

Emerging Markets and Emerging Technologies

R. C. Pfahl, Jr., James B. McElroy, Sr.
International Electronics Manufacturing Initiative (iNEMI),
2214 Rock Hill Road, Suite 110,
Herndon, VA 20170 USA

Abstract

Last year we discussed “Innovation Priorities” at this meeting. Since then iNEMI has completed its 2007 Roadmap. Our roadmap identifies that while digital convergence occurs ever more rapidly for existing markets, the key emerging markets are those with social value such as health care, energy, and security. To address both converging markets and emerging markets, iNEMI is focusing its project agenda on the technology to support minaturization; high reliability medical electronics; and energy and the environment. The technology to meet these focus areas includes system in package, energy storage and conversion, sensors, advanced manufacturing processes, and advanced materials. This article not only highlights projects that iNEMI is establishing to support these focus areas, but also the gaps in technology that we have identified, from the 2007 roadmap, which may limit the growth of the electronics industry during the next decade. Given the limited resources available for industry, academia, and governments to apply, it is crucial that R&D efforts focus on these high priority knowledge gaps.

Emerging Markets

As the electronics industry matures, many product segments are entering the commodity phase of the lifecycle. Accordingly, breakthrough technology may no longer be sufficient to ensure business success. Customers are demanding the right solution at the right cost from winning enterprises. This drives a whole series of business behaviors that are quite different from the past. The OEMs (Original Equipment Manufacturers) are looking to identify the “Next Big Thing.” The electronics industry is completing a major restructuring, moving the center of manufacturing competence from the OEMs to the EMS (Electronics Manufacturing Services) providers and ODMs (Original Design Manufacturers).

- Business models in the electronics industry have changed - leading to significant shifts in roles and responsibilities across the supply chain.
- There has been a dramatic movement of manufacturing and manufacturing support to China from North America, Europe, and other Asian countries because of: 1) a low-cost, highly skilled workforce; and 2) a massive market opportunity.
- Supply Chain Management (SCM) offers the potential to increase productivity.
- The ability for supply chains to support Pb-containing and Pb-free bills-of-material (BOMs) is providing significant challenges and increasing investments.

- The increasing scope of outsourced operations requires loosely coupled business processes spanning multiple companies and continents.

Regulatory

Two European Union Directives, RoHS (Restriction on use of certain Hazardous Substances) and WEEE (Waste from Electrical and Electronic Equipment), which govern the material content and end-of-life management of electronic products, were implemented on July 1, 2006 and August 13, 2005, respectively. Legislation impacting the design and recycling of electronic products is being enacted throughout the world including China.

- Environmental legislation in various product segments requires the electronics industry to share detailed material content data of their products and components.
- To meet regional legislative requirements, manufacturers must remove environmental “Materials of Concern,” such as lead.
- A number of “High Reliability” product manufacturers are taking Pb exemptions under the EU RoHS, and requiring a dual supply chain for components.
- The electronics industry is facing end-of-life or producer responsibility legislation.

Market

The boundaries between computers, communications and entertainment products are blurring. Large, flat panel displays are experiencing rapid growth. Wireless products, particularly WiFi and Bluetooth, are now widely used, and digital cameras are merging into cellular phones.

Home and office functionality is being added to automotive products. RFID systems are being used for security and increased efficiency of commerce. The needs of the telecommunication and data communication infrastructure are converging. With the move to all digital communications and storage we see the convergence of a number of markets:

- Medical-Consumer
- Automotive-Entertainment
- Communication-Entertainment
- Computing-Entertainment

Prismark Partners predicts market growth as follows:

- Worldwide production of computers and office equipment is expected to reach \$431Bn in 2006, and grow at an average rate of 5.4% per year to reach \$532Bn in 2010, driven by business and individual consumer spending. This is the largest segment of the \$1.2Trn electronics industry, accounting for about 36% of overall equipment production.

- Global production of communications equipment is expected to reach \$176Bn in 2006, representing about 15% of the electronics industry. This segment is expected to increase at an average rate of 7.9% per year to reach \$239Bn in 2010.

- Portable and consumer electronics production will reach \$267Bn in 2006, following several years of exceptional growth. Overall, the consumer electronics segment is expected to increase at an average rate of about 3.4% per year to reach \$305Bn in 2010.

- Medical electronics equipment production will be \$53Bn in 2006, accounting for about 4% of the global electronics industry. This market is expected to continue to increase at an average rate of 5.6% per year to reach \$66Bn in 2010.

- In 2006, over 3Bn SiPs were assembled. By 2010, this number is expected to reach 6.65Bn, growing at an average rate of about 17% per year.

Emerging Technology

The end of traditional 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 microprocessor frequency metric, and the corresponding increase in importance of the system's throughput metric. This shift in the system's performance metric will generate an increased demand for higher bandwidth to and from the microprocessor. 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.

This roadmap did not identify a major need for optical transmission within high performance printed wiring boards during the next decade. Growth in silicon device size is slowing.

- The rate of reduction in feature size has resumed a three-year cycle, its historical rate.

- RF System-in-Package (SiP) applications have become the technology driver for small components, packaging, assembly processes and for high density substrates.

- SIP continues to be the fastest growing packaging technology, although still representing a relatively small percentage of the unit volume.

- LCD and plasma displays are taking over the CRT market, while OLED (Organic LED) has the promise of providing thin, lightweight – even roll-up – display technology that could compete with LCDs.

- Application of MEMS technology is making new capabilities feasible in a number of old and new markets such as microphones, displays, servo control for mass data storage, and optical and RF switches.

- A number of alternative approaches to today's established data storage technologies will develop over the next decade. These include magnetic random access memory (MRAM), probe-based, molecular, fluorescent multilayer

optical, near-field optical and 3-D holographic storage components and systems.

- Li-ion and Li-ion polymer electrolyte batteries have become the dominant rechargeable energy sources across the entire portable electronics segment.

Highlighted Needs

Significant needs and trends in Design Technologies, Manufacturing Technologies, and Component/Subsystem Technologies were identified in the 2007 iNEMI Roadmap efforts. They are already affecting electronics manufacturing and the way we do business.

Design Technologies

Design and simulation tools are the main roadblocks to more rapid introduction of new technologies by OEMs in a number of rapidly developing areas:

- Mechanics and reliability modeling.
- Thermal and thermo-fluid simulation.
- Co-design of mechanical, thermal, and electrical performance of the entire chip, package, and associated heat removal structures.

- Improved design tools for emerging technologies like embedded passives and nano-materials.

- Integrated design and simulation tools (circuit, EM, thermal, mechanical, manufacturing, etc.) for higher functionality in mixed-mode wireless chips and modules.

Commercial design for manufacturability, test, and assembly tools are needed by the EMS firms to increase manufacturing productivity and reduce costs.

Manufacturing Technologies

With research and development (R&D) responsibility shifting from OEMs to the EMS companies, government, academia and industry consortia need to formulate new ways to adopt and develop emerging technologies (such as nanotechnology) into the manufacturing process. These new approaches will have to be consistent with viable business and funding models (see Strategic Concerns) required to create new industrial infrastructures.

- Process development to accelerate miniaturization.
- Advanced board assembly processes that support three-dimensional structures and low temperature processing.

- Product traceability.
- Lower testing costs, particularly for new non-digital technologies.

Component/Subsystem Technologies

- Implementation of advanced, non-classical CMOS device with enhanced drive current.

- Medium-power, low-loss, high-selectivity filters and wideband filters for consumer and portable products.

- Higher thermally conductive materials, such as carbon nanotubes, carbon fiber, aluminum nitride, and even diamond, to cool optical and electronic devices. Cost reduction for flat panel displays if CRTs are to be fully displaced.

- In-circuit test technologies that can be incorporated into the build process.

- Low cost, high density, high performance substrate technology.
- Lower dielectric constant materials to improve the performance of high-speed digital systems.
- New technologies and materials for next generation optical storage devices.

Paradigm Shifts

Many of the Technology Working Groups identified paradigm shifts that are taking place now and potential paradigm shifts that might occur in the future. This information is critical for infrastructure providers to identify where non-linear changes may occur in the future. These changes provide both opportunities and risks for individual firms.

The need for continuous introduction of complex, multifunctional new products to address the converging markets identified in 2004 has continued to favor the development of functional, modular components or SiP. This paradigm shift in the design approach increases the flexibility and shortens the product design cycle, and places the test burden on the producers of the modules.

The standard platform movement that is developing in the telecom market is helping to address the disrupting and disaggregating of both the design chain and the supply chain. This movement could accelerate the introduction of new functions by making them easier to do. Further, it could create efficiencies and opportunities for higher volume niche operations such as circuit faceplates or thermal solutions or CAD templates. Telecom, computing, IT, and military sectors are affected.

Flash memory has become the mass storage medium of choice for many mobile applications, such as digital still cameras, MP3 players and cell phones, due to its low cost (in lower capacity points than hard disk drives) and greater ruggedness than alternative storage devices. Flash memory has also replaced floppy disks as the universal transfer medium in the form of USB flash drives; and it appears poised to play an important role as write cache memory in hybrid hard disk drives for mobile applications.

Other paradigm shifts identified in the 2007 iNEMI Roadmap include:

- Manufacturing organizations are producing smaller batches more frequently.
- MEMs are becoming important as microphones.
- Communication devices are changing from single band to powerful devices with transparent accessibility in heterogeneous networks.

- Computing devices are becoming communication devices and vice-versa.
- This roadmap identified a push out in the need for optical transmission within high performance printed wiring boards.

Emerging or potential paradigm shifts, identified in the 2007 iNEMI Roadmap include:

- Multichip modules are being replaced by integrated RFICs in many portable communication products. The trend will be completed for cell phones and other transceivers, excluding power amplifiers (PAs), in the next one to two years, and will even include PAs within the next five years.
- A transition from analog to digital sensor architectures for automotive applications.
- Nanotechnology will be a very disruptive technology during the period covered by this roadmap.
- Energy storage system technologies that may present new opportunities include fuel cells and high power batteries for hybrid electric vehicles.

Strategic Concerns

The restructuring of the electronics industry over the last decade from vertically integrated OEMs to a multi-firm supply chain has resulted in a disparity in R&D needs versus available resources. Critical needs for research and development exist in the middle part of the supply chain (IC assembly services, passive components, and EMS assembly) as illustrated in Figure 1, and yet these are the firms least capable of providing the resources. A partial solution has been the development of vertical teams to develop critical new technology while sharing the costs.

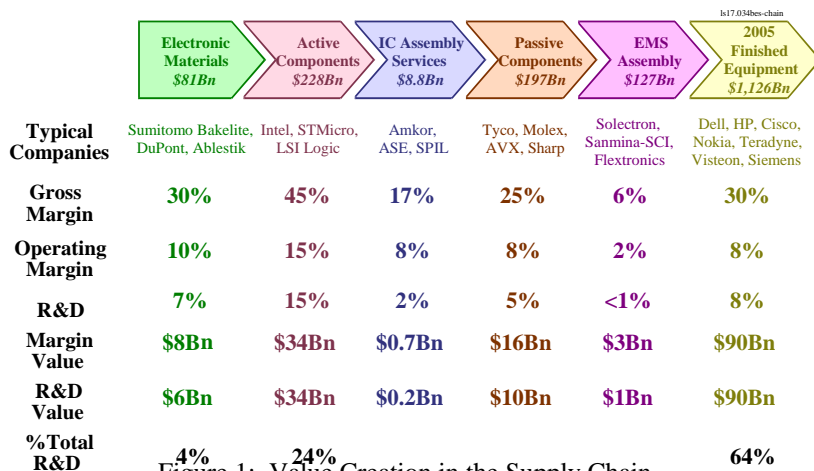


Figure 1: Value Creation in the Supply Chain
(Courtesy of Prismark Partners)

Other strategic concerns include:

- With R&D responsibility transitioning to the EMS companies in low cost geographies, government, academia and industry consortia will need to formulate ways to adopt and develop emerging technologies (such as nanotechnology) into the board assembly process and higher functional units within the global outsourcing environment.
- Consumers are increasingly concerned about the impacts that electronics products may exert regarding safety, energy usage, and environmental impact. These concerns need to be addressed proactively by the industry.
- Harmonization of environmental regulations for electronic products through international standardization.
- The ability for the supply chain to support both Pb-containing and Pb-free bills-of-material will provide significant challenges and investments for some time to come.
- The materials supplier base does not have adequate demand at a high enough sales price to drive many of the needed new materials developments. As a result, materials developments are not keeping pace with the demand.
- The disaggregated supply chain is leading to non-optimized packaging solutions and delaying the introduction of technology.
- Improvement in the productivity of design, test, and modeling software is becoming critical throughout the supply chain.
- There needs to be increased emphasis on “DfX” to aid the EMS firms in reducing cost and accelerating new product introduction.
- The mechanisms for cooperation between industries, and among researchers working in all advanced technologies, must be strengthened. Cooperation between OEMs, EMS firms, and component suppliers is needed to focus on the right technology and to find a way to deploy it in a timely manner.
- Disruptive technology offers opportunity for innovation. In order to ensure success, the supply chain must be willing to invest with a long-term perspective in mind.

Identified Gaps in Materials, Packaging, and Sensors

Design

The increasing OEM focus on time-to-market and the complexity of emerging technology will require significant development and investment in design tool infrastructure. The following areas need increased research and development:

Mechanics and reliability modeling.

Thermal and thermo-fluid simulation.

Co-design of mechanical, thermal, and electrical performance of the entire chip, package, and associated heat removal structures.

Simulation tools for nano devices and materials.

Improved design tools for emerging technologies like embedded passives and optoelectronic PWBs.

Integrated design and simulation tools for RF modules and devices.

Electronics manufacturing simulation and modeling tools for the designer.

Manufacturing Technology

Two major strategic needs generate the recommendations in manufacturing technology: the miniaturization of products and the need for simplified, next generation assembly processes:

Explore and demonstrate the application of low temperature and room temperature attachment technologies to the SMT assembly process, including biomimetic-based dry adhesive technology.

Develop automated printing, dispensing, placement, and rework equipment capable of the pitch requirements for SiP package assembly at current process speeds.

The ceramic substrate interconnection technology industry must make a conscious effort to adopt innovative technology to provide cost-effective electronic system solutions.

The development of new approaches to organic substrate fabrication that address needs for dramatic increases in density, reduced process variability, improved electrical performance, and radical reductions in cost.

Government, consortia and academia need to focus research funding on final assembly manufacturing processes for the electronics industry.

Materials Development

A combination of materials and fabrication research is needed to support the development of monolithically integrated optics and electronics that take advantage of the electronics infrastructure.

Technology development is needed in areas such as “optical solders” and board level wave-guides to enable more complex and higher density, board level products.

Low cost, higher thermal conductivity, packaging materials, such as adhesives, thermal pastes, and thermal spreaders.

Next generation of solder materials to replace the high cost/high temperature silver containing alloys.

New interconnect technologies deploying nano-materials to support decreased pitch and increased interconnect frequencies.

High-performance laminates that are competitively priced.

Clearer specifications for new materials which are supported by a broad base of customers, to increase market size and reduce the risk for materials R&D.

Energy and the Environment

Develop and implement scientific methodologies to assess true environmental impacts of materials and potential trade-offs of alternatives.

Fund a multi-stakeholder project to do environmental LCA and economic analyses with the goal of identifying a preferred e-waste recovery and recycling system.

The electronics industry needs to be more involved in policy making on material restrictions so that policy makers understand trade-offs inherent in material substitution.

Develop cost-effective, energy efficient power supplies.
Systems

Advanced cooling systems such as high performance heat pipe, thermoelectric cooling technology, and direct liquid cooling technology need to be developed.

Fuel cell systems, lithium-metal/SPE technology, and thin-film batteries have the potential of providing very high energy density and specific energy. These technologies are recommended for further development on an R&D level.

iNEMI Projects to close these gaps

Based on the results of the iNEMI 2005 Innovation Leadership Forum, iNEMI selected three focus areas for projects: minaturization; medical electronics; and energy and the environment. The following three sections give an example of projects established to address gaps in these focus areas

Minaturization: Warm Assembly Projects

The thermal excursions associated with mass reflow, which is typically used in SMT processes, present a reliability risk to temperature-sensitive components used in electronic assembly, especially with higher-temperature Pb-free assembly processes. Low-temperature or room temperature assembly processes have the potential to improve field reliability, streamline manufacturing, and reduce cost. Some of the approaches also offer the opportunity to increase I/O density which could facilitate the future miniaturization of electronics assemblies. The Board Assembly TIG is planning a series of projects to investigate "warm assembly."

The first effort to be organized as part of the Warm Assembly initiative is the Nano-Attach Project, which is looking into nano-attach techniques, such as nano-velcro and biomimetic dry adhesive. Both offer promising solutions.

Medical Electronics: Medical Components Reliability Specifications

Medical products increasingly rely on electronics for their functionality, and there are unique reliability and operating condition requirements for these components. This new project is working to develop testing and use condition guidelines to help assure reliability of electronic components used in medical applications. Leveraging industry knowledge and existing standards, the project team plans to create a minimum set of requirements for electronic components used in implanted or life-critical devices.

Energy and the Environment: Pb-Free Nano-Solder Project

This iNEMI effort is investigating the application of nanotechnology to suppress Pb-free solder reflow temperature. Pb-free materials and products require the use

of solders that have higher melting points than SnPb solder and, therefore, require higher processing temperatures. Higher reflow temperatures can negatively affect product reliability, require tougher qualification requirements for components, and sometimes result in significant changes in manufacturing processes.

The goal of the iNEMI Pb-Free Nano-Solder Project is to research and develop a nano-solder paste that can effectively suppress the melting point temperature of Pb-free solders. The team plans to demonstrate the feasibility of such a solution, and to demonstrate manufacturability and joint reliability. The project is planned as a four-phase effort: (1) research, develop and demonstrate a nano-solder paste; (2) demonstrate manufacturability; (3) demonstrate joint reliability; and (4) develop/demonstrate manufacturing equipment.

Summary

This article has highlighted the converging and emerging markets for electronics. It also highlighted emerging technology and a number of gaps that call for industry attention. iNEMI is establishing projects that will address a number of the identified gaps; however, we have also identified gaps in technology that may limit the growth of the electronics industry over the next decade. Given the limited resources that industry, academia, and governments can apply, it is crucial that we focus R&D efforts on these high priority knowledge gaps. Later this year iNEMI will publish the *2007 iNEMI Research Priorities*. We hope that the research community will study and utilize this document and to set their agenda to match identified needs.

Acknowledgments

We wish to thank the more than 500 volunteers from the electronics industry who helped create the 2007 iNEMI Roadmap. We also welcome participation in the creation of the 2009 roadmap which we will begin working on in the fall of 2007.