Globalization of the Electronic Materials Industry

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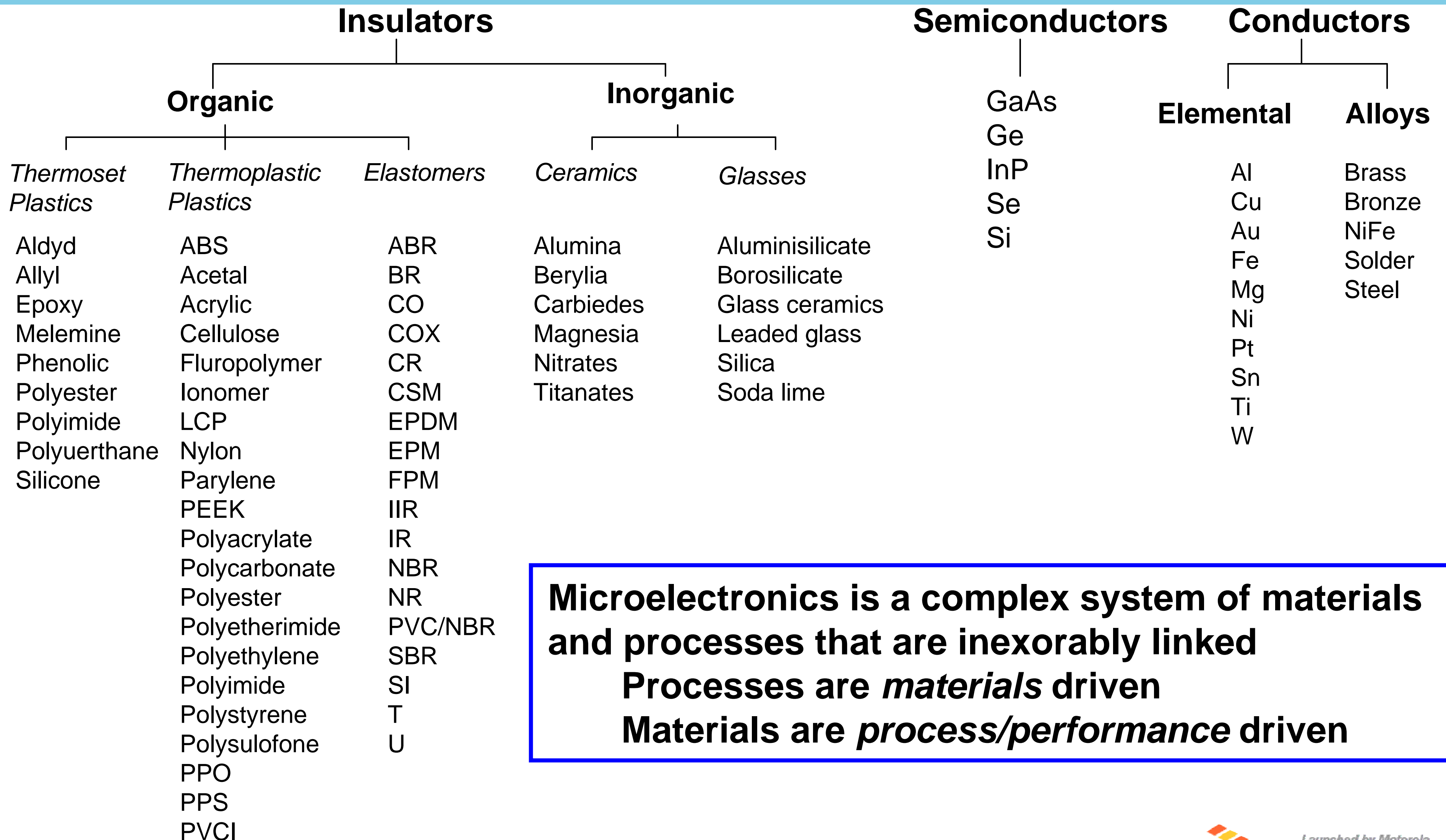
Materials in Electronics



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Overall Trend in Semiconductor Industry

Increased functionality at smaller size and lower cost

- Finer Pitch Lithography
  - Moore's Law: 30% reduction in size of printed dimensions every 2 years
  - 90nm now, 65nm in 2 years, 45nm in 4 years, etc.
- System on Chip (SoC)
- System in Package (SiP)
  - Two or more chips with different functionality in a package
- Increased levels of speed
  - Microprocessors at >1GHz
  - Cell phones at >2.5GHz
- Increased levels of power (heat dissipation)
  - Cell phones (1W), Automotive (2-5W), Microprocessor (5-10W), Basestation (>100W)
- Environmentally Friendly Electronics

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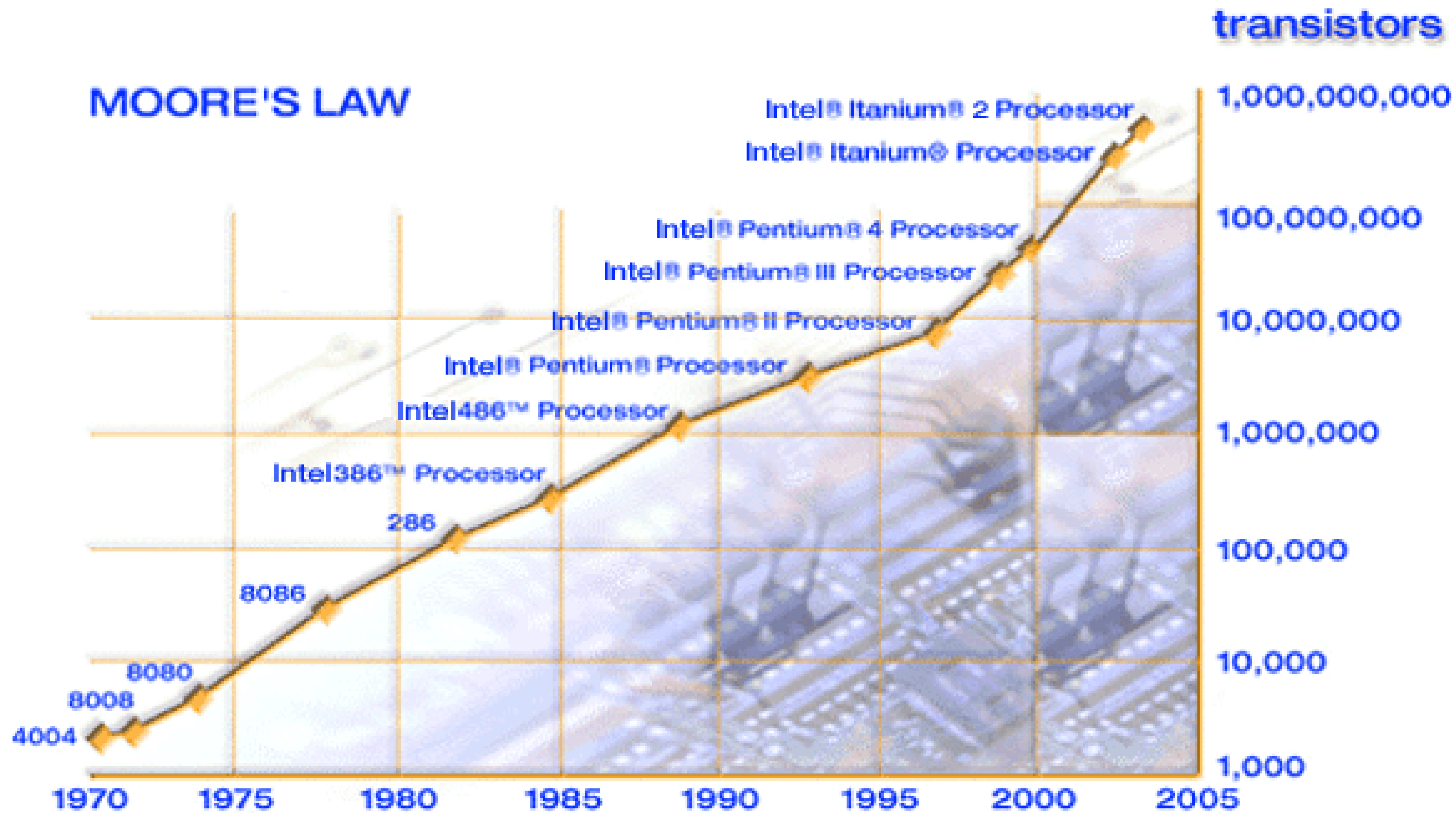
Increased Functionality at Smaller Size



Gordon Moore (Intel) observed in 1965 that the number of transistors would grow exponentially, doubling every couple of years

From: Intel website

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International Technology Roadmap Nodes

Semiconductor Highlights

	2004	2005	2006	2007
Pitch (nm)	90	65	45	18
Memory (Gb)	1	2	4	32
Cost/bit (micro-cents)	2.7	0.96	0.34	0.021
Physical gate (nm)	37	25	18	7
Speed (GHz)	4.2	9.3	15	53

	1990	2001	2012	2019
Wafer size (mm)	200	300	450	675

Packaging Highlights

- SiP
- 3D Packaging
- Wafer Level Packages
- Thinned Die
- MEMS
- Optoelectronics
- Bio Chips

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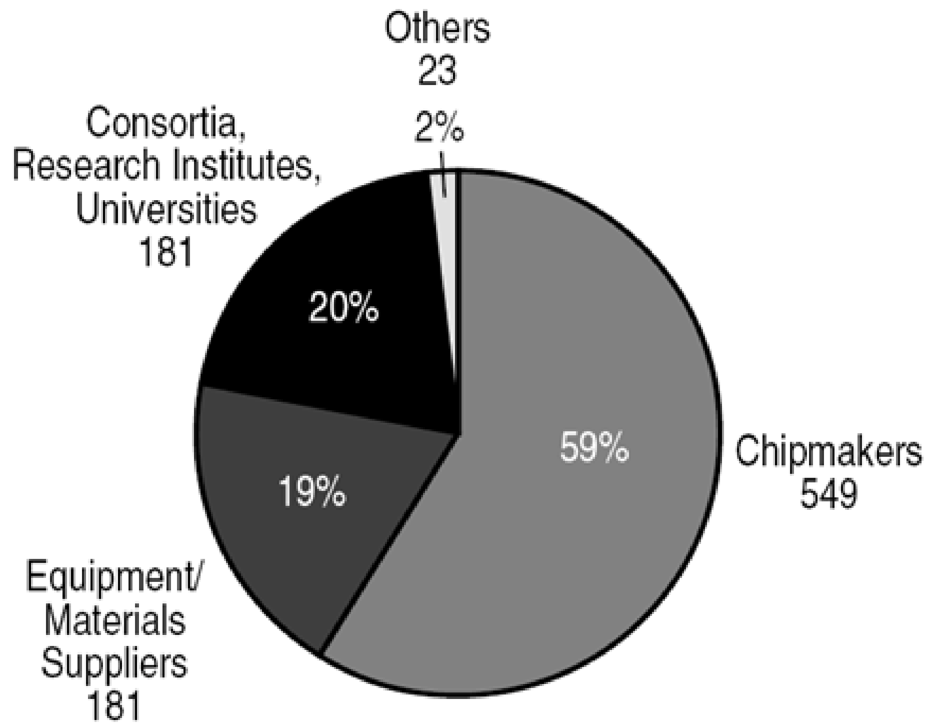
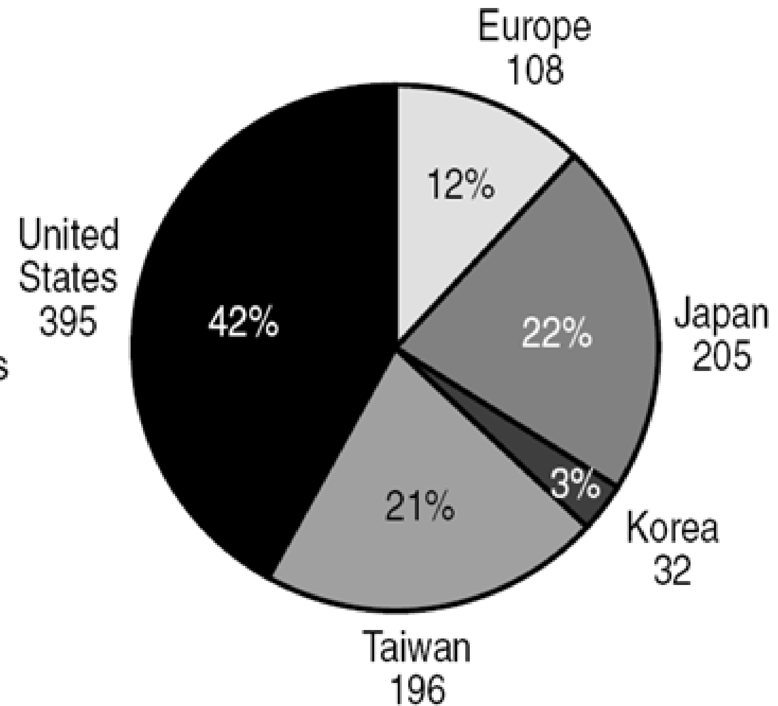
International Technology Roadmap for Semiconductors: Technical Working Group





a TWG Members by Affiliation b TWG Members by Region

- **The future of semiconductor technology is internationally defined**

From: W.H. Hunt "Global Perspectives on Electronic Materials: Challenges and Opportunities", JOM June'04

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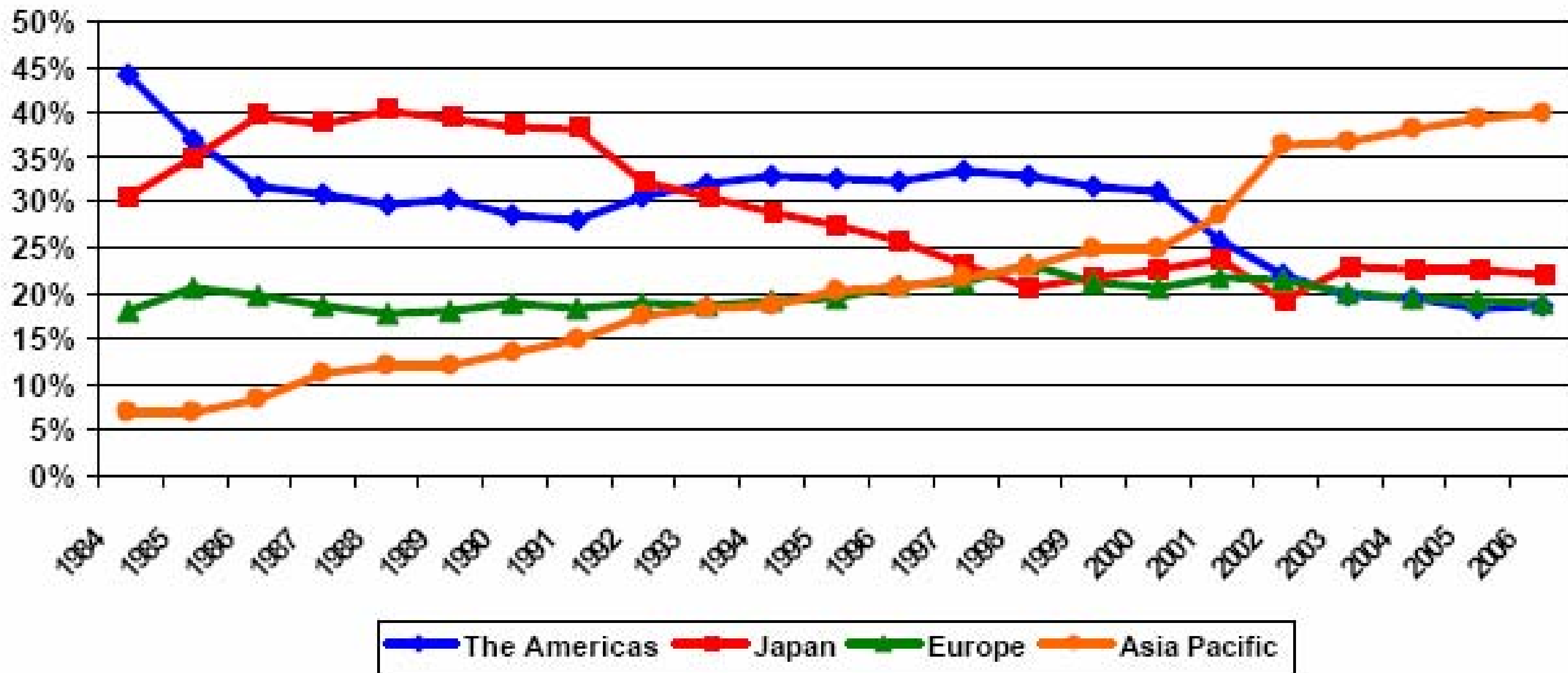
Worldwide Consumption of Semiconductor Electronics



- **Asian semiconductor market surpassed the U.S. market in 2001 and is expected to widen the gap thereafter**

From: W.H. Hunt "Global Perspectives on Electronic Materials: Challenges and Opportunities", JOM June'04

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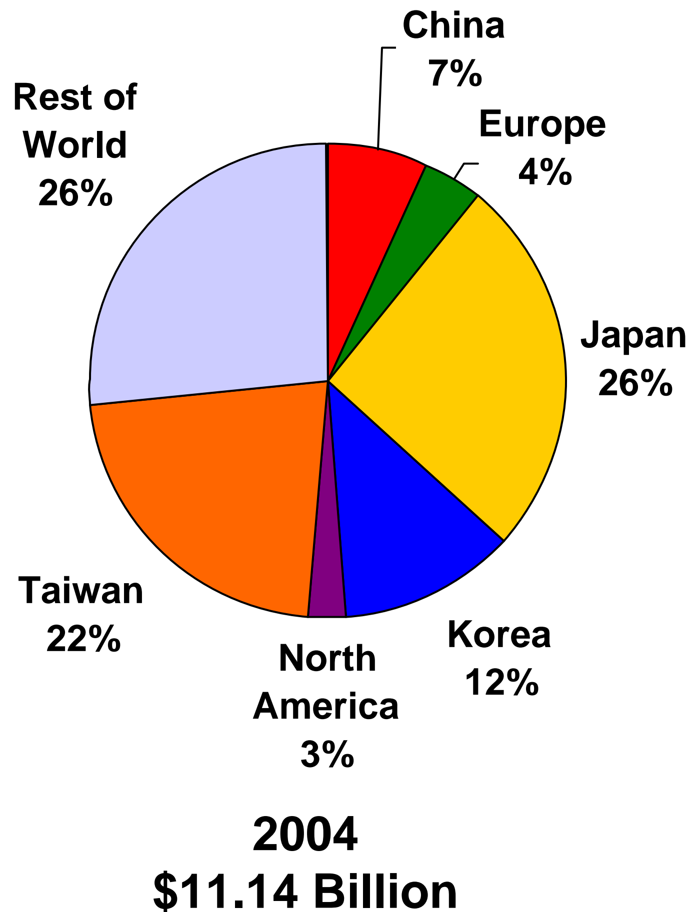
Semiconductor Packaging Materials Markets



2004
$11.14 Billion

Region	2003 $B	2004 $B	% Change
China	0.65	0.75	15%
Europe	0.43	0.49	14%
Japan	2.46	2.90	18%
Korea	1.12	1.30	16%
North America	0.32	0.36	13%
Taiwan	2.03	2.48	22%
Rest of World	2.47	2.86	16%
Total Regions	9.48	11.14	18%

Totals may not add due to rounding

Source: SEMI January 2005

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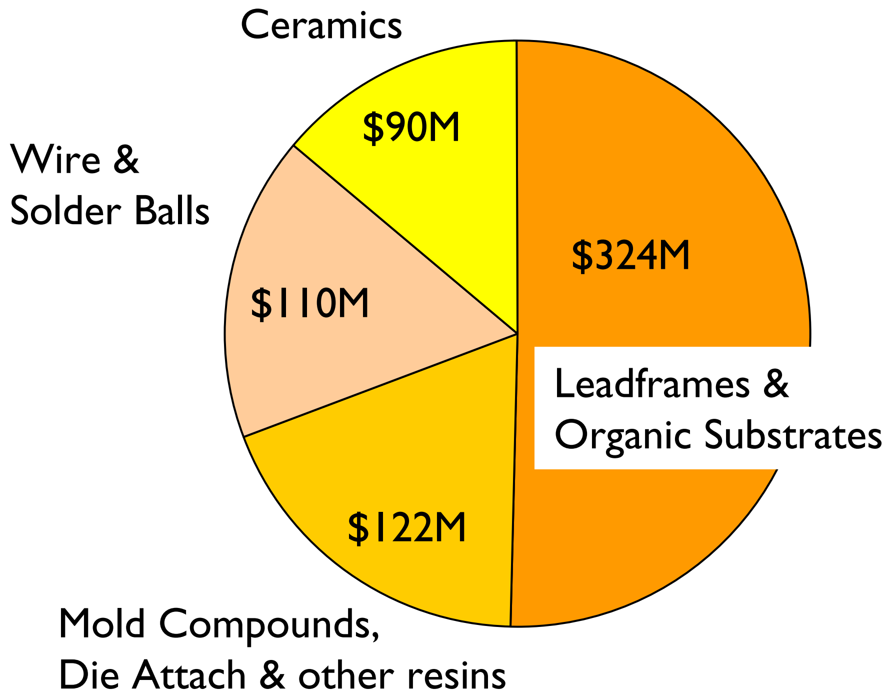
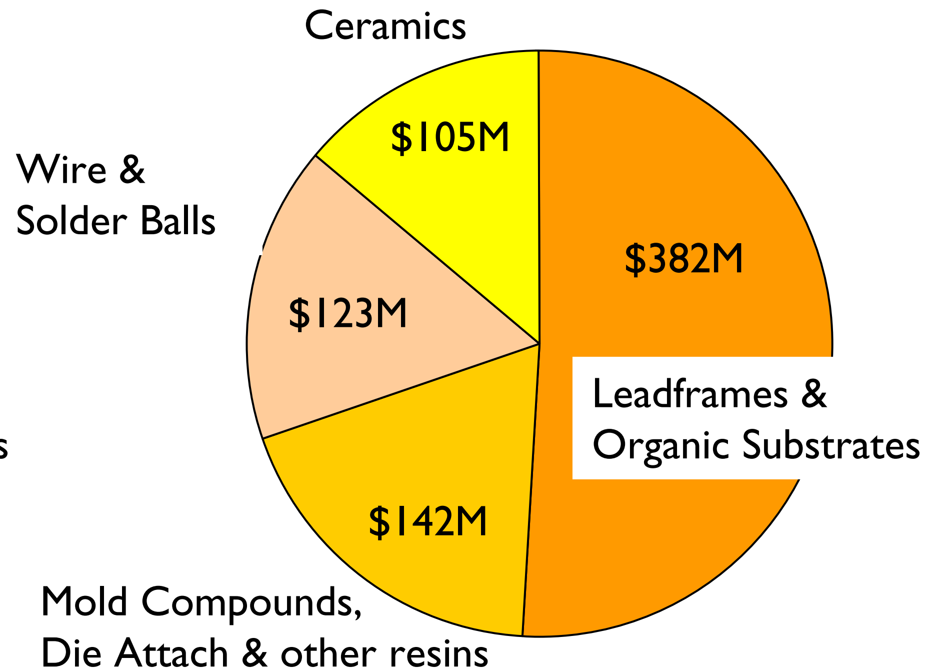
Packaging Materials Market in China

2003 China Market = $646M



2004 China Market = $752M



Source: SEMI January 2005

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China- Emergence of Packaging Materials Manufacturing

Company	Material	Number of Plants
APIC Yamada	**Leadframes**	**1 plant, stamping and plating**
ASM Pacific	**Leadframes**	**1 plant, stamping and plating**
Enomoto	**Leadframes**	**1 plant, stamping**
FuSheng Industrial	**Leadframes**	**1 plant, stamping and plating**
Mitsui High-tec	**Leadframes**	**4 plants (inc. Hong Kong) plus new one in 2005**
Possehl Electronics	**Leadframes**	**2 plants (inc. Hong Kong), stamping, etching and plating**
QPL	**Leadframes**	**2 plants**
SDI Corp	**Leadframes**	**1 plant, stamping**
Sumitomo Metal Mining	**Leadframes, Wire**	**2 plants for leadframes, expand stamping and add etching** **1 plant for gold wire production**
E'Dale Technology	**Mold Compound**	**Plant in Wuxi**
Sumitomo Bakelite	**Mold Compound**	**1 plant**
Henkel Technologies	**Underfill, Encapsulants, Die Attach**	**1 plant in Yantai**
Heraeus Holding	**Wire**	**2 plants for gold wire production**
Nippon Micrometal	**Wire**	**Gold wire production**
Tanaka KK	**Wire**	**Gold wire production**

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Packaging Materials Market Summary

- **17.5% growth in 2004, with strongest growth in laminate substrates, underfill, solder balls and WLP dielectrics materials**

- **Forecasting 8.3% growth in 2005**
  - **Laminate substrates will lead growth**
  - **Low single digit growth for traditional packaging materials**

- **Expanding supplier base in China and Asia**

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Global Environmental Materials Issues

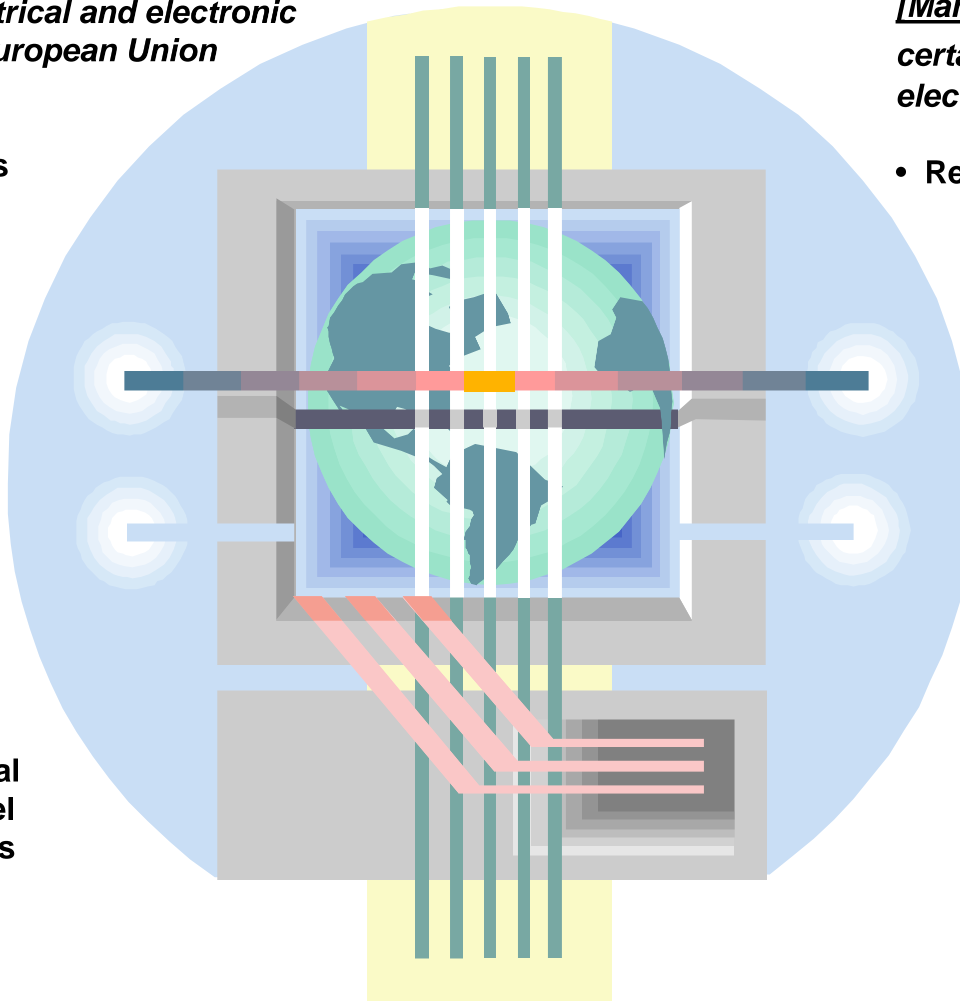
WEEE: Waste of Electrical and Electronic Equipment (August 2005)

Recycling of Electrical and electronic products in the European Union

- OEM to support recycling process and waste management by providing material composition

China – RoHS (definition in progress)

- Similar to the European RoHS
- May have additional marking & label requirements



RoHS: Reduction of Hazard Substances - European Union (July 1, 2006)

[Manufacturing process of] Restricts certain substances in electrical and electronic equipment

- Reduce lead content (<0.1% by weight)
  - Reduce cadmium, mercury, hexavalent chromium, and certain flame retardants

ELV: End-of-Life Vehicle (Now, since July 1, 2003)

Restricts certain substances in vehicles and sets requirements for increasing the reuse, recycling and other forms of recovery of end-of life vehicles (ELV) and their components

- Reduce lead content
- OEM to support recycling process and waste management by providing material composition

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Consortia: In-Country Focus

- Up to 1980, in-house R&D
- Japanese companies capture market share world-wide in semiconductor materials, equipment and manufacturing (1980)
- Semiconductor Research Council (form 1982)
  - Basic/Applied research on semiconductors (Materials and Design focus)
  - Mission: Assure US technology leadership
  - Sponsored by US Gov't (DARPA, NIST, NSF)
- Sematech formed in 1987
  - Companies combine resources to develop US-based tools and manufacturing technology
- Semiconductor Leading Edge Technologies (SELETE)
  - Japanese consortia
  - Similar mission as Sematech for Japan

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Consortia: Industry Focus

Companies join together to address significant process issues (late 1990’s)

- Cu/lowk interconnect, 300mm wafers

Reason: Cost

- FABs cost in excess of $3 to $4B, each tool >$1M

Industry Focus Consortia

International Sematech

- International companies join in 1998, no US Gov’t funding

Crolles Alliance (Philips, ST, Freescale, TSMC)

- 300mm and Cu/lowk shared R&D and manufacturing in France

Interuniversity Microelectronics Center (IMEC)

- EU consortia in The Netherlands

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US Manufacturing and R&D

The United States has held several advantages in attracting high technology investment.

- **Coherent R&D system (universities, government, and industry)**
- **Research universities**
- **Research consortia (SRC)**
- **Flexible and entrepreneurial business climate**
- **Governmental rule of law (IP protection)**
- **Strong infrastructure**
- **Largest market for high tech products**

If lower labor costs and proximity to emerging markets outweigh U.S. advantages then manufacturing will move offshore

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Globalization of Manufacturing and R&D

Capital costs dominate high-end semiconductor manufacturing

- Labor consists of only 10% to 15% of costs
- Tax considerations are now even more important than lower-cost labor

Semiconductor R&D requires use of high cost manufacturing tools

- Companies co-locate manufacturing and R&D to use the same equipment can be used for both activities

Tax consequences affect further expansion offshore

- Returning dollars back to the U.S. contribute to foreign, rather than domestic, expansion.

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Globalization of Manufacturing of Electronics

Volume manufacturing of semiconductors distributed world-wide

- US, Europe, Asia
- Shift in volume from US and Europe to Asia
  - e.g., TSMC

Packaging materials fabricated primarily in Asia

Volume manufacturing of final assembly (electronic packaging) primarily in Asia

- Some still in Europe
- Large customer base in Asia, lower costs

Specialty materials and assembly in US

- Lower volumes, high value
- Niche products

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Direction of Global Electronic Materials Research

Packaging materials research growing in Asia

- Primarily in the US up to 1990
  - Supported by defense and vertically integrated companies
- China and Korea have exhibited the most growth in the last 10 years
  - Based on papers submitted/published (JEM - ~90% Asia-Pac)
  - 10% from Europe and US
- Globally distributed effort. (Complexity of the problem…)

Semiconductor materials research

- Gradual shift over last 10 years from US to Asia-Pac
  - JEM publications from Asia significantly up to about 80%
  - Electronic Materials Conference has seen increased participation from Europe and Asia
- International research alliances growing
  - SMA (Singapore-MIT Alliance) joint academic alliance (nanofab, material physics and materials chemistry)
  - Europe is changing degree programs to align with US
    - BS, MS, Ph.D.
    - Greater opportunities for collaboration (US/Europe/Asia)

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Summary

- **Electronic materials are global**
- **Volume manufacturing**
  - **Packaging materials and assembly: primarily Asia**
  - **Semiconductors: Global (US/Asia/Europe)**
- **Manufacturing location driven by market and cost**
- **Research following materials and manufacturing development**
  - **Growth in effort in Asia on manufacturing materials**
  - **Fundamental research is global**
  - **Global academic and research alliances are growing**

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