Topics

• iNEMI Introduction
• Roadmap Process Overview
• Situation Analysis
• Strategic Concerns
• Paradigm Shifts
• Technology Roadmap/Project Highlights:
  – MEMS
  – Environmental
• Summary/Next Steps
About iNEMI


5 Key Deliverables:
- Technology Roadmaps
- Collaborative Deployment Projects
- Research Priorities Documents
- Proactive Forums
- Position Papers

3 Major Focus Areas:
- Miniaturization
- Environment
- Medical Electronics

International Electronics Manufacturing Initiative (iNEMI) is an industry-led consortium of over 100 global manufacturers, suppliers, industry associations, government agencies and universities. Working on advancing manufacturing technology since 1994. Visit us at www.inemi.org
Unique Attributes of the iNEMI Consortium

• Strong Global Membership accompanied by a mission that focuses on identifying global manufacturing challenges.
• Delivery of a total industry set of priorities every two years:
  – A Technical Plan that defines key collaborative opportunities and gaps in the 1-5 year horizon
  – A set of Research priorities for the 5-10 year horizon
• A proven methodology for effective pre-competitive collaboration.
• Ability to execute an integrated supply chain approach on solving complex manufacturing and systems integration issues.
• A growing reputation as a proactive leading organization in the environment and sustainability.
# International Members Across The Total Supply Chain

## The International Membership

<table>
<thead>
<tr>
<th>INEMI Member Business Type</th>
<th>North America</th>
<th>Asia Region</th>
<th>Europe</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>OEM</td>
<td>14</td>
<td>3</td>
<td>2</td>
<td>19</td>
</tr>
<tr>
<td>ODM/EMS (inc. pkg. &amp; test services)</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Suppliers (materials, software, services)</td>
<td>8</td>
<td>18</td>
<td>12</td>
<td>38</td>
</tr>
<tr>
<td>Equipment</td>
<td>9</td>
<td>0</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>Universities &amp; Research Institutes</td>
<td>8</td>
<td>2</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>Organizations</td>
<td>11</td>
<td>1</td>
<td>2</td>
<td>14</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>55</strong></td>
<td><strong>28</strong></td>
<td><strong>21</strong></td>
<td><strong>104</strong></td>
</tr>
</tbody>
</table>

## Key Observations:

- 66% Growth Overall Since 1/1/2010
- 140% Growth in University/Research Institutes Since 1/1/2010
- **Total Global Supply Chain Integration**
Roadmap
Process & Scope
## 2013 Product Emulator Groups (PEGs)

<table>
<thead>
<tr>
<th>Emulator</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumer / Portable</td>
<td>Produced in high volumes, cost is the primary driver, handheld battery powered products are also driven by size and weight reduction</td>
</tr>
<tr>
<td>Office</td>
<td>Driven by the need for maximum performance over a wide range of cost targets</td>
</tr>
<tr>
<td>Automotive Products</td>
<td>Products that must operate in an automotive environment</td>
</tr>
<tr>
<td>High-End Systems</td>
<td>Products that serve the high performance computing/storage markets including networking, datacom and telecom and cover a wide range of cost and performance targets</td>
</tr>
<tr>
<td>Medical Products</td>
<td>Products that must operate with high reliability and, in some cases, support life critical applications</td>
</tr>
<tr>
<td>Aerospace / Defense</td>
<td>Products that must operate reliably in extreme environments</td>
</tr>
</tbody>
</table>
## Roadmap Development

### 2013 Product Sector Needs Vs. Technology Evolution

<table>
<thead>
<tr>
<th>TWGs (21)</th>
<th>Product Emulator Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semiconductor Technology</td>
<td>Indoor / Consumer</td>
</tr>
<tr>
<td>Business Processes</td>
<td>Office Systems</td>
</tr>
<tr>
<td>Prod Lifecycle Information Mgmt.</td>
<td>Defense and Aerospace</td>
</tr>
<tr>
<td>Design Technologies</td>
<td>Medical Products</td>
</tr>
<tr>
<td>Modeling, Thermal, etc.</td>
<td>Automotive</td>
</tr>
<tr>
<td>Manufacturing Technologies</td>
<td>High-End Systems</td>
</tr>
<tr>
<td>Board Assy, Test, etc.</td>
<td></td>
</tr>
<tr>
<td>Comp./Subsyst. Technologies</td>
<td></td>
</tr>
<tr>
<td>Packaging, Substrates, Displays, etc.</td>
<td></td>
</tr>
</tbody>
</table>

- **Roadmap Development**
- **2013 Product Sector Needs Vs. Technology Evolution**

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**INEMI**

Advancing manufacturing technology

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8
2013 Technology Working Groups (TWGs)

- Modeling, Simulation, and Design
- Solid State Illumination
- Large Area, Flexible Electronics
- Semiconductor Technology
- Photovoltaics
- Ceramic Substrates
- Organic PCB
- Information Management Systems
- Connectors
- MEMS/Sensors
- Packaging & Component Substrates
- RF Components & Subsystems
- Passive Components
- Optoelectronics
- Mass Storage (Magnetic & Optical)
- Energy Storage & Conversion Systems
- Test, Inspection & Measurement
- Thermal Management
- Environmentally Conscious Electronics
- Customer

Red=Business  Green=Engineering  Purple=Manufacturing  Blue=Component & Subsystem
Methodology

Roadmap

Competitive Solutions

Research

Projects

Product Needs

Technology Evolution

Disruptive Technology

Academia

Government

Global Participation

Gap Analysis/Technical Plan

No Work Required or Outsourced

Industry Solution Needed

Available to Market Place

Project Completion

Implementation

iNEMI
Users & Suppliers
Regional Collaboration

Advancing manufacturing technology
Fourteen Contributing Organizations
Roadmaps and Projects

- Board assembly
- Final assembly
- Test, inspection & measurement
- Electronic connectors & cables
- Energy storage & conversion systems
- Interconnect substrates – ceramic
- Interconnect PCB – organic
- Mass data storage
- Optoelectronics
- Packaging & Component Substrates
- Passive components
- Photovoltaics
- RF components & subsystems
- Semiconductor technology
- MEMS/Sensors
- Solid state illumination
- Information management
- Environmentally conscious electronics
- Modeling, simulation & design tools
- Thermal management
- Medical Electronics
- Large area, flexible electronics

Roadmaps
- Open to Industry
- Cover Entire Infrastructure
- Developed by TWGs

Projects
- Open to Members
- Focus on High Priority Areas
- Managed by TIGs

Red = Both Roadmapping & Projects
Black = Roadmapping
Situation Analysis
Situation Analysis Market

- **No boundaries among computers, communications and entertainment products.**
  - Flat Panel Display is the norm for virtually all applications with touch screen.

- **Proliferation of Wireless products**
  - This opens up new applications in a number of segments.

- **Home and office functionality is being added to automotive products**
  - It is growing concerns over driver distraction.

- **Convergence of markets and applications**
  - Medical – Consumer - Automotive – Entertainment – Communication – Computing – Security
### 2011 EMS/ODM Penetration in the Electronics Industry

<table>
<thead>
<tr>
<th>Sector</th>
<th>EMS/ODM ($Bn)</th>
<th>Electronics ($Bn)</th>
<th>EMS/ODM Penetration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Industry</td>
<td>$360</td>
<td>$1,560</td>
<td>23%</td>
</tr>
<tr>
<td>Computers and Peripherals</td>
<td>$126</td>
<td>$388</td>
<td>32%</td>
</tr>
<tr>
<td>Consumer Devices (inc. Handsets)</td>
<td>$90</td>
<td>$423</td>
<td>21%</td>
</tr>
<tr>
<td>Datacom and Telecom Infrastructure</td>
<td>$55</td>
<td>$147</td>
<td>37%</td>
</tr>
<tr>
<td>Server and Storage Infrastructure</td>
<td>$35</td>
<td>$103</td>
<td>34%</td>
</tr>
<tr>
<td>Medical</td>
<td>$11</td>
<td>$91</td>
<td>12%</td>
</tr>
<tr>
<td>Automotive</td>
<td>$7</td>
<td>$164</td>
<td>4%</td>
</tr>
<tr>
<td>Industrial/Military</td>
<td>$36</td>
<td>$244</td>
<td>15%</td>
</tr>
</tbody>
</table>
Situation Analysis
Environmental Regulatory

- Continuous Regulatory requirements on a global basis
- Explosion of new requirements from many regional, national and local governments.
  - Manufacturers must remove environmental “Materials of Concern” (endless list of banned materials)
  - “High Reliability” product manufacturers are especially vulnerable (new materials)
  - Regulatory Challenges for medical electronics market to receive prompt approval of new technology
  - Subject to new sourcing and supply chain requirements
  - Determination of carbon footprint is an expanding requirement on industry with consistent methodologies.

2012 Regulations and Outlook by Region
Exponential Growth

Data Supplied by Compliance and Risk
Major Growth on Eco Design, Energy, Batteries, & REACH and RoHS substance regulations
Situation Analysis Technology

- Multi-core processors are now the norm for most computing applications
- Traditional scaling requires improved cooling and operating junction temperature reduction due to large leakage currents.
- Consumer’s demand for thin multifunctional products has led to increased pressure on alternative high density packaging technologies.
- High-density 3D packaging has become the major technology challenge
- SiP:
  - Technology driver for small components, packaging, assembly processes and for high density substrates
- New sensors and MEMs:
  - Expected to see exponential growth driven by portable products
  - Motion gesture sensors expanding use of 2D-axis & 3D-axis gyroscopes
  - Segment maturing, encouraging industry collaboration
- 3D IC with TSV:
  - Driven by Performance and Size requirements
Strategic Concerns
Strategic Concerns

• Restructuring from vertically integrated OEMs to multi-firm supply chains
  – Resulted in a disparity in R&D Needs vs. available resources

• Critical needs for R&D
  – Middle part of the Supply Chain is least capable of providing resources

• Industry collaboration
  – Gain traction at University R&D centers, Industry consortia, “ad-hoc” cross-company R&D teams

• The mechanisms for cooperation between industries must be strengthened.
  – Cooperation among OEMs, ODMs, 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

• Collaboration is iNEMI’s Strength; We play an important role.
<table>
<thead>
<tr>
<th>Typical Companies</th>
<th>Gross Margin</th>
<th>Operating Margin</th>
<th>R&amp;D Margin</th>
<th>Value</th>
<th>% Total R&amp;D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sumitomo Bakelite, DuPont, Henkel</td>
<td>40%</td>
<td>10%</td>
<td>7%</td>
<td>$11Bn</td>
<td>7%</td>
</tr>
<tr>
<td>Intel, STMicro, LSI Logic</td>
<td>40%</td>
<td>10%</td>
<td>10%</td>
<td>$26Bn</td>
<td>34%</td>
</tr>
<tr>
<td>Amkor, ASE, SPI,</td>
<td>17%</td>
<td>8%</td>
<td>2%</td>
<td>$0.2Bn</td>
<td>8%</td>
</tr>
<tr>
<td>Tyco, Molex, AVX, Sharp</td>
<td>25%</td>
<td>8%</td>
<td>3%</td>
<td>$17Bn</td>
<td>8%</td>
</tr>
<tr>
<td>Sanmina-SCI, Flextronics, Jabil, Hon Hai</td>
<td>6%</td>
<td>2%</td>
<td>&lt; 1%</td>
<td>$3Bn</td>
<td>3%</td>
</tr>
<tr>
<td>Dell, HP, Cisco, Nokia, Teradyne, Visteon, Siemens</td>
<td>30%</td>
<td>8%</td>
<td>3%</td>
<td>$103Bn</td>
<td>51%</td>
</tr>
</tbody>
</table>
Paradigm Shifts

• Need for continuous introduction of complex multifunctional products to address converging markets favors modular components or SiP (2-D & 3-D):
  – Increases flexibility
  – Shortens design cycle

• Cloud connected digital devices have the potential to enable major disruptions across the industry:
  – Next 4-5 years likely to be a major transition to business models
  – Huge data centers operating more like utilities (selling data services)
  – Local compute and storage growth may slow (as data moves to the cloud)
  – “Rent vs. buy” for software (monthly usage fee model)

• Rapid evolution and new challenges in energy leading businesses such as SSL, automotive and more.

• Sensors everywhere – MEMS and wireless traffic!
A Few Examples: Gap Analysis Leads to iNEMI Collaborative Projects

MEMS & Environment

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iNEMI MEMS Roadmap

Projects to Close Gaps

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Consumer MEMS Phones and Tablets

- Accelerometers
- Gyroscopes
- Electronic Compass
- Pressure Sensors
- Microphones
- Micro speakers
- Auto focus
- (Pico) Projectors
- RF MEMS

Source: Yole Development
Automotive MEMS
## Grand Challenges

<table>
<thead>
<tr>
<th>Difficult Challenges</th>
<th>Potential Solutions</th>
</tr>
</thead>
</table>
| Integration of MEMS in the Package                       | • Standardization for MEMS packaging to support integration.  
• Packages are needed that reduce or eliminate mechanical stress and enhancing hermeticity.  
• Package data that can be used to accurately predict the effect of the package on device performance. |
| Testing of MEMS                                           | • More testing towards the wafer level.  
• Validated tools to predict device device performance from wafer tests.  
• Methodologies for “Design for Test” or “Design for NO Test.” |
| Validated accelerated life testing for MEMS               | • More knowledge of the physics of failure is required to develop accelerated life tests.  
• Need to share information. Individual solutions exist but are not being generalized across the industry. |
MEMS Test Methods and Capabilities

Statement of Work Complete
• There is a lack of uniformity of tests and terminology for specifying device performance in the data sheets.
  – System and component integrators must retest devices to understand and compare device performance between manufacturers.
  – Device manufacturers must (re)test and report the performance of their products to meet the custom requirements of their customers who often have no in-house expertise in MEMS.
  – Net effect is test methods for MEMS are not well defined and are inefficient and often times inadequate.
Phase 1 Scope of Work

- Identify a common set of practices required to improve communication between the device manufacturers and their customers through the common definition of performance specifications & testing
- The Phase 1 project will focus on Inertial Sensors, including MEMS accelerometers, MEMS gyroscopes and inertial measurement units (IMUs).
- The project will:
  - Survey what specifications are reported (e.g., sensitivity, noise, temperature coefficient, offset, etc.), & how the specifications are defined,
  - The protocols used to measure the performance metric
- Identify the opportunities and gaps that must be addressed to develop a uniform set of standardized tests and terminology for specifying device performance in data sheets.
Focus Area: Environment

History of iNEMI Efforts

Project Example

Advancing manufacturing technology
iNEMI Actions in Environmental Area

- Roadmap of Environmental Conscious Electronics (since 1996)
- Established the Environmental Leadership Steering Committee to set strategic direction & priorities
- Issued iNEMI Position papers on Product Carbon Foot printing and Definition of Low Halogen
- Issued white paper on Timeline for conversion of Notebook and desktops to HFR-Free and PVC free
- Leading Projects on Pb-free reliability (since 2000)
- Leading Projects on PVC alternatives (since 2009)
- Leading Projects on HFR-free reliability (since 2008)
- Developing LCA tools for ICT products (since 2010)
- Defining Environmental Research Priorities
- Rare Earth Metals Project
Characterization of Pb-Free Alloy Alternatives

Chair: Greg Henshall, Hewlett-Packard; Co-chair: Stephen Tisdale, Intel
Goal: Perform accelerated thermal cycle experiments on new Pb-free alloys

<table>
<thead>
<tr>
<th>Project Chair: Greg Henshall, HP</th>
<th>Project Co-Chair: Stephen Tisdale, Intel</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strategy</strong></td>
<td><strong>Tactics</strong></td>
</tr>
<tr>
<td>• Validate the impact of Ag concentration in the range of 0 to 4% on thermal fatigue resistance</td>
<td></td>
</tr>
<tr>
<td>• Evaluate the impact of commercially common dopants</td>
<td></td>
</tr>
<tr>
<td>• Assess how alloy composition affects the acceleration behavior</td>
<td></td>
</tr>
<tr>
<td>• Provide basic thermal fatigue data for several of the most common alternate alloys</td>
<td></td>
</tr>
<tr>
<td>• Depending on the availability of cells in the DoE, provide an opportunity to assess the performance of some new commercial and experimental alloys</td>
<td></td>
</tr>
<tr>
<td>• Make Pb-free alloy choice easier to manage</td>
<td></td>
</tr>
<tr>
<td>• Reduce the complexity in selecting Pb-free alloys</td>
<td></td>
</tr>
<tr>
<td>• Develop a set of material test requirements for new Pb-free solder alloys.</td>
<td></td>
</tr>
<tr>
<td>• Work with IPC and the IPC Solder Products Value Council to establish standard test methods</td>
<td></td>
</tr>
<tr>
<td>• Identify test methods to reduce impact on manufacturing</td>
<td></td>
</tr>
<tr>
<td>• Provide thermal cycle reliability data on a variety of commercially and scientifically important alloys</td>
<td></td>
</tr>
<tr>
<td>• Provide data from which thermal fatigue acceleration models can be derived for a range of alloy</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Issues</strong></th>
<th><strong>Graphics</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• The increasing number of Pb-free alloys provides opportunities to address shortcomings of near-eutectic SAC alloys, such as:</td>
<td></td>
</tr>
<tr>
<td>− Poor mechanical shock performance</td>
<td></td>
</tr>
<tr>
<td>− Alloy cost</td>
<td></td>
</tr>
<tr>
<td>− Copper dissolution</td>
<td></td>
</tr>
<tr>
<td>− Poor mechanical behavior of joints in bending</td>
<td></td>
</tr>
</tbody>
</table>

**Focus Area:** Miniaturization
**TIG:** Board Assembly
**Oct-12**
Focus Area: Characterization of Pb-Free Alloy Alternatives

TIG: Oct-12

Project Members

20 companies; 66 individuals
Solder alloy suppliers, component suppliers, EMS providers, OEMs
Next Steps for 2013 Roadmap Completion
Completing the 2013 iNEMI Roadmap

• 2013 iNEMI Roadmap Development Cycle is wrapping up!
  – Global Workshops Held:
    • San Diego, CA  5/29/12
    • Berlin, Germany  6/12/12
    • Hong Kong, China  6/14/12

• Complete integration of chapters & editing by: 10/31/12.

• Available to Members by: 12/05/12.

• 2013 iNEMI Roadmap Availability to industry 3 months later (March 2013):
  – Order the 2013 iNEMI Roadmap CD at www.inemi.org (watch web site for status)
  – Individual roadmap chapters will also available as a PDF document at www.inemi.org

• Get Involved in iNEMI – A growing organization with an eye to the future and a means to get there.
Packaging/Interconnect
Packaging Challenges

- Extreme Low-k (ELK)
- Form Factor
- System-level Package Reliability
- Warpage Control
- Thermal Performance
- Pb-free

Next-generation Package Solutions
iNEMI Packaging/Interconnect Projects

• Advanced Si-Node Pb-Free Underfill Reliability
• Copper Wire Bonding Reliability
• Primary Factors in Component Warpage
• Package Warpage Qualification Criteria
• Packaging Equipment Requirements Convergence
• Wiring Density for Organic Packaging Substrates