iNEMI

International Electronics Manufacturing Initiative

Roadmap Trends and Emerging Technologies

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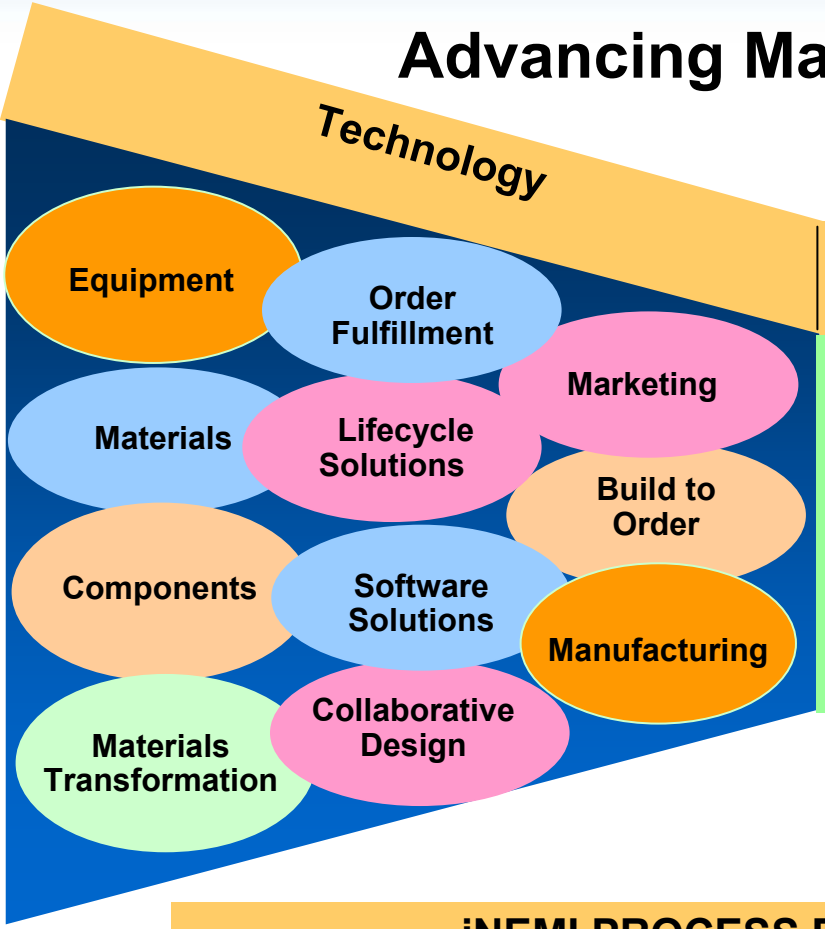
Advancing manufacturing technology

Topics

- iNEMI Overview
- 2007 iNEMI Roadmap
- Research Priorities
  - Key Gaps
    - By Roadmap Areas
    - By Research Areas
  - Projects to address iNEMI Strategic Thrusts
  - Pb-free Conversion: Current Situation
- Conclusions and Summary

The iNEMI Mission:

Advancing Manufacturing Technology



Supply Infrastructure

Information Technology
Logistics
Communications
Business Practices

- **Accelerated deployment of new technologies**
- **Dissemination of efficient business practices**
- **Development of industry infrastructure**
- **Stimulation of standards**

iNEMI PROCESS FUNNEL
Identify and close technology gaps, which includes the development and integration of the electronics industry supply infrastructure.

→ **Customer Deliverables**

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2007 iNEMI Roadmap

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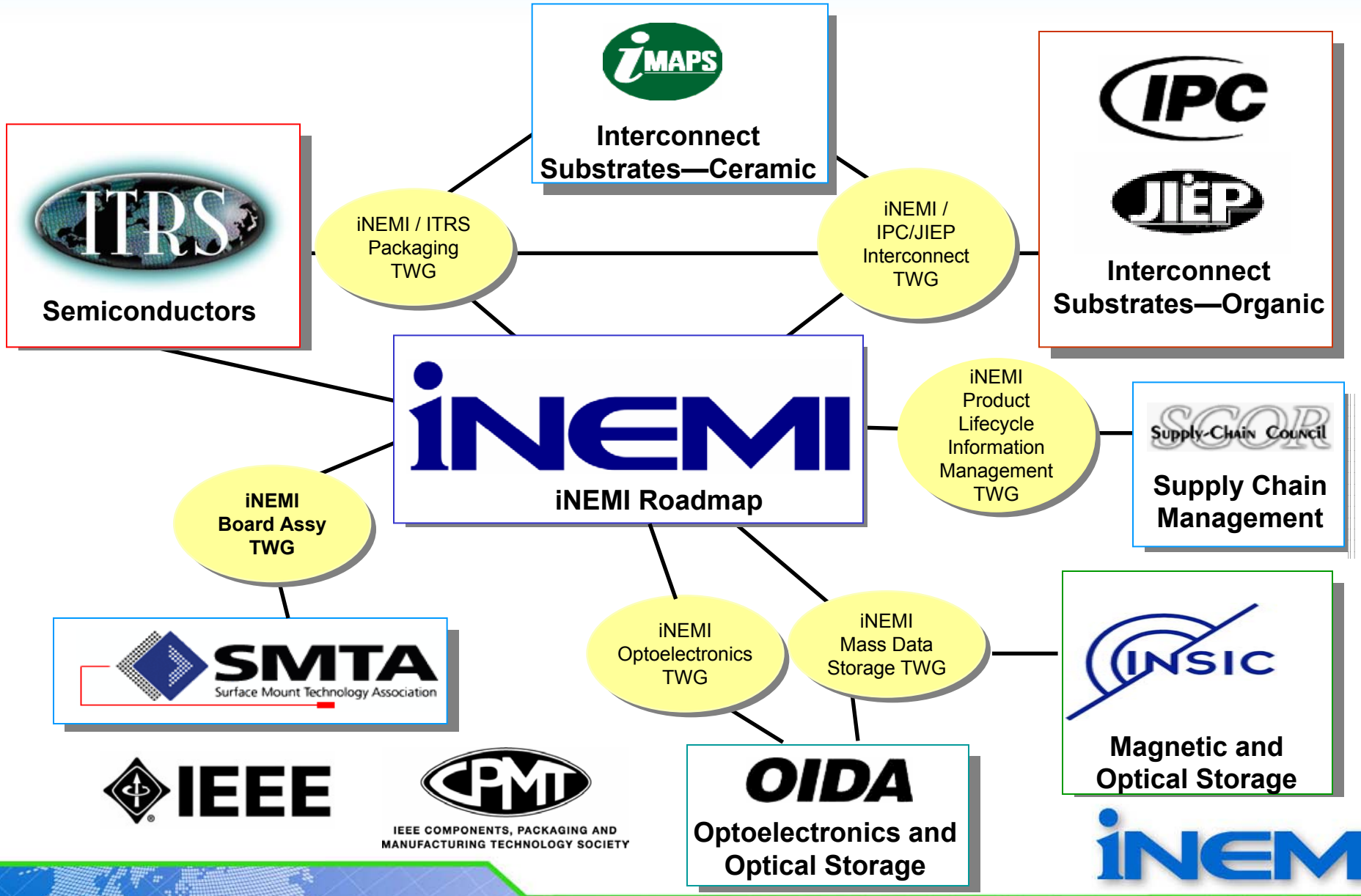
Statistics for the 2007 Roadmap

- > 500 Participants
- > 265 Companies/organizations
- 17 Countries from 4 Continents
- 19 Technology Working Groups (TWGs) (added Organic & Printed Electronics)
- 5 Product Emulator Groups (PEGs)
- Over 1300 Pages of Information
- Roadmaps the needs for 2007-2017

2007 Roadmaps
19 Individual Roadmap Chapters

- Semiconductor Technology
- Packaging
- Mass data storage
- Board Assembly
- Final Assembly
- Environmentally Conscious Electronics
- Interconnect Substrates Organic
- Interconnect Substrates Ceramic
- Connectors
- RF Components & Subsystems
- Optoelectronics
- Passive Components
- Energy Storage Systems
- Organic & Printed Electronic
- Modeling, Simulation & Design Tools
- Thermal Management
- Test, Inspection & Measurement
- Product Lifecycle Information Management
- Sensors

9 Contributing Organizations



The Changing Industry

- Consumers are concerned about the impacts that electronics products may exert regarding safety, energy usage, and environmental impact.
- There has been a dramatic movement of manufacturing and manufacturing support to China from North America, Europe, and other Asian countries because of:
  - A low-cost, highly skilled workforce
  - A massive market opportunity.
- The increasing scope of outsourced operations requires loosely coupled business processes spanning multiple companies and continents.
- Business models in the electronics industry have changed - leading to significant shifts in roles and responsibilities across the supply chain.

Strategic Concerns
Value Creation in the Supply Chain

ls17.034bes-chain

Typical Companies	Sumitomo Bakelite, DuPont, Ablestik	Intel, STMicro, LSI Logic	Amkor, ASE, SPIL	Tyco, Molex, AVX, Sharp	Solectron, Sanmina-SCI, Flextronics	Dell, HP, Cisco, Nokia, Teradyne, Visteon, Siemens
Gross Margin	30%	45%	17%	25%	6%	30%
Operating Margin	10%	15%	8%	8%	2%	8%
R&D	7%	15%	2%	5%	<1%	8%
Margin Value	$8Bn	$34Bn	$0.7Bn	$16Bn	$3Bn	$90Bn
R&D Value	$6Bn	$34Bn	$0.2Bn	$10Bn	$1Bn	$90Bn
%Total R&D	4%	24%				64%

Source: Prismark Partners

Changing Regulations

- 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 requesting a dual supply chain for components.
- The electronics industry is facing end-of-life or producer responsibility legislation.

Market Growth

- 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.
- Global production of communications equipment is expected to reach $176Bn in 2006, representing about 15% of the electronics industry.
- Portable and consumer electronics production will reach $267Bn in 2006, following several years of exceptional growth.
- Medical electronics equipment production will be $53Bn in 2006, accounting for about 4% of the global electronics industry.
- 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.

Converging Markets

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

Emerging Technology

- The end of traditional semiconductor scaling.
- Reduction of emphasis on the microprocessor frequency metric, and the corresponding increase in importance of the system's throughput metric.
- Higher bandwidth to and from the microprocessor.
- Increased need for improved cooling & reduced power.
- Minaturization including 3D Packaging.
- 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.
- The 2007 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.

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Research Priorities

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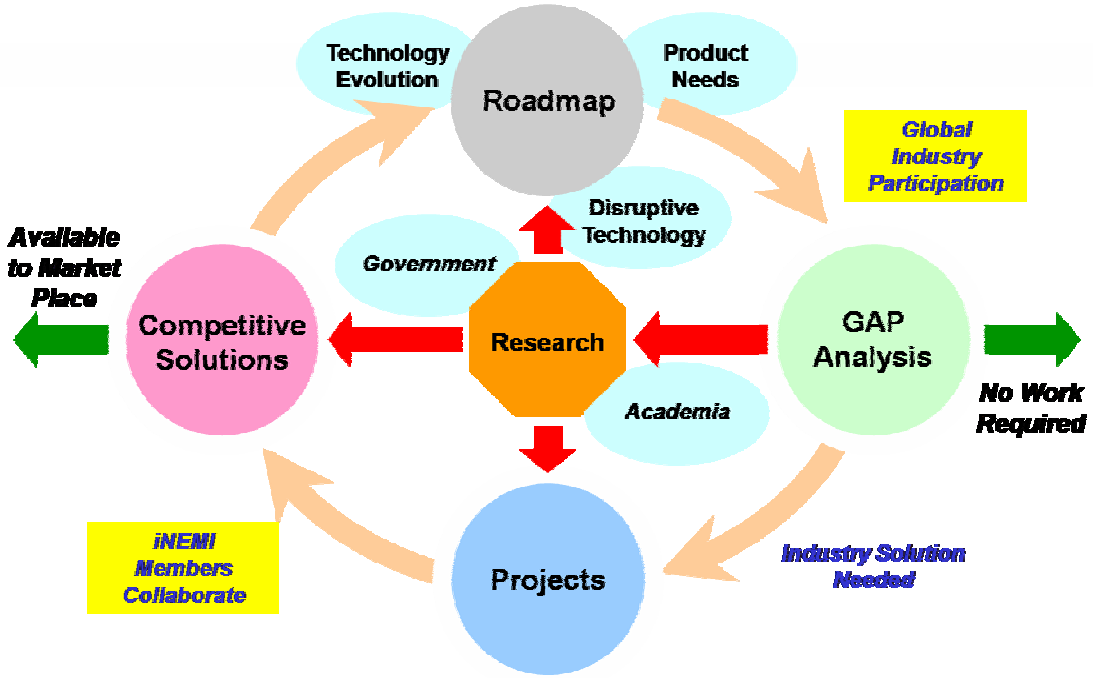
Leadership through Innovation

- **A research vision with three major thrusts:**
  - **Energy & the Environment**
  - **Miniaturization**
  - **Medical Electronics**



Research Priorities

- 2007 gap analysis just completed
- 10 year R&D priorities identified
- Available at http://www.inemi.org/cms/ri/
- Contents:
  - Technology Research Needs by Product Sector
  - Priorities Summarized by Research Area
    - *Manufacturing Processes*
    - *System Integration*
    - *Materials & Reliability*
    - *Energy and the Environment*
    - *Design*
  - Significant Gaps and Issues from Roadmap
  - Options for Innovation

Key Gaps by Roadmap Area

- **Board Assembly**
  - Low cost fine line/via PCB Technology
  - Inspection and test capability
  - Board flex standards
  - Design for Manufacturing standards
- **Environmentally Conscious Electronics**
  - Alternatives to Cd, Hg, CrVI, PBB, and PBDEs
  - Industry involvement in policy making on material restrictions
  - Scientific methodologies to assess environmental impact of materials
  - Effective basic energy efficiency metrics
- **Substrates**
  - Low cost, fine line/via PCB Technology
  - Moisture reliability
  - High Tg
  - Low cost, low loss tangent materials

Key Gaps by Roadmap Area

- **Medical**
  - Component reliability standards and standard test methods
  - Standardized characterization process for RoHS-compliant components
  - Development of advanced printed circuit board and flexible printed circuit technologies
  - Safety study of clinical and home-health wireless environment.
- **Thermal Management**
  - Closed Loop, Liquid Cooling Solutions
  - Cooling of 3-D Stacked Dies
  - Data Center cooling strategies
  - Reliable low-cost pumps
- **Board & System Test**
  - Test access for miniaturized products
  - Increased adoption of boundary scan in digital and analog devices
  - Tools to determine defect coverage.
  - Standards for board flexure of lead-free BGAs
  - Test solutions for High Density Interconnect

Key Gaps by Research Area

- **Manufacturing Processes**
  - There is a need for a new methodology/strategy for R&D to be conducted in the global outsourcing environment
  - The infrastructure to produce high volume, low cost, high density interconnect substrates for portable electronic products
  - Inspection/test technologies need to keep up with density of board designs and component packages.
- **Energy and the Environment**
  - Accepted and sound scientific methods to evaluate environmental impact of materials that are also accepted by regulators, NGOs and industry
  - New innovative energy sources
  - R&D to develop a sustainable infrastructure and viable recycled materials market for use in new products and other applications
- **Materials and Reliability**
  - Improved Pb-free alloys for better area array shock, lower cost, lower temperature and reduced copper dissolution issues
  - Halogen free material for substrates and PCBs
  - Second level underfill solution needed that is reliable / reworkable and cost effective
  - Need for sensor specific material standards - especially thin films

Key Gaps by Research Area

- **System Integration**
  - 3D interconnect structures with associated thermal management
  - Standardized test methods / figures of merit for printed electronics
  - The capability to do system level comparisons (performance, power, and cost) between optical and RF technology from the device level to the system level.
- **Design**
  - Improved, integrated and standardized DfX tools for compatibility across supply chains
  - Low cost solutions for carrying >10Gb/s signal rates between components on a PCB
  - Better tools for concurrent design of packages and PCB for better system optimization.
    - Includes metrology and
    - Methodologies for:
      - Materials characterization and
      - performance validation

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iNEMI Projects to address Strategic Thrusts

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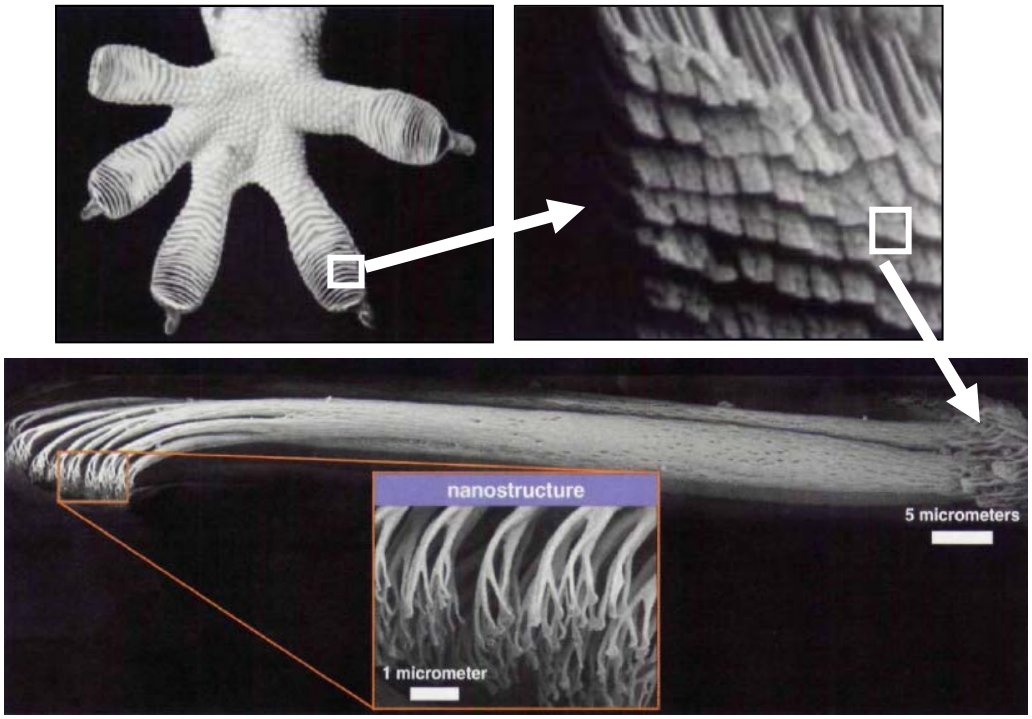
Emerging Scenario for iNEMI Projects

- **Meet needs of members (both users & suppliers) in key segments:**
  - **High volume/portable**
    - **Expand & strengthen miniaturization projects**
  - **Medical electronics**
    - **Complete initial Medical Electronics Project & build momentum for this segment**
  - **High reliability (Telecom, Computing)**
    - **Establish "End Game" for High Reliability segments for Pb-free conversion:**
      - **Close remaining knowledge gaps**
      - **Work source of supply issues (BGAs) in the interim**
    - **Advanced Thermal Management Technologies**

Miniaturization

- Established Projects
  - Nano Attach Project
  - Pb-free Nano-solder Project
- New Project
  - Functional Test Coverage Assessment Project – Launched July 2007
- Initiatives
  - High Temperature Co-planarity Requirements for Components and PWBs
  - RFID Item Level Tag Roadmap and Gap Analysis

Gecko



Adhesion: van der Waals forces

foot:

- 14,400 setae/mm^2
- 10 N/cm^2
- uses only 3% of setae

setae:

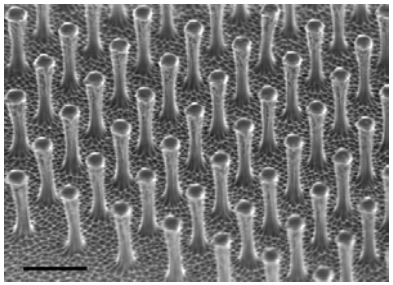
- 110 μm long
- 5 μm diameter

hair:

- branches to100 to 1,000
- 0.2 μm long and wide
- spatula-shaped endings
- 100 nN/hair

K. Autumn, Y.A. Liang, S.T. Hsieh, W. Zesch, W.P. Chan, T.W. Kenny, R. Fearing, and R.J. Full, "Adhesive Force of a Single Gecko Foot-Hair", *Nature*, 405, 681 (2000).

Nanotechnology Approaches



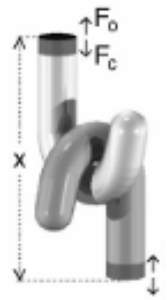
[1]

Biomimetric Dry Adhesive

- single sided attachment
- van der Waals forces

- 1 – 10 N/cm^2 for mm^2 to cm^2 attachment area
- 1,600 N/cm^2 on point contact attachment

[1] A.K. Geim et al., Nature Mat., 2003.



[2]

Nano-Velcro

- double sided attachment
- mechanical & van der Waals forces

- theoretically 300,000 N/cm^2

[2] S. Berber et al., Phys Rev Lett., 2003.

Adhesion Reference: Tape ~1s N/cm^2, Solder ~1,000s N/cm^2

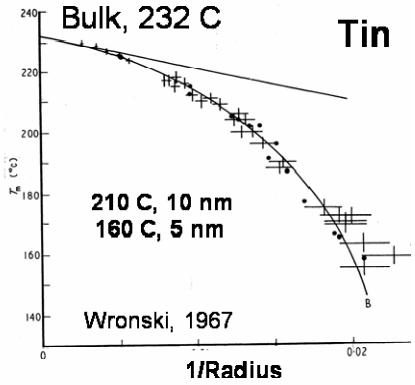
Pb Free Nano Solder

Goal: Investigate the application of nanotechnology to suppress Pb-free solder reflow temperature.

Strategy	Impact
• Research and develop a nano-solder paste that can effectively suppress the melting point temperature of Pb-free solders • Demonstrate the feasibility of such a solution • Demonstrate manufacturability and joint reliability	• Reduce reflow temperatures which can negatively affect product reliability, require tougher qualification requirements for components, and may require significant changes in manufacturing processes

Issues: Pb-free materials and products require the use of solders that have higher melting points than SnPb solder and, therefore, require higher processing temperatures

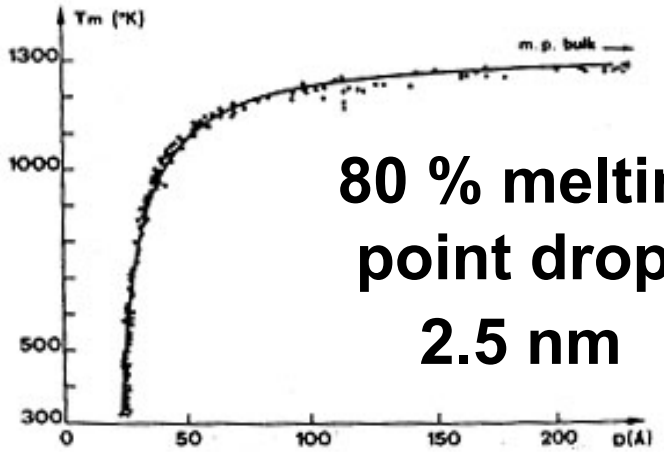
Key Milestones	Status
Phase 1: research, develop and demonstrate a nano-solder paste	Complete
Phase 2: Demonstrate manufacturability	Ongoing
Phase 3: Demonstrate joint reliability	Ongoing
Phase 4: Develop/demonstrate manufacturing equipment	Ongoing



Melting Point Suppression of Non-Lead Solder Alloys

- Nano-particles have higher internal energy vs. bulk materials that results in lower melting temperatures of the particle
- Nano-scale nonlead solder alloy particles (< 15 nano-meters), could potentially melt at 160 C (compared to bulk of 220C – 232C)

Gold



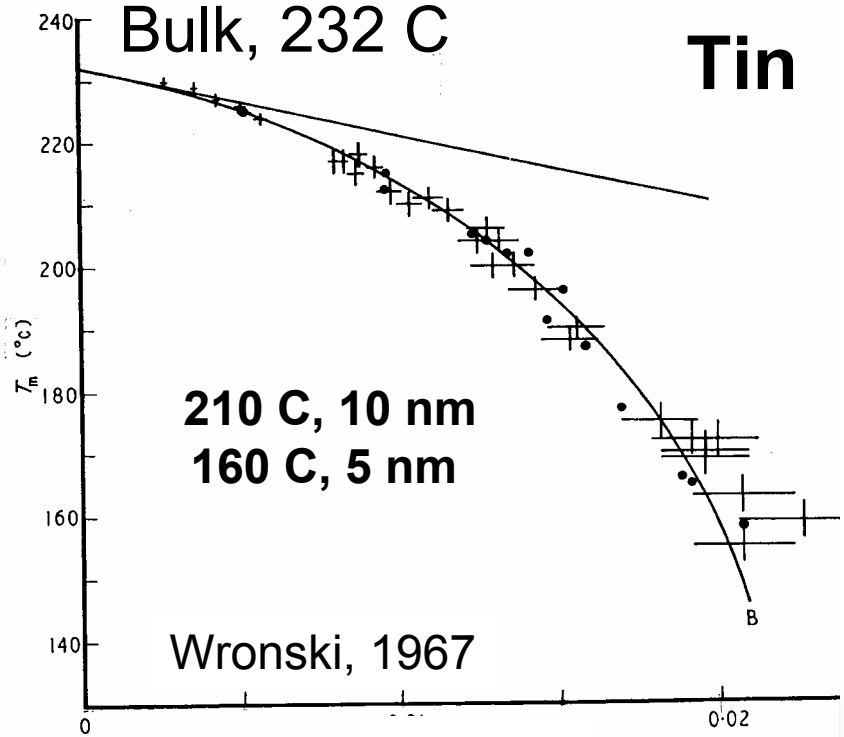
80 % melting point drop !

2.5 nm

Radius

Buffat and Borel, 1976

Tin



210 C, 10 nm

160 C, 5 nm

Wronski, 1967

1/Radius

Evaporated metals

iNEMI RFID Item Level Tag Roadmap

ILT Roadmap – Why now?

- Major barriers exist at ILT RFID implementation
- To provide RFID stakeholders guidance for ILT infrastructure and supply chain development
- To drive ubiquitous deployment of RFID solutions
- The ILT roadmap effort is being driven by the RFID supply chain members
- This roadmap activity is open to all RFID stakeholders. Your participation is most welcome!

Standards and Roadmap Efforts to Establish the Printed Electronics Infrastructure

Standards

IEEE

IEEE 1620™, IEEE 1620.1™, IEEE P1620.2

http://grouper.ieee.org/groups/1620/
http://grouper.ieee.org/groups/1620/1/
http://grouper.ieee.org/groups/1620/2/

Roadmaps

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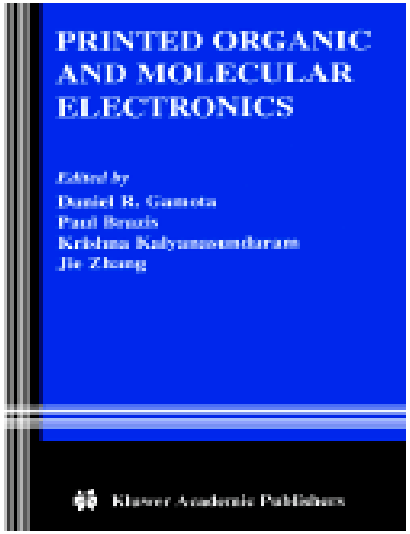
Released at APEX 2007
http://www.inemi.org

Presentations & Publications



Printed Organic and Molecular Electronics (ISBN 1-4020-7707-6)

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Medical Electronics

- **Established Project**
  - **Medical Grade Component Reliability Specifications**
- **Initiative**
  - **iNEMI Substrates for Medical Devices**

Energy & the Environment

- Established Projects
  - Tin Whisker Phase II Project
  - Lead-Free Rework Optimization Project
  - Pb-free Wave Soldering Assembly Process Project
  - Lead-Free Rework Optimization Project
  - Pb-free BGAs in SnPb Assemblies Project
- New Project
  - Halogen-Free Project Phase II – Launch June 2007
- New Initiatives
  - BGA Metallurgy Proliferation
  - Advanced Thermal Management Technologies (under discussion)
- High Reliability Task Group
  - Prioritization of remaining Pb-free knowledge gaps
  - Strategy for closing gaps
  - Industry coordination for Pb-free transition

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Pb-free Conversion: Current Situation

- *High Volume Market has converted*
- *High Rel. Market has not converted*

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Industry Readiness

- 9 of 11 Telecommunications OEMs Polled took Pb-free Exemption for Solder In Network Infrastructure Equipment
- A dual component supply chain has resulted
  - Pb-free components for high volume consumer market
  - Traditional SnPb components for
    - Telecommunications
    - Servers
    - Military products
    - Medical electronics
- Reliability of Pb-Free Components with Eutectic Solder has not been fully demonstrated for long life products.
- Some Telecom service providers are now demanding that mission critical equipment remain with SnPb solder.
- Suppliers are not willing to provide traditional components to small high reliability market.

iNEMI High Rel Task Group

Objectives

- Gain a common understanding of the supply chain challenges facing High Reliability OEMs/EMS providers who are:
  - Taking Pb exemption (e.g. telecom switching, high end servers, etc.)
  - Out of Scope of RoHS (e.g. measurement equipment, medical)
- Share experiences between OEMs/EMS providers on current state of supply base
- Define the gaps that this Pb-free move leaves for the high reliability products.
- Influence supply base to meet on-going needs of these industry segments (especially BGAs).
- Consumer Electronics drive the cost and the market
  - The high rel. market must develop a viable scenario to take advantage of consumer components and meet their reliability requirements.

Scenarios

- **Long term solution is to reduce reliability risk of Pb-free components and assembly.**
  - **The economic incentive is compelling**
  - **Well worth technology investment**
  - **Could take several years to complete but this is cumulative, so strides made today are useable.**
- **What can we do in the short term to help encourage the availability of SnPb compatible BGAs?**
- **What can we do in the mid term to close remaining knowledge gaps that the High Rel. segments face?**
- **What can be done longer term to better understand and predict reliability of electronics hardware using Pb-free components and assembly?**

Additional Issues

- **Proliferation of Pb-Free metallurgies is significantly complicating the issue of closing knowledge gaps!**
  - **Alloys behave differently**
  - **Can effect form/fit/function**
    - **supplier A part does not behave like supplier B part in mfg. and/or use.**
  - **Users are demanding new part numbers from their suppliers**
- **Transition in Reliability Concerns**
  - **Initial concerns with SAC alloys were thermal cycling**
  - **Current concern is mechanical failure.**

Conclusions

- **All Materials will continue to be modified:**
  - **Reliability verification of these changes is crucial.**
- **Consumer Electronics drive the cost and the market:**
  - **All high rel. segments combined represent about 10% of electronic components market!**
  - **The high rel. market must develop a viable scenario to take advantage of consumer components and meet their reliability requirements.**
- **Firms are expected to be Socially Responsible:**
  - **Industry must establish proactive science based programs to addresses potential environmental risks.**
  - **Stakeholders must be involved in the process from the beginning.**

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Conclusions & Summary

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Conclusions

- **Consumer Electronics has become the major driving force for our industry:**
  - **New Technology to enable miniaturization**
  - **Relentless cost reduction**
  - **Volume manufacturing capability**
- **Disruptive technology offers opportunity for innovation. To ensure success, the supply chain must invest with a long-term perspective in mind.**

Summary

- **The 2007 iNEMI Research Priorities identifies R&D needs that must be met.**
- **Given the limited resources that industry, academia, and governments can apply, it is crucial that we focus our R&D efforts on these high priority knowledge gaps.**

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