HIGHLIGHTS OF 2011 iNEMI TECHNOLOGY ROADMAP

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ABSTRACT

iNEMI released its 2011 Technology Roadmap to industry on March 29, 2011. The Roadmap covers six product segments and 21 technology areas pertinent to electronics manufacturing. Every two years iNEMI maps future manufacturing technology needs of the global electronics industry for the next ten years. It discusses the major business and technology issues, paradigm shifts, emerging technologies and markets, technology gaps, and identified needs in each of six product segments: aerospace/defense, automotive, consumer/portable, medical, Netcom, and office/large business systems. This paper highlights two product sector chapters (Automotive, Medical) and three technology chapters (MEMS, Packaging, and Environmentally Conscious Electronics).

INTRODUCTION

The iNEMI roadmap charts future opportunities and challenges for the electronics manufacturing industry. Our widely utilized roadmaps influence Research & Development (R&D) investments and technology deployment around the world.

Updated every two years, the roadmap sets direction for technology development and deployment by predicting future packaging, component and infrastructure needs and describing critical technical and business elements required to support industry growth. This information provides the basis for collaborative projects undertaken by our members (via iNEMI's Technology Plan Document) as well as research priority focus for the global electronics industry (as identified in iNEMI's Research Priorities Document).

ROADMAP PROCESS:

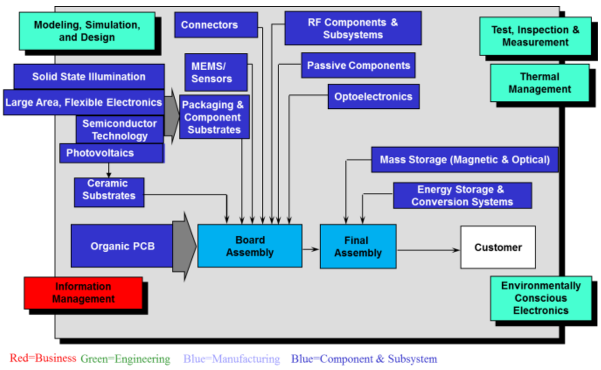

Figure1 Twenty-one TWGs

The 2011 Roadmaps were developed by twenty-one Technology Working Groups, in response to inputs from representatives of OEMs in six Product Emulator Groups. These are; Automotive, Medical, Consumer / Portable, Office / Large Business Systems, Netcom - Network / Datacom / Telecom, Aerospace / Defense.

The leading electronic systems manufacturers are basing their strategic planning for new products on the assumption that the electronics infrastructure will develop and implement the technology to meet these key drivers.

SITUATION ANALYSIS

BUSINESS:

The electronics industry has done better than most in seeing solid growing demand in many of the market segments – in spite of the economic conditions – as consumers continue to demand creative new products that can improve productivity, facilitate ubiquitous communication and entertain.

Rapid consumer product lifecycles quickly drive premium pricing towards commodity levels with only the most creative products enjoying a relatively longer period of healthy margins at the OEM level.

Asia continues to enjoy a very high percentage of electronics manufacturing. Security concerns, rising transportation costs, and an increasing emphasis on sustainable business practices have recently had the effect of slowing down this movement in some segments.

REGULATORY:

Regulatory requirements continue to expand on a global basis both in terms of new directives as well as expansion of existing laws and guidelines. We are now seeing an explosion of new requirements from many regional, national, and local governments. Industry is struggling to keep up with the ever expanding portfolio of regulations.

• To meet regional legislative requirements, manufacturers must remove environmental "Materials of

Concern”. The list of banned materials is expanding with no end in sight. Harmonization of global requirements is a major challenge.

• “High Reliability” product manufacturers are vulnerable as they are being pressured into using new materials for which reliability may not be well understood.

• Determination of carbon footprint is an expanding requirement on industry with significant challenges remaining to deploy consistent methodologies.

MARKET:

The boundaries among computers, communications and entertainment products have blurred. Flat panel displays are the norm for virtually all applications with touch screen becoming more prevalent in a number of product categories. Wireless products continue to proliferate, and this expansion is opening up new applications in a number of segments. Home and office functionality is being added to automotive products with growing concerns over driver distraction. The needs of the telecommunication and data communication infrastructures 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
• Computing-Security

TECHNOLOGY

Multi-core processors are now the norm for most computing applications. A 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. The consumer’s demand for thin multifunctional products has led to increased pressure on alternative high density packaging technologies. High-density three-dimensional (3D) packaging of complete functional blocks has become the major challenge in the industry.

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

• The use of motion-gesture sensors in various consumer and portable devices will expand the MEMS gyroscope landscape (both 2D-axis and 3D-axis), and is expected to see an exponential growth.

• RFID finally will be replacing the barcodes and 2D identification and a number of OEMs will integrate to Information Technology (IT) systems for tracking Printed Circuit Boards (PCBs) and full system level products.

• Performance requirements such as increased bandwidth and lower power are driving the 3D ICs designed with through silicon vias.

Medical Product Sector

As the medical electronics market matures and develops, a wider group of companies has begun serving this growing market due to sustained growth, and higher margins than traditional electronics assembly markets. This growth has lead to the need for better understanding of the technical challenges associated with medical electronics manufacturing. This is reflected in the shift of focus within the electronics industry and within iNEMI to concentrate on the medical product sector. While this product sector encompasses traditional or widely known products such as; implantable medical devices, information technology used for patients’ records, medical diagnostic tools, and monitoring devices, the medical electronics market is being currently fueled by an explosive growth in personal medical electronics. The shift towards home or patient centric health care has lead to a very rapid growth in personal healthcare monitoring, diagnostic and preventative medical electronics. Examples, such as glucose monitoring, pedometers, external portable defibrillators, thermometers, women’s health products and others, are a few products readily available at a local pharmacy or department store. In addition, the drive towards patient records portability has spurred a growth in information technology in the medical sector as healthcare providers and insurance companies strive towards global accessibility of personal health records of patients.

Situation Analysis

Aging of the population is a world-wide phenomenon. The most dramatic growth is expected in many smaller and/or developing nations. For example, Latin America will exhibit a dramatic increase in the elderly, especially in countries such as Cuba, Puerto Rico, Chile, and Trinidad and Tobago. Over the next 3 decades, the aging index is expected to double or triple..

Market Size Prediction

In a similar fashion to the last roadmap cycle, iNEMI has asked Prismark to provide a range of direct support services related to the synthesis and production of its upcoming bi-annual roadmap.

- Prismark estimates that medical electronics equipment production totaled $76Bn in 2009, accounting for about 6% of the global electronics industry. This market is expected to continue to increase at an average rate of 5% per year to reach $103Bn in 2015. Other than military and aerospace electronics, medical electronics was the only sector not to experience a decline in 2009 compared to 2008, and actually grew by about 7% year-over-year.

  Most medical electronics systems by value are produced in North America today. However, Asian countries, such as China and India, are the fastest growing markets for medical equipment, and leading medical electronics companies, such as Siemens, GE, and Philips, are increasing product design and assembly capabilities in these countries. One unique aspect of medical electronics produced in developing markets is that primarily, the products are being produced for local/regional use rather than for export. Some notable exceptions, however, are in Malaysia and Singapore, where contract assembly houses have sought and received certification to produce medical products. Most of those goods are external portable or sensory products (thermometers, blood pressure sensors and similar).

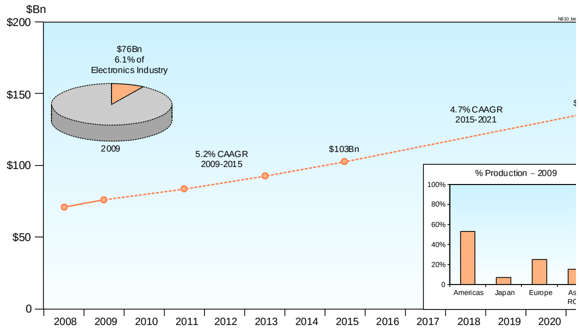

Figure 2: Prismark Partners estimate of medical market size.

Product Classification in Medical Sector

Equipment

- *Large Infrastructure Medical Equipment* includes products such as medical imaging systems (e.g., x-ray and MRI), IT equipment (e.g., picture archival communication systems PACs), and biochemical analysis equipment (e.g., lab instruments and DNA analyzers).
- *Small Stationary and Portable Medical Equipment* includes products such as patient monitoring systems that are used to measure and monitor patients' vital signs and other bodily functions. The segment also includes home diagnostics products such as blood pressure cuffs (including wireless), blood glucose meters, pulse oximeters, and biochemical analysis meters.).
- *Implantable Medical Equipment* includes major therapy devices such as pacemakers and implantable cardioverter defibrillators (ICDs), and the market is rapidly expanding beyond these systems. Devices such as neurostimulators (e.g., for Parkinson's disease) and drug pumps (e.g., for insulin release) are also being brought to market. Increased reliability, greater functionality, and miniaturization are the main technical drivers in this segment.

IT Sector

- Office Information Technology: The final category includes devices that store and manage patient data and move information for the medical community, as well as novel personal health devices that may be brought to the health care provider's office and health information is downloaded. These devices may not have regulatory or form factor restrictions. The devices in this category include Picture Archival Communication Systems, (PACS), telemedicine devices, electronic health records carried by the patient, and computers in the medical offices, to name a few.

Critical Issues

There are three critical issues that impact the medical products group, that are unique to the sector, and are difficult to control, influence or affect. The first is the growing uncertainty of the Pb-free solder issues and long term availability of Sn-Pb components. The second and third are non technical issues, but are broadly impacting. They include the growing litigation in society that is expanding the overhead of regulatory organizations in the Americas, and the third is the high rate of cost escalation and hospital insolvency.

Automotive Product Sector

The main factor that distinguishes the Automotive Product Sector Emulator from the other iNEMI (International Electronics Manufacturing Initiative) Product Emulators is the environment in which the product must perform. The products must perform reliably in automobiles, light-duty, medium-duty, and heavy-duty trucks. Many of the attributes, such as cost, density, and components, overlap into the other emulators. Increasing density is important for these applications because of cost, size, and weight reductions. The assembly and manufacturing / test equipment requirements are also critical because of the reliability requirements.The challenge for the Automotive Product Sector Emulator is to adapt other emulators' technologies to meet the high temperature, environmental, and reliability requirements cost effectively.

Market Size Prediction

The automotive electronics industry is approximately 9% of global electronics production and was $114 billion in 2009. Growth is expected to increase about 8.9% per year through 2015. This growth rate is driven by a disastrous 2009 used as the base year, combined with an increase in average electronic module content per vehicle, and very strong unit car sales growth in Asia. In 2009, China surpassed the U.S. as the largest car market in the world.

Situation Analysis

The major trends driving the demand for increased electronics penetration in automobiles include:

- Stricter fuel economy and emissions mandates
- Legislated requirements for advanced safety systems, such as advanced airbags and on-board tire pressure monitoring
- Consumer demand for greater vehicle efficiencies driven by escalating global crude oil prices

- Consumer demand for greater safety, comfort, and convenience features
- Consumer demand for luxury features
- Growth of hybrid and electric vehicles

Given very rapid growth in local car production and the gradual shift to low cost production in Asia, Asia now accounts for the majority of production value of automotive electronics, with about 37% share in 2009. This region is followed by Europe with 31% production share, Japan with 17% share, and the Americas with 16% share.

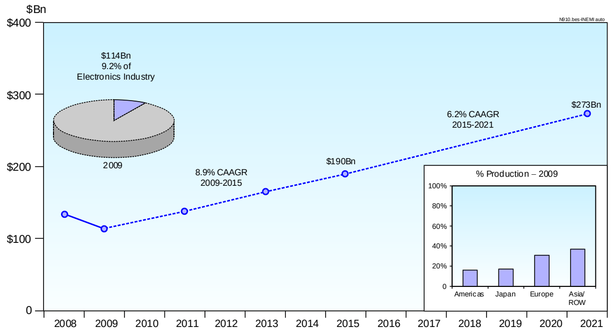

Figure 3: Prismark Partners' estimate of Automotive Electronics market size.

Embedded and non-embedded sensors are used in many automotive systems. Many of these sensors are MEMS devices. MEMS applications for the automotive sector have come a long way since the introduction of a micro-machined MAP sensor in 1979. An average car today consists of over 40 different sensors, ~30% of which are micro-machined. Application areas include engine management, passenger safety and comfort as well as environmental care. A new emerging application area is the office and entertainment sector, which will require devices such as integrated microphones and devices for optical signal handling. In addition, wireless systems such as direct tire pressure have been introduced in the last year.

MEM automotive application areas can be broadly classified as shown below,

- Integrated sensors for pressure (MAP, Fuel, Occupant Detection, Tire, Air Bags), acceleration, non contact temperature, airflow, fuel flow, angular rate (Electronic Stability Control, Roll Over) sensor.
- Gas/Chemical sensors for in-cabin air quality, monitoring exhaust gas composition and oil quality.
- Actuators/valves for fuel injection
- Optical/Infra-Red sensors for in-car LANs, HVAC control, Occupant Sensing, Night-Vision and in-vehicle displays.
- Polymer based sensors for humidity detection
- Radar based sensors for Back-up Aid, Blind Spot Detection, and Adaptive Cruise Control

Key Drivers: Cost, Size, Quality, Reliability

The key driver for the automotive sector is cost. All other drivers are assumed to be met and cost is often used to determine the company that wins..

Size is also a premium in the automotive environment. Space in the passenger compartment, engine compartment, on-engine, and on-transmission are limited. The supplier that offers a smaller box that is equal or better in cost has an advantage. Some higher end vehicles can have up to 100 electronic controllers in a vehicle.

Quality is a key metric that all automotive suppliers are measured on by using Assembly Plant Returns (APR). This metric is kept in parts per million (ppm). Assembly Plant Returns are returned to the supplier for root cause and corrective action.

Reliability is measured in warranty returns from the field. Warranty rates are calculated for 30, 60, 90, 180, and 360 days of exposure in the field. This metric is measured in Incidents per Thousand Vehicles (IPTV).

Critical (infrastructure) Issues

There are several paradigm shifts occurring now in the automotive sector. The first is the electrification of the vehicle.

The second paradigm shift is the connected vehicle. Internet access in the vehicle will grow to 62.3 million vehicles by 2016.

The third paradigm shift will be the advancement of safety systems. Systems like adaptive cruise control to maintain a safe distance. Systems that detect vehicles in blind spots, warn if a driver is falling asleep, help see at night and/or in foggy conditions. Systems that detect lane departures and systems like vehicle stability control that help the driver maintain his or her commanded path. Many of these systems already exist today. The key is to reduce their cost so that lower end vehicles can afford these systems.

MEMS

Similar to discrete sensor technologies, Micro-Electro-Mechanical Systems (MEMS) have an extremely diverse application set, ranging from physical to optical, chemical, and biological, as well as a diversity of materials and methods used to manufacture them. A first impression of MEMS would undoubtedly start with the theme of miniaturization for realizing ever-smaller sensors and actuators. However, where they truly stand apart is by the integration (also referred to as co-integration) of added functionalities: combining sensing and actuation operations with information processing, signal conditioning, built-in test, and communications. MEMS technology is a child or ancillary innovation of semiconductor electronics much as people have pointed toward the information technology being an ancillary innovation of semiconductor technology. However, MEMS diversity, including front end manufacturing techniques, back end manufacturing techniques, required testing procedures, diversified materials and the lack of a unit cell or standardized precursers such as the transistor and MOS or Bipolar technologies, make the MEMS manufacturing activity much more like a job shop than a High Volume Semiconductor facility.

MEMS are the second wave of micro manufacturing which emphasizes the mechanical nature of materials often used in semiconductor manufacturing. The three main manufacturing technologies for MEMS are: Bulk Micromachining, Sacrificial Surface Micromachining and HARM or High Aspect Ratio Micromachining. Both Bulk Micromachining and Sacrificial Surface Micromachining use materials similar in nature to semiconductor materials for the most part but HARM based products have exceptionally larger materials selection (including plastics).

Most of today's leading applications of MEMS are found in office automation (inkjet), firms that initiated their efforts in office automation and found other market avenues (TI's DMD) and the current application in the portable consumer electronics market, such as the mobile phone and electronic gaming systems, has resulted in new directions for growth in the industry. The recognition of the consumer's desire for MEMS manufacturers are responding to this demand by increasing functionality, adding more axes of inertial sensing, developing new devices such as micro speakers, and pico projectors, for example, and adding intelligence (information processing) and new interfaces (communications). This says nothing about the myriad of biomems devices both current and future that promise to reinvigorate the industry still again.

Market

The MEMS Market is diverse, with solutions for a wide variety of applications. The MEMS market is rebounding in 2010 after two years of recession in 2008 and 2009. The CAGR of the next 5 years for the MEMS industry is estimated to be close to 11% compared to 6% for the IC industry according to the IC insight MEMS 2010 report. Out of the 7B$ of 2010 MEMS market, more than half of it should come from consumer and automotive applications.

The Automotive industry sector is a very large market for MEMS and all cars on the market today are equipped with multiple sensors. Looking forward, more attention is being placed on new clusters of inertial sensors for electronic stability control (ESC) in an effort to avoid crashes. Automakers must include ESC as standard equipment on new U.S. cars by the 2012 model year.

Europe announced that it will also force ESC and Japan should shortly announce the same. ESC is making use of accelerometers and gyros.

Standardization

The global competition to manufacture high-volume innovative products with enhanced functions and performance enabled by MEMS/NEMS is intense because nations want to strengthen their economies and create new jobs for their citizens. International standards and their associated metrologies are significant enablers for success at all stages of MEMS/NEMS innovation - from research, development, initial deployment, high-volume commercialization, end of initial useful life, to recycling and disposal. Successful MEMS/NEMS innovation requires international standards based on the best of science and engineering.

The MEMS industry requires a high degree of customization in its manufacturing methods. Major product lines of the industry have traditionally been led by vertically integrated companies who operated in-house design, manufacturing, packaging, test, and distribution, and who could set their own internal standards. However, the recent growth in availability of MEMS foundries has occurred with a shift in the business model for new product development in order to lower costs. The "fabless" business model-approach includes developing relationships with companies who specialize in device and system design, foundries for manufacturing, packaging houses, testing, and distribution partners. This has renewed interest and discussion in the role for standards, especially the characterization and testing of materials and devices, to reach a common language for the buyer-seller interface in the marketplace.

The industry has adopted some existing standards from the semiconductor electronics industry. Beyond that, SEMI and ASTM have led the development of new standard protocols for MEMS device testing.

The MEMS Industry Group (MIG), NIST, SEMI, and IMEC, have partnered to organize a series of workshops to identify, prioritize, and roadmap standardization needs for the industry. This work is in progress, but there is consensus growing that material and device level test and calibration methods are an area of industrial need.

MEMS fabrication in general shares many commonalities with IC fabrication as both employ automated batch wafer processing in a semiconductor cleanroom environment. Accelerometer and gyroscope fabrication borrows many standard processing technologies and equipment for ICs, e.g., lithography, thin film deposition, and dry etching. However, it differs substantially from IC's when it comes to the formation and the subsequent release of free standing microstructures which are essential for inertial sensing. These microstructures are often quite large (100's of μm across to well over 1 mm) and relatively thin (from a few μm to 10's of μm). They are therefore very fragile and prone to mechanical damage prior to encapsulation. It often takes a tremendous time and effort to develop a viable MEMS fabrication platform.

Since most accelerometer and gyroscope die are encapsulated at the wafer level, they are not unlike regular IC die and for which standard assembly processes and plastic packages for ICs are usually applicable. What used to be "one product, one package" for MEMS is gradually standardizing into a few common QFN or LGA packages for accelerometers and gyroscopes.

A mechanical stimulus is typically required for accelerometer and gyroscope testing. This can get complicated and costly as the number of sensing axes and functionality increase. Many high end products, e.g., those for automotive applications, also require temperature testing. MEMS companies have initially come up with their own custom test solutions along with many innovative designs for the mechanical stimulus, mechanization, test fixture, and handler.

Unlike the IC model, there is currently no pure play MEMS foundry which offers a standardized, production proven, accelerometer or gyroscope process platform for open use. For the backend, there are well -established, semiconductor packaging houses with more than a decade of experience in the high volume assembly of MEMS devices. Package level testing, however, remains well guarded IP as it is very challenging to provide adequate test coverage at low cost for the increasingly sophisticated MEMS system-in-package products which are loaded with smart algorithms for the sensing of multiple physical parameters. As a result, Design for Testability has received utmost attention for these products. The cost of package level testing and the associated yield loss at this step can often be a significant cost differentiator among MEMS IDMs. The lack of test standardization or solution, however, remains a significant bottleneck for the MEMS industry.

Accelerometer and Gyroscope Future Needs

A future trend for consumer applications is toward sensor fusion, or the integration of multiple sensor components in the same package, e.g., an 11-DOF (Degree of Freedom) sensor system-in-package that combines a 3-axis accelerometer, 3-axis gyroscope, 3-axis magnetometer, altimeter, and temperature sensor, to perform sophisticated tasks of motion sensing and navigation (in conjunction with GPS).

Medical MEMS

MEMS being utilized in medical products are finding new applications everywhere in the health industry with rapid growth significantly past 2015.

The microsystem technologies market for healthcare applications will grow from $1.2 billion in 2009 to $4.5 billion in 2015, representing over 1 billion units per year in 2015. Meanwhile, wireless systems will exceed 50% market share..

MEMS enable dramatic new possibilities for detecting, analyzing, and manipulating biomaterials, from proteins to bacteria to blood.

MEMS combine silicon-based microelectronics with micromachining technology, making it possible to develop complete systems on a chip. Devices generally range from a millimeter down to 20 micrometers.

Lab on a chip and Related Microdevices:

- Biochemical assays
- Immunoassay: detect bacteria, viruses and cancers based on antigen-antibody reactions.
- Dielectrophoresis: detection of cancer cells and bacteria.
- Blood sample preparation: can crack cells to extract DNA.
- Cellular lab-on-a-chip for single-cell analysis.
- Ion channel screening (patch clamp)
- Testing the safety and efficacy of new drugs, as with lung on a chip

Some of the healthcare improvements promised to future generations are: new in-vitro diagnostic systems, new therapy strategies, genetic disease treatment, artificial pancreas, drug discovery processes, and others.

Regulation

The industry is in the early stages of discussions on the need to establish standard protocols and testing methodologies that can be used to help streamline the process for FDA approval of portable medical diagnosis and drug delivery systems. The types of testing required for these products must be finalized and agreed to by all participating companies. Class I, II, and III medical devices will need their own set of regulations and requirements.

PACKAGING

The pace of change in packaging technology today has accelerated to the highest rate in history. The penetration of electronics into virtually every segment of society is driving his demand. Communication, transportation, education, agriculture, entertainment, health care, environmental controls (heating and cooling), defense and research all rely heavily upon electronics today. This diversity of application and the never ending demand for both lower cost and higher performance cannot be achieved without major changes in architecture, materials and manufacturing processes. These new technologies include SiP, Wafer Level Packaging (WLP), wafer thinning and Through Silicon Vias (TSV) today. In the near future, we will see additional changes with the incorporation of nano-materials.

TECHNOLOGY CHALLENGES:

Reliability

Many factors determine the reliability of electronic components and systems. SiP products have higher thermal cycle count due to the use pattern of consumer electronics and greater mechanical stress due to vibrations and dropping for the same reason. The storage and use environments also have a wider range than many conventional electronic systems. Meeting the reliability requirements of future SiP components and systems will require tools and procedures that are not yet available.

Manufacturing Equipment and Processes

The shift in equipment for single chip packaging from dedicated hard tooling based equipment to more flexible manufacturing platforms is still in process. The drive for higher parallelism in package assembly, higher speed and other changes to reduce cost continues with increased importance in the current economic environment.

Packaging innovations such as WLP and SiP have specialized equipment requirements. New generations of equipment will be required for wafer level interconnect structures, specialized under bump metallurgy, TSV, and embedded wafer level structures.

Emerging SIP products require assembly equipment with greater versatility and precision. Assembly of SIP with a variety of IC types, optical devices, MEMS devices, and biochips on the same substrate will require substantial extension of current assembly equipment capability.

Materials

New requirements for improved reliability, performance, cost, and compatibility with new semiconductor materials are driving the development of a broad base of compliant materials for packaging applications.

The migration to “green” materials that are lead-free and halogen-free compatible are in full swing. Materials for the traditional wire bond and flip chip packages will have to be improved to meet lead-free, halogen-free, and low-κ /ultra low-κ requirement.

The development of new packaging technologies, such as SiP, WLP, embedded die and passives, and TSV, will call for innovations in design of materials and materials processing innovations beyond what is available today. WLP will require materials with improved or different properties as it evolves to meet new packaging applications. Different metallization systems for both redistribution traces and under bump metallization, as well as new dielectric polymers, are needed to meet the ever changing reliability requirements for portable electronic devices. The development of fanout WLP and embedded passives/actives will require new low-temperature embedding polymers and low-temperature cure redistribution layer polymers. TSVs will benefit from new dielectric insulators and conductive via filling media for improved low cost manufacturability. Integrated passive devices (IPDs) will also require better materials, with improved electrical properties, for both resistive and capacitive devices.

Warpage

The increasing package diameter, decreasing package thickness, smaller ball size required for the increasing pin count and higher reflow temperatures associated with lead free solder are resulting in warpage becoming the primary limiting factor for ball pitch and ball size in BGA packages.

Package Substrates

The package substrates are now the most expensive component in a typical package. Substrate cost will present an increasing challenge as the thermal density continues to increase and the pitch continues to decrease. The technology exists to meet the requirements but in many cases the cost of more advanced materials and finer pitch may be prohibitive.

Table 1: Package Substrate Parameters

Year of Production		*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*
Parameter	unit								
Package Type	-	P-BGA	P-BGA	P-BGA	P-BGA	P-BGA	P-BGA	P-BGA	P-BGA
Interconnect Method	-	Wire Bonding	Wire Bonding	Wire Bonding	Wire Bonding	Wire Bonding	Wire Bonding	Wire Bonding	Wire Bonding
Chip to Substrate Interconnect Land Pitch	µm	120	120	110	110	110	100	100	100
Min. External I/O Pitch	mm	1.0	1.0	1.0	0.8	0.8	0.8	0.8	0.8
Typical External I/O Pitch	mm	1.0	1.0	1.0	0.8	0.8	0.8	0.8	0.8
Min. Total Thickness	mm	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Core Material Tg	°C	180	180	180	210	210	210	210	210
Core Material CTE (X-Y)	ppm/°C	14	14	14	13	13	11	11	11
Core Material CTE (Z)	ppm/°C	40	35	35	30	30	30	30	30
Core Material Dk@1GHz	-	4.2	4.2	4.2	4.2	4.2	4.0	4.0	4.0
Core Material Df@1GHz	-	0.013	0.013	0.013	0.013	0.013	0.010	0.010	0.010
Core Materials Young's Modulus	GPa	24	24	24	24	24	24	24	24
Core Material Water Absorption	%	0.10	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Min. Line width/Space	µm	50/50	50/50	50/50	50/50	50/50	40/40	40/40	40/40
Min. Conductor Thickness	µm	25	25	25	25	25	25	25	25
Min. Through Via Diameter	µm	150	150	150	150	150	125	125	125
Min. Through Via Land Diameter	µm	300	300	300	300	300	275	275	275
Min. Through Via Pitch	µm	350	350	350	350	350	325	325	325

Wafer Level Packaging

WLP is one of the most rapidly growing packaging technologies. Today WLP includes packages that are larger than the die with both fan-in and fan-out terminals. WLP enables decrease in size, increase in operating frequency and cost reduction compared to wire bonding or flip chip. WLPs with fan-in design today are typically for low I/O count and small die sizes. They are mainly being used in portable consumer markets where small size, thickness, and weight are an additional advantage to cost. WLP now incorporates many different structures to meet specific application targets.

Environmentally Conscious Electronics

Global environmental issues and the resulting stakeholder concerns are accelerating the demand for environmentally conscious electronics (ECE) products. Active public debate has been focusing on climate change, access to clean water, e-waste, hazardous materials, and conflict free materials sourcing. These issues are influencing policy makers, advocacy groups, and consumers to demand greater transparency from manufacturers on the environmental aspects of electronic products.

These concerns are emerging in new industry standards, legislation, and eco-labels that are expanding their scope to cover product environmental and sustainability performance throughout the entire product lifecycle. This includes extraction and manufacture of input raw materials, product manufacturing, transport and logistics, product use, and end of life management.

The Information and Communications Technology (ICT) industry has an unprecedented opportunity to enable new technologies to help solve these global environmental challenges. Part of the solution is to make electronics products more energy efficient and sustainable, but the key to the broader problem is to develop new technologies that can be deployed broadly across many sectors of the economy.

As in previous years, the 2011 ECE Roadmap is structured around five topic areas: Materials, Energy, Recycling, Eco-Design, & Sustainability

Key recommendations and issues raised in the five sections follow:

Materials:

The need for new and novel materials in emerging technologies runs counter to the growing global restrictions on materials use. An urgent need is a more consensus approach to technically sound assessment methodologies to quantify environmental impacts of materials and potential trade-offs of alternatives. A second urgent need is development of data structures and databases for the environmental aspects of materials and their alternatives.

Continued support is needed for solving remaining challenges for lead-free reliability and manufacturability issues, as well as the work on PVC alternatives and HFR – free leadership for printed circuit boards.

Industry must be more involved in policy making on material restrictions so that the regulatory community better understands the trade-offs inherent in material substitution.

Energy:

Harmonization of global energy efficiency standards and labeling remains a priority including closing gaps in metrics, measurement, and testing.

Support the iNEMI product carbon footprint position by promoting credible, workable methodologies and appropriate use of comparative data.

Support research and initiatives to increase the energy efficiency of electronic products, but more importantly, support development of new energy saving technologies that can improve efficiencies in many economic sectors.

Support energy efficiency and harmonized standards for data centers and cloud computing.

Recycling:

A patchwork approach to regulations, recycling methods, and product eco-design continues to hamper the development of a sustainable infrastructure with a viable recycled materials market for use in new products and other applications. Key recommendations include:

Establish new electronic applications for postconsumer blended plastics (e.g., housings for power supplies) and for recycled CRT leaded glass

Develop design guidelines for both product reuse and demanufacturing

Establish a forum to encourage communications with manufacturers, recyclers, NGOs, and policy makers to resolve barriers to recycling

Encourage efficiency, reduced costs and innovation in electronics recycling systems through competition and other market-based mechanisms

Eco-Design:

Provide more and earlier feedback to Eco-label organizations and regulators on new technologies, life-cycle thinking, scientific / test data and design cycles. A multi-stakeholder group that includes industry can successfully develop accepted environmental standards based on harmonized principles

Continue supporting IEEE 1680 as a workable design standard, but support efforts to resolve the adversarial revision process.

Sustainability:

Electronics are a solution towards sustainability. While there is the responsibility to minimize the electronics industry's environmental impact from operations, products, and services, the compelling news is that the electronics industry has a particular opportunity to make society function more efficiently and easily and thereby mitigate society's impact on the environment. Solutions that enable other sectors to improve their environmental footprint make use of electronics and need to be implemented now to enable opportunities.

Brominated Flame Retardants (BFRs)

Taking their lead from both regulatory and NGO-driven market pressures, a number of consumer electronics OEMs have made public goals to limit the use of brominated flame retardants (BFRs) and polyvinyl chloride (PVC) from their products in 2009 and 2010. A few have gone even further, promising to remove all organic and inorganic halogens, a chemical group which includes fluorine, chlorine, bromine, iodine, and astatine. Despite the wide variety in goals, the term "halogen-free" is often used to refer to any type of halogen restrictions. However, there is much debate as to what level of reduction constitutes "halogen-free."

While there are over 75 BFRs, the ones most commonly used in electronics include decabromodiphenyl ether (deca-BDE) and tetrabromobisphenol A (TBBPA). Octa- and penta-BDEs are rarely (if ever) used in electronics. Deca-BDE is used in some television casings and TBBPA is widely used in circuit boards and other component casings. PVC is used in electronic cabling and plastic parts.

While many OEMs have already committed to removing BFRs and PVCs, discussion still surrounds exactly to what extent halogens need to be removed from electronics products. While the removal of BFRs and PVCs is the first of the environmental groups' goals, other flame retardant compounds have already been identified as future targets.

In the absence of other standards, many electronics manufacturers are applying the 900 ppm limits for chlorine and bromine in laminate materials to entire electronic products.

ROADMAP RESEARCH KEY TOPICS

DESIGN:

- 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.

• Integrated design and simulation tools for RF modules and devices.

• Electronics-manufacturing simulation and modeling tools for the designer.

• Cost effective, improved thermal management.

• New capability to close the gap between chip and substrate interconnect density.

MANUFACTURING TECHNOLOGY:

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

• Manufacturing processes for dealing with warpage and thin format products – Wafer, Package, PCB

• 3D Package Stacking Development - Assembly, Cooling, Reliability

• 3D TSV Commercialization by the development of the industry infrastructure as well as the supply chain.

• Low Temperature Assembly

MATERIALS DEVELOPMENT:

• A combination of materials and fabrication research to support the development of monolithically integrated optics and electronics.

• 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.

• • Reliability testing methodologies for new materials.

ENERGY AND THE ENVIRONMENT:

• Establish shared, peer reviewed, data bases for sustainability.

• Need to engage with policy makers and NGOs to establish life cycle basis for decisions.

• Need Materials Usage modeling to track material flows within and between nations.

• Support R&D to create a sustainable infrastructure and viable recycled materials market.

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 (first identified in 2004) has continued to favor the development of functional, modular components or SiP (both 2-D and 3-D structures). This paradigm shift in the design approach increases the flexibility, 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. Telecom, computing, IT and military sectors are affected.

The board assembly roadmap is predicting another migration to lower temperature and lower cost lead-free solder materials in 2011-2017.

Other paradigm shifts include:

• Optical Interconnects at the backplane/board level will eventually be deployed – driven by increasing performance requirements and more cost effective solutions.

• Printed electronics moving into initial applications with many infrastructure challenges.

• Electronic component suppliers are looking to utilize embedded passive and active components, systems in package, systems on chip, or any other means to densely pack ICs with increased functionality.

• High density PCBs will use discrete devices only down to 0201 format.

• High Density Substrates will use embedded passives or 01005 discretes based on size constraints.

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