optical, electronic, magnetic and /or structural properties. Recent developments indicate that the first practical applications of semiconductor materials are occurring in biology and biomedicine rather than optics and electronics. This presentation will describe the recent advances of research and commercialization in luminescent semiconductor quantum dots. The main focus will be on two major applications of these nanomaterials in the areas of biology and biomedicine: 1) single quantum dots as ultrasensitive biological labels for live cells, in vivo imaging, detection and diagnostics; 2) quantum dots encoded microspheres for multiplexed optical encoding and high throughput analysis of genes and proteins. As a potent application in healthcare, semiconductor nanomaterial beased nanosensors will also be a great area to develop.

3:40 PM Invited
Plasmonic Nano-Optics: *Bill Choi*[1]; [1]NanoLambda
NanoLambda is presenting an effort to commercialize the newly discovered plasmonic nano-optic phenomena occurring when a light meets metallic nanoscale structures. Unlike the highly integrated semiconductor chips, most of the optical components have the limitation on scaling down the size and lowering the cost because of the diffraction limit and the manufacturing process. Recently, plasmonic technology has opened a new paradigm in scaling down optical components below the diffraction limit. By introducing metallic nanoscale structures, plasmonic devices can provide a unique way to control polarization, phase, and wavelength of light passing through the structures. One of the notable properties of surface plasmons is that their spatial dimension can be made significantly smaller than that of the optical wavelength. Surface plasmons with this novel characteristic enable subwavelength-scale optical components and thus dramatic size reduction of optical systems, modules, and circuits. Based on the fundamental plasmonic

nano-optics research done at the University of Pittsburgh, NanoLambda is developing subwavelength-scale optical components. One of the first commercial products is an ultra-compact low-cost spectrometer-on-a-chip. The size of the chip is just a few mm x mm, smaller than 1/10 of the conventional solutions. This ultra-compact low-cost spectrometer-on-a-chip can be used in various applications such as mobile/wearable health monitoring, multiple gas detection, and high-resolution color sensing. It is anticipated that the total addressable market for this spectrometer-on-a-chip will be over $1 billion in 2012. Considering the manufacturability of the technology and the readiness of the markets, it is feasible to commercialize the technology within 3 years. Based on the fundamental plasmonic nano-optics research done at the University of Pittsburgh, NanoLambda is developing subwavelength-scale optical components. One of the first commercial products is an ultra-compact low-cost spectrometer-on-a-chip. The size of the chip is just a few mm x mm, smaller than 1/10 of the conventional solutions. This ultra-compact low-cost spectrometer-on-a-chip can be used in various applications such as mobile/wearable health monitoring, multiple gas detection, and high-resolution color sensing. It is anticipated that the total addressable market for this spectrometer-on-a-chip will be over $1 billion in 2012. Considering the manufacturability of the technology and the readiness of the markets, it is feasible to commercialize the technology within 3 years.

4:05 PM Invited

Synthesis and Processing of Ceramic and Metal Colloids for MesoScale Components and Devices: *James H. Adair*[1]; Nicolas Antolino[1]; Greg Hayes[1]; Christopher Szepesi[1]; Mary Frecker[1]; Christopher Muhlstein[1]; Ying Yuan[1]; [1]Pennsylvania State University

Nanoparticulates in colloids have much promise in the manufacture of bulk devices and components. In this presentation, the opportunities provided by well-dispersed inorganic nanoparticulates are reviewed. The talk will focus on the manufacture of mesoscale structures included MEMS, sensors, multilayer components, and surgical instruments. An investment casting process has been developed to manufacture sub-100 micron (meso) devices. In particular, Frecker's optimal topological modeling has been used to design a combined forcep-cutting instrument. In a preliminary study, 40 micron square parts have been produced that have an as-sintered edge resolution less than one micron. The engineering and scientific issues that were addressed in the development of the investment casting approach will be discussed including the mold fabrication, introduction of the nanocolloids into the molds, and sintering approaches for nanometer size particulates.

4:30 PM Invited

Novel Use of Nanoparticles in Ballistic Body Armor Applications: *Zane Frund*[1]; Celeste Hort[1]; Sudha Vijaykumar[1]; [1]MSA Company

There is an ever increasing demand for body armor having greater V50 performance when challenged against a broad range of ballistic threats, less resultant trauma when impacted, yet lighter in weight and more comfortable. With these goals in mind, research is underway by industry, academia and government to modify fibers, fabrics, metallics and inorganics with nanoparticles which, when used in body armor applications, will enhance one or more of aforementioned characteristics. For example, university researchers are developing blends of metallic and polymeric nanomaterials which undergo a stress induced material transformation when impacted at high velocities (normally associated with a ballistic event). Such reactions will assist in stopping projectiles by absorbing their energy and using it in chemical reactions to develop a tough/hard region capable of stopping the projectile. University researchers, in collaboration with the military, have also developed a nanoparticle-containing shear thickening fluid that hardens upon impact.

Commercialization of NanoMaterials 2006: Coatings 2

Tuesday PM Room: Ballroom 4
September 19, 2006 Location: Hilton Pittsburgh

Session Chair: Todd Osman, TMS

3:15 PM Invited

Nanotechnology for Advanced Surface Engineering: *Aharon Inspektor*[1]; [1]Kennametal

Cutting tool industry is a traditional proving ground for new technologies and among the first to commercialize new breakthrough products. In this paper, we will share our perspective and results in nanotechnologies for surface engineering, and our experience with industry-academia partnership, where the whole is more than the sum of its parts.

3:40 PM Invited

The Development of NanoStructured Steel "From Basic Discovery To Mainstream Technology": *Daniel J. Branagan*[1]; [1]NanoSteel Company Inc

Steel is one of the oldest materials known to mankind and has been used for at least 3,000 years. While modern society utilizes many types of advanced materials, steel can still be considered the backbone of industry and often the material of choice due to its combination of superior properties including its ease of manufacturing, ability to be recycled, its availability, and relatively low price. Over its history, driven by its importance to society, steel has been extensively studied and more is known about steel than any other class of material with more than 25,000 different records of steels in 51 different ferrous groups. It has been understood for decades that if nanostructured steel could be developed that it would offer improved combinations of properties but it has not been known until very recently how to achieve this on an industrial scale. At The NanoSteel Company, we have focused on bringing *new developments in nanomaterials from basic discovery to mainstream technology* enabling the achievement of nanostructured steel products in an ever increasing array of industrial processing techniques and commercial application strategies in the thermal spray and hardfacing areas.

The realm of demonstrated properties which will be discussed include developing steel alloys which have the hardness of alumina ceramics, the wear resistance of hardmetals, the strength of carbon based fibers, the strength to weight ratio of titanium alloys, and the corrosion resistance of nickel based superalloys. We will show that the foreseeable future of materials nanotechnology may not be programmable assemblies, replicators, and swarms of nanomachines acting in unison, as some have suggested, but is instead the mainstream; i.e. the bulldozer, the mining crusher, and the automobile.

4:05 PM Invited

Enhancing the Performance of Mechanical Components with Nanocomposite Coatings: *Ryan Evans*[1]; Gary L. Doll[1]; [1]Timken Technology Center

Nanocomposite coatings consisting of nanometer-scale crystalline metal carbides embedded in amorphous hydrocarbon or carbon matrices (MC/a-C:H or MC/a-C) are used to improve the performance of rolling element bearings, gears, and engine components. MC/aC:H thin film coatings are applied by reactive magnetron sputtering at substrate temperatures lower than 180°C. The nanocomposite film structure offers the surface free energy and elasticity of a polymer (a-C:H matrix) with the hardness and wear resistance of a carbide ceramic (MC crystallites). Films suitable for use on mechanical components typically have low friction coefficients, high fracture strength, and hardness and modulus levels higher and lower than that of carburized steel, respectively. Tribological benefits of nanocomposite films on bearing surfaces include increased fatigue life, improved debris tolerance, protection against false brinelling, increased operational speed, friction reduction, and delay of failure with lubricant loss. Preferred deposition methods, film properties, and examples of coating applications are summarized.

4:30 PM Invited

Commercialization of Nano Cobalt Hard Chrome Alternative, Nano Invar Molds, Nano Rapid Prototyping: *Frank Cotter*[1]; Bob Samuel[1]; [1]Integran

Integran Technologies Inc. is a market leader in the development of electroplated nano materials. Integran has successfully commercialized nano plated and formed products in the environmental alternative for hard chrome plating, cost effective alternative for invar molds, and nano coating rapid prototype forms for improved durability. Integran employs a customer business case focus for commercialization of plating solutions. Successes include the nano Cobalt hard chrome alternative plating system. The product has been successful marketed via licensing agreements with key manufacturers. Hard chrome has been targeted by environmental groups due to the toxins produced by the process. The nano Cobalt plate provides a compelling alternative based on a strong business case in addition to the environmental benefits. The commercialization of Integran's invar mold solution has been based on solving customer cost and time to market issues. Invar molds are employed in the aerospace and industries that require large frame manufacturing. Historically the molds have been manufactured out of blocks of solid invar metal. Integran has developed a process of electro forming the molds. The result is a low cost alternative that has a superior delivery cycle. Rapid prototyping processes produce a light weight and fragile output. Coating the prototype with nano material results in a durable prototype that can be employed in realistic testing scenarios.

Commercialization of NanoMaterials 2006: Coatings and Structural

Tuesday PM Room: Le Bateau
September 19, 2006 Location: Hilton Pittsburgh

Session Chair: Dan Rardon, PPG Industries, Inc.

3:15 PM Invited

Nanomaterials for Sporting Goods, Consumer and Luxury Goods: *Edward Hughes*[1]; [1]PowerMetals Technologies, Inc.

Throughout time, material developments have impacted sports in every discipline. PowerMetal Technologies, Inc. is a leading high-performance component supplier of nanomaterials to the billion dollar sporting goods, consumer and luxury goods industries. With an extensive intellectual property portfolio, PowerMetal partners with industry leaders to design, and develop nanometal components with unique properties that foster breakthrough, performance-enhancing products. PowerMetal clients benefit from a high-tech legacy of innovation and a $25 Million investment to service the Nuclear Power and Defense industries. The company's proprietary nanometals are created by leveraging electro-deposition techniques to add structural shells and performance nanolayers to engineering plastics, graphite/epoxy components, specialty steels and metallic substrates. The inherent design flexibility of the electro-deposition process empowers clients to create innovative designs that surpass their competition in consumer applications where strength, weight, wear resistance and durability are critical performance parameters. Together with HEAD, PowerMetal developed proprietary nanometal tennis and squash racquets.

3:40 PM Invited

Nanotechnologies and Steel: Challenges and Opportunities: Mike Simko[1]; [1]United States Steel Corporation

The utilization of nanoscale features for property enhancement in steels has been commonplace for decades. The techniques for producing such microstructures in large volume producion is well known; however, the vast majority of the 50+ new sheet grades introduced by U. S. Steel in recent years have utilized other methods to achieve property enhancement. This presentation highlights important considerations when comparing "nano" techniques to more conventional approaches as well as identifies promising areas for the application of nanotechnologies for large scale steel production.

4:05 PM Invited

Polymer Nanocomposites: Qualitative Changes in Polymer Matrices upon Reinforcement with Inorganic Nanoparticles: *Evangelos Manias*[1]; Charles E. Bakis[1]; T. C. Chung[1]; Sridhar Komarneni[1]; Ayusman Sen[1]; Qing Wang[1]; [1]Pennsylvania State University

Nanometer-sized inorganic fillers are currently being explored for the improvement of the mechanical, thermal, barrier, and electric properties of various polymers. Empirical/engineering approaches and recent R&D efforts have allowed for several industries to capitalize on the qualitative changes in nature of polymer nature, which occur upon nanocomposite formation, and have led to a few tens of commercialized applications. However, the exact details of the mechanisms underlying these effects remain elusive and the true potential of nanocomposites remains largely untapped. An overview of fundamental concepts from our current research will be presented along these lines, and examples connecting them to commercialized and potential technologies will be given. An attempt to envision the future directions of these systems will also be presented.

4:30 PM Invited

Nanotechnology and Product Realization: *Mark J. Mezger*[1]; [1]US Army Research, Development and Engineering (RDE) Command

The United States Army is actively engaged in the development and implementation of nanotechnologies for the next generation army. This presentation will highlight the Army's need of nanotechnologies capable of addressing military problems and applications. Critical to this mission is the use of Public-Private Partnerships to acquire resources and capabilities to achieve product realization. Additionally, the establishment of capabilities to rapidly prototype and conduct manufacturing technology studies at the Army's Picatinny Arsenal is a key component in the Army's program for nanomaterial implementation.

Commercialization of NanoMaterials 2006: Keynote: EH&S Issues Management

Wednesday AM Room: Ballroom 1&2
September 20, 2006 Location: Hilton Pittsburgh

8:30 AM Keynote

Managing EH&S Issues and Regulatory Development for an Emerging Technology: *Paul D. Ziegler*[1]; [1]PPG Industries, Inc.

During the presentation Environmental, Health, and Safety issues surrounding Nanotechnology will be highlighted along with what is going on Globally in the Regulatory arena. We will outline what is being done to manage such a SMALL thing with a very BIG interest. Nanotechnology is global in scope, with many interested entities-government agencies;non-governmental organizations(NGOs;Universities;industry;general public-each having an interest, different agenda, different approach regarding how this technology should be developed. Nanotechnology holds great promise across many scientific fields and many sectors of the economy. We must promote and advocate the development of nanotechnology in conjunction with Global Product Stewardship and Sustainable Development principles.

Commercialization of NanoMaterials 2006: Environmental Health and Safety Panel

Wednesday, 9:00 AM Room: Le Bateau
September 20, 2006 Location: Hilton Pittsburgh

Panel Moderator: *Paul Ziegler*[1]; [1]PPG Industries, Inc.

Toxicological Concerns about Nanoscale Materials and Potential Regulatory Issues: *Shaun Clancy*[1]; [1]Degussa

Research on the development of nanoscale materials has been growing at a rapid rate. Some nanoscale materials are smaller versions of chemicals than are already commercialized (e.g. titantia, zirconia) whereas others are different molecular forms of existing chemicals (e.g. fullerenes, carbon nanotubes). There are also new chemicals that are designed to be of nanoscale size for which there is not a larger-scale analogue (e.g. Quantum Dots). Questions have arisen regarding the toxicology of nanoscale materials and if their size results in unique toxicological properties. These questions have bred additional questions regarding existing regulations and whether or not they are sufficiently protective. My contribution to the Panel Discussion is to be able to describe the state of affairs on these issues and to describe ways to minimize their impact on commercialization of nanoscale materials.

NIOSH Nanotechnology Research Council Activities: *Charles Geraci*[1]; [1]NIOSH

The National Institute for Occupational Safety and Health (NIOSH) is the federal agency charged with the responsibility to conduct research and make recommendations for preventing work-related injuries, illnesses, and deaths. NIOSH participates in The National Nanotechnology Initiative (NNI) as a member of the Nanotechnology Science, Engineering, and Technology Subcommittee (NSET) of the National Science and Technology Council Committee on Technology. NIOSH works closely with other federal agencies,

academia, and private sector partners to plan, conduct, and facilitate research that will support the NNI strategic goal of Responsible Development of Nanotechnology. The NIOSH Nanotechnology Research Center was created to identify critical knowledge gaps and issues; develop goals; organize and coordinate NIOSH research; develop and disseminate information and guidelines; and support field investigations. Current project areas and products that will be presented and discussed include: 1) The NIOSH Nanotechnology Web Page: Frequently Asked Questions, Approaches to Safe Nanotechnology, Nanoparticle Information Library, NIOSH Research Program. 2) Toxicity Studies: Pulmonary, Cardio-pulmonary and Dermal. 3) Risk Assessment Methods: Metrics, dosimetry and quantitative risk assessment methods. 4) Exposure Assessment Methods: Nanoparticle measurement methods development, aerosol characterization, instrument evaluation, control technology evaluations. 5) Protective Equipment: Respirator filter efficiency studies and dermal protection. 6) Field Research Team: Better characterization of different segments of the nanotechnology industry including research, development, production and use of nanomaterials; evaluate and share best practices; evaluate exposure measurement methods.

Nanotechnology – HSE Challenges: *Kimberly McDonald*[1]; [1]Bayer MaterialScience

As nanotechnology flourishes, concerns increase about the lack of HSE information related to material characterization, exposure, or fate and transport. Initial studies indicate that some nanomaterials can enter living systems, trigger inflammatory responses, and even penetrate individual cells. Industry is challenged to develop cost-effective methods for detecting, measuring, and evaluating the potential risks associated with nanomaterials and protecting human health and the environment. Exposure and toxicity, risk implications, and public perception are among the factors that could affect how nanotechnology fares in the marketplace.

Environmental Considerations in Nanomaterial Production and Use: *Elizabeth McMeekin*[1]; [1]PPG Industries, Inc.

There continue to be many unknowns concerning the potential environmental impacts from the manufacture, use, and disposal of nanomaterials. Numerous studies are underway around the world to try to understand and define any health hazards or environmental effects that may be associated with nanomaterials and to identify appropriate controls and operating practices for their manufacture, use, and disposal. Initial results from several studies indicate there may be significant environmental benefits associated with nanomaterial production, such as: reduction in use of raw materials; minimization (or possible elimination) of the generation of wastes and emissions; and reduction of toxics associated with production. PPG is currently involved in many promising nanotechnology commercial development projects. Recognizing the many unkowns and questions currently associated with nanomaterial use and manufacture, as a precautionary measure, PPG's Corporate Environmental, Health, and Safety Department has implemented internal EHS guidelines for their operations to follow when handling and manufacturing nanomaterials.

Commercialization of NanoMaterials 2006: Functional Materials 3

Wednesday AM Room: Ballroom 3
September 20, 2006 Location: Hilton Pittsburgh

Session Chair: Warren Hunt, TMS

10:45 AM Invited

Plexcore™: Nanomaterial for Printed Electronic Devices: *Andy Hannah*[1]; [1]Plextronics

Plextronics develops active layer technology for printed electronic devices - organic displays and lighting, polymer solar cells and printed circuitry. Active layer technology is the printed semiconductors and conductors that drive device performance. Plextronics has unsurpassed control of the polymer design and ink formulation as well as an intimate understanding of device physics and its impact on device performance. This knowledge is applied in the creation of Plexcore™ technology which is designed specifically to maximize device efficiency and lifetime of each application. Plexcore is a true nanomaterial. It has the ability to be designed, controlled and tuned at the molecular scale. The breakthroughs represented by this technology have the opportunity to dramatically accelerate the market of printed electronics, an estimated $250B market by 2020. This talk will focus on the both the technology and the applications of this nanomaterial.

11:10 AM Invited

Nano-Optics Technology: From Materials to Chip-Scale Instrumentation: *Hong Koo Kim*[1]; [1]University of Pittsburgh

Nano-optics technology involves the phenomena that occur when a light interacts with nano-structured materials. When the material is metal, a particular interest arises with a phenomenon called surface plasmons. Surface plasmon is a collective oscillation of electrons at metal/dielectric interface. The spatial extension of surface plasmon (SP) fields is governed by the size of a nanostructure and can be made much smaller than the wavelength of light. The SP phenomena can overcome the limitations of conventional optics and can be easily incorporated into an on-chip configuration, with an integration level comparable to those of the state-of-the-art microelectronic chips. As such, nano-plasmonics technology is expected to play an important role in the long-pursued efforts to alleviate the disparity and the apparent immiscibility existing between electronics and photonics areas. In this talk, I will give an overview of this emerging field of nano-optics/plasmonics, and will discuss about the opportunities and challenges in developing multifunctional chip-scale instruments. A chip-scale optical spectrum analyzer is presented, which is based on the plasmonic nanofilter array and offers high sensitivity (better than $\lambda/100$) in a broad spectral range (visible to infrared). We present high-sensitivity surface plasmon resonance spectroscopy based on a metal nanoslit array. Refractive transmission of light through a nanoslit array is investigated to form metal nanolenses. Enabling ultimate miniaturization of optical instruments, the nano-optics technology is expected to revolutionize many areas, such as spectroscopy, imaging, data storage, and environmental and biomedical sensing.

11:35 AM Invited

What Does it Take to Commercialize Functional Nanomaterials?: *Alan Gotcher*[1]; [1]AltairNano

The science of Nanotechnology represents an opportunity for mankind to create very real and substantial advances in almost every part of our lives. At the core of these advances are nanomaterials, atoms assembled in harmony with Natures own set of rules to give us the ability to produce very beneficial new macroscopic effects. There are a number of ways to produce functional nanomaterials at small scale and high cost however the key to the success of creating a profitable functional nanomaterials business is the ability to develop, produce, control and manufacture them cost effectively in large volume. This paper discusses a cost effective process for making nanomaterials which is derived from the manufacture of TiO2 pigment, using low cost raw materials in a scalable large volume production setting, supported by a creative team of chemists and engineers. Commercializing these materials requires strong partnerships where both parties are prepared to cross the new technology chasm together. Examples of how we plan to commercialize specific materials will be discussed.

Commercialization of NanoMaterials 2006: Coatings 3

Wednesday AM Room: Ballroom 4
September 20, 2006 Location: Hilton Pittsburgh

Session Chair: Jian Li, United States Steel Corporation

10:45 AM Invited
Nanoparticle-Based Structures: Materials of the Future: *Nigel Sanders*[1]; [1]Minerals Technologies Inc

Nanotechnology presents new opportunities for differentiation in materials. The development of nanoparticle-based structures which offer unique or enhanced functionality in composite materials and coatings will be reviewed. The potential impact of nanoscale phenomena such as very high surface activity, nanoparticle / nanopore morphology, polymer interactions and particle self-assembly on materials functionality will be considered. I will suggest the benefits of controlling such phenomena to present and future materials applications using examples drawn from experience with synthetic mineral nanoparticles such as Precipitated Calcium Carbonate (PCC) pigments. Finally, the challenges in consistently producing such nanoparticle-based structures at the scale needed for the target materials markets will be addressed.

11:10 AM Invited
Synthesis and Processing of Nanostructured Materials for Energy and Other Applications: *J. Richard Schorr*[1]; [1]MetaMeteria

This talk will review how MetaMateria Partners utilizes nanomaterials and materials processing to improve performance and lower cost in applications such as energy storage, energy generation, water treatment and improved mechanical and optical properties. MetaMateria starts with synthesis of engineered nanoparticles, dispersion in liquids for use in preparing nanostructured coatings and bulk shapes. Examples of on-going activities will be presented.

11:35 AM Invited
Novel Nanostructured High-Surface-Area Catalysts and Supports for DMFC Applications: *Moni K. Datta*[1]; N. Rock[1]; Prashant Kumta[1]; [1]Carnegie Mellon University

Fuel cell technology has a strong impact on the world environment and economy. Amongst the different fuel cells, the direct methanol fuel cell (DMFC) has gathered much interest mainly due to the use of liquid methanol fuel. However, there is still a need to improve the power densities and stability of DMFC to render them viable due to the relatively slow kinetics and stability of the electrochemical reactions. Noble metal Pt-Ru alloys have been identified as the optimal electro-catalysts. However, the catalyst loading and costs make it imperative to search for alternative catalyst systems and methods to synthesize high surface area dispersions. In the present study, a novel sol-gel based approach was developed to synthesize high surface area (139-160 m^2/g) nanoparticles (~5nm) of homogeneous Pt-Ru and other related systems containing lower noble metal fractions exhibiting good catalytic activity.

Commercialization of NanoMaterials 2006: IP Panel

Wednesday, 12:00 PM Room: Ballroom 1&2
September 20, 2006 Location: Hilton Pittsburgh

Description of IP Panel Discussion: *Scott Cummings*[1]; [1]Buchanan Ingersoll and Rooney

The panel will discuss intellectual property issues and developments currently impacting the nanotechnology industry. The panel will also discuss strategies relevant to the creation, management and commercialization of nanotechnology-focused intellectual property with particular emphasis on patents, trade secrets, and know-how.

Panel Moderator: *Carl Mather*[1], [1]Carnegie Mellon Univeristy

Panel Members: John Caldwell[1]; Konrad Kaeding[2]; *Scott Cummings*[3]; [1]Woodcock and Washburn, LLP; [2]Dupont; [3]Buchanan Ingersoll and Rooney