EMERGING NANOTECHNOLOGY AND ITS EFFECT ON ELECTRONICS MANUFACTURING

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ABSTRACT
In the next ten years we will see a dramatic upheaval in the electronics industry as we try to find the replacement for CMOS in order to continue Moore's Law - as well as enhance CMOS technology to take us forward until the technology is ready. iNEMI has been working with the NSF and NSI among others to identify the effects this turmoil will have on components, packaging and assembly. Based on a gap analysis of the 2004 roadmap, iNEMI has identified key areas and is working with members, government agencies and universities to ensure that these gaps are filled. This presentation outlines the identified gaps and the actions underway.

Key words: nanotechnology, electronic packaging, electronics manufacturing

INTRODUCTION
Roadmapping is a well-established process in the electronics industry and brings the best minds in the industry together to predict the evolution of the industry over the next ten years. There are a number of roadmaps for individual areas such as optoelectronics, but the most complete coverage for the electronics supply chain is provided by three critical roadmaps:
ITRS – covering the semiconductor and IC packaging industry.
iNEMI – covering product needs and identifying process issues.
IPC – covering mainly assembly and circuit board issues.

All three roadmaps are distinct but overlap; all three run on approximately a 2-year cycle. Overlapping membership ensures an overall consistency in the future vision although perspectives and opinions may differ. All three use time-based projections to identify technology evolution (e.g. pitch, i/o, power consumption, pad size, dielectric materials choice, etc.) and identify gaps in technology or the supply chain that need to be filled if we are to meet anticipated consumer needs. The linkages between roadmaps is illustrated in figure 1.

The 2004 iNEMI Roadmaps were developed by nineteen Technology Working Groups (TWGs), in response to inputs from representatives of OEMs in seven Product Emulator Groups (PEGs). The nineteen TWGs are identified in figure 2 and can be classified into four categories:

- Business Technologies – (Product Lifecycle Information Management (PLIM));
- Design Technologies (Modeling, Simulation, and Design; Thermal Management; Environmentally Conscious Electronics);
- Manufacturing Technologies (Board Assembly; Final Assembly, and Test, Inspection and Measurement);
- Component/Subsystem Technologies (Semiconductor Technology, Packaging, Interconnection Substrates – Organic and Ceramic, Passive and RF Components, Optoelectronics, Displays, Mass Data Storage, Energy Storage Systems, Sensors, and Connectors).

The 2004 iNEMI Roadmap consists of over 1200 pages, with more than 470 participants from over 220 companies, universities and associations from 11 countries. This document is intended to serve as a resource to all who are tasked with directing R&D (both funding and execution).

The roadmapping process does not explicitly identify disruptive technologies, but by identifying needs, particularly those for which there are no known solutions that meet the performance and cost requirements, members of the iNEMI roadmapping team implicitly identify areas for innovation and the utilization of disruptive technologies. As an example, the first NEMI Roadmap in 1994 determined that the introduction of area array packaging created a need for a new substrate technology. Recent concern in North America over the loss of manufacturing capabilities to China has stimulated discussion that North America must place greater emphasis on innovation and the development of disruptive technologies. iNEMI is committed to improving the roadmapping process to better identify disruptive technologies, find matches to current needs, and help anticipate new applications and products. As we move beyond the digital convergence of electronic products, we anticipate the merger of micro and nano chemical, mechanical, and biological sensors with micro and nano electronics for disruptive innovations in many areas.

In some cases the disruptive technologies may also find application by being embedded in conventional product embodiments. As an example, nano-particle fillers may enhance select properties of existing polymeric materials. These applications will likely result in new opportunities to extend the life of current materials and manufacturing infrastructure - enabling them to deliver enhanced device or component functionality.

Breakthroughs may take the form of disruptive technologies that supplant existing technologies. Examples of these are quantum computing systems, molecular electronics, and spintronics replacing CMOS semiconductor technology. Others may be radically new applications, such as sensor and drug delivery systems that detect emerging disease in the body or treat existing diseases. Such personal healthcare systems would give an added dimension to the iNEMI consumer and portable product sectors.

IDENTIFIED GAPS

Six strategic gaps have been identified from the 2005 iNEMI gap analysis:

Active device technology

The predicted end of traditional CMOS semiconductor scaling is generating significant reverberations in approaches and structures of computing systems. The first consequence is the gradual but certain reduction of emphasis on the frequency of microprocessor frequency metric, and the corresponding increase in importance of the system's throughput metric.

Thermal management

Another consequence of the expected demise of the traditional scaling of semiconductors is the increased need for improved cooling and operating junction temperature reduction due to large leakage currents and increase in chip power.

Increased serial communications bandwidth

The third consequence of the end of the traditional semiconductor and the gradual but certain reduction of emphasis on the frequency of microprocessor metric, and the corresponding increase in importance of the system's throughput metric, is an increased demand for higher bandwidth to and from the microprocessor in any system. Current designs have already utilized 3-6 Gbps data rates, and designs in the near future are expected to increase this bandwidth capability to 10-12 Gbps for electrical interconnects. At some point, circa 2010-2015, the limits of electrical transmission in high performance systems may be reached. Optical systems are likely to provide part of the solution, particularly if Optical ICs are developed.

Next generation packaging technology

Every score of years the electronics industry has introduced a new generation of packaging technology, which has taken a decade to develop. It is very apparent that a new generation of low-cost packaging technology will be required during the next decade. This new generation will need to interface with the interconnect structures of the new nano-devices, provide the required thermal cooling and electrical performance, and be compatible with a number of devices and applications including rf, optical, sensors, MEMs, and biological. This next generation packaging technology will require materials with enhanced properties and advanced manufacturing processes to address the rapidly decreasing dimensions and cost expectations.

Design and simulation tools

The lack of tools for mechanical, electrical, thermal, environmental, optical co-design from the device to the system level is delaying the introduction of new technology. Significant research and development is needed both in tools and techniques for effectively partitioning the design and simulation. The new simulation areas that need research (Opto, Nano-Scale / Spintronics) will become critical after 2007. Simulations related to nanotechnology could have a large impact on the semiconductor and the electronic materials industry. It is clear that an increase in an unusual combination of business and quantum-mechanics perspective is required for nanotechnology to be successful. Proper funding of simulation tools will be critical to nanotechnology growth and funding will be contingent upon business conditions going forward.

Sustainability metrics

The concept of sustainability is being widely adopted and promoted by companies throughout the electronics supply chain as a core tenet and measure of performance of their business operations, largely in response to heightened interest by stakeholders in corporate social and environmental responsibility. There is currently no industry-wide consensus on how to measure or report sustainability. While there are differing views on the degree to which such comparisons are practical or useful, the electronics industry would benefit greatly from a more unified, coherent and meaningful approach to sustainability reporting.

POTENTIAL SOLUTIONS FOR THE IDENTIFIED GAPS

The potential solution to three of the six strategic gaps may be the innovative use of nanotechnology: New nano-device structures or nano-scale CMOS extensions will likely provide the next generation device technology. New material structures with embedded nano-particles will likely play a role in thermal management and the next generation of packaging technology.

On the other hand, the use of materials with nano-fillers, or active nano-devices will put increasing pressure on closing the gap in design and simulation tools. Also the potential environmental impact of nano-devices and new nano-materials will need to be proactively addressed.

FIRST iNEMI PROJECT UTILIZING NANOTECHNOLOGY

iNEMI has established its first project that utilizes nanotechnology to close a tactical gap. The project, Pb-free Nano-solder: The Application of Nanotechnology to Suppress Non-Lead Solder Reflow Temperature, is investigating the feasibility of using nano-metallic spheres to reduce the melting point of Sn-Ag-Cu (SAC) alloys. The objective of this project is to develop a SAC solder paste with the same melting point as Sn-PB eutectic solder.

CONCLUSION

In the next ten years we will see a dramatic upheaval in the electronics industry as we try to find the replacement for CMOS in order to continue Moore's Law - as well as enhance CMOS technology to take us forward until the technology is ready. This impact will be felt not only at the device level, but also at the package and system level. A key focus will be package and substrate technology, which provides the bridge from the device to the system. Nanotechnology may provide the solutions to six of the strategic gaps identified by the iNEMI gap analysis process.

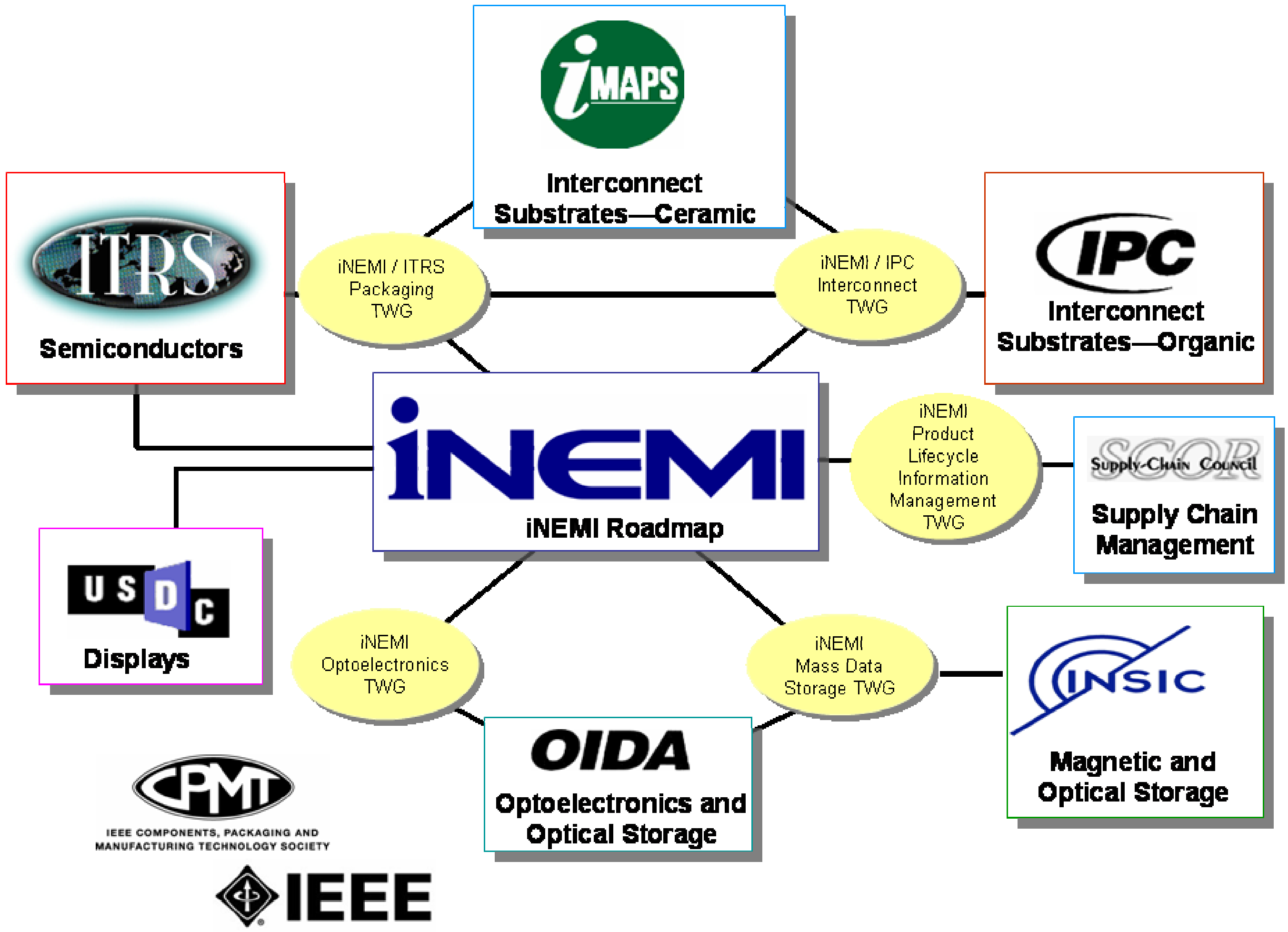

Figure 1. Roadmap linkages.

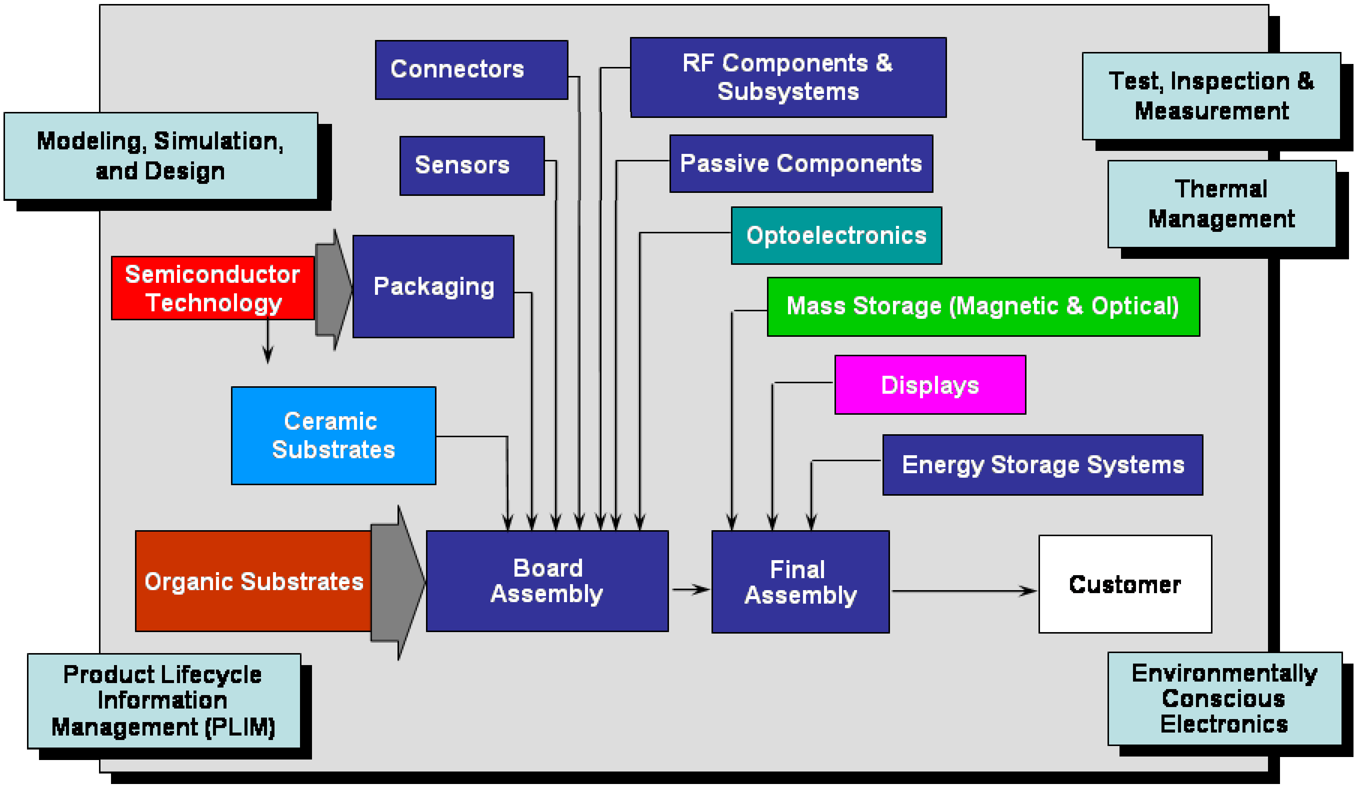

Figure 2. 2004 iNEMI Technology Working Groups (TWGs)