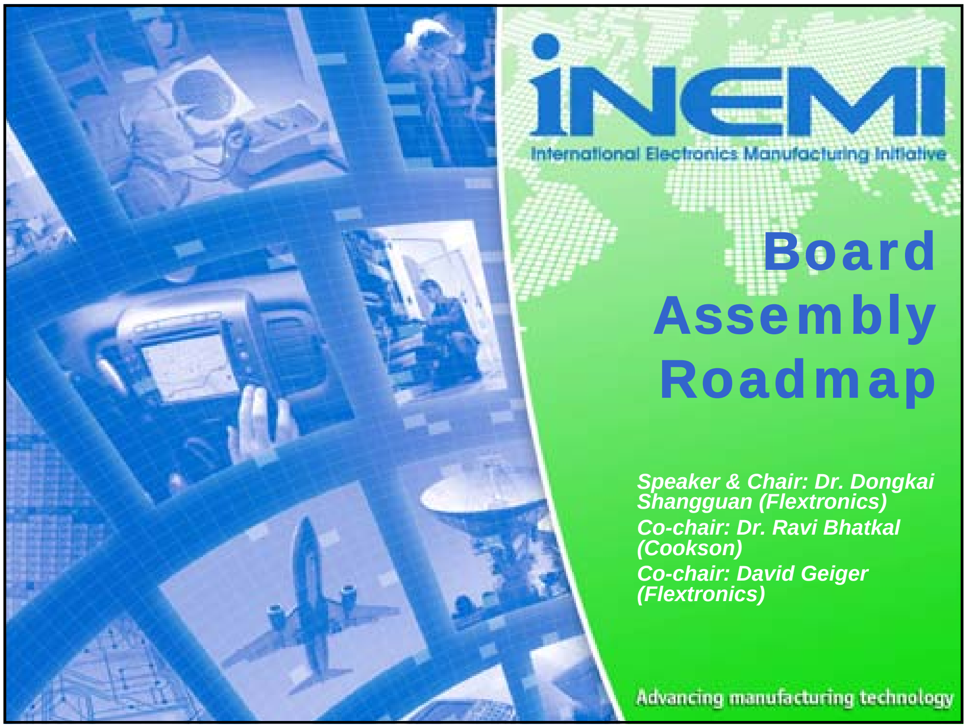

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International Electronics Manufacturing Initiative

Board Assembly Roadmap

Speaker & Chair: Dr. Dongkai Shangguan (Flextronics)

Co-chair: Dr. Ravi Bhatkal (Cookson)

Co-chair: David Geiger (Flextronics)

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Agenda

- **Roadmap Development Approach**
- **Chapter Overview**
- **Key Trends**
- **Technology Gaps & Challenges**
- **Business Issues / Potential Barriers**

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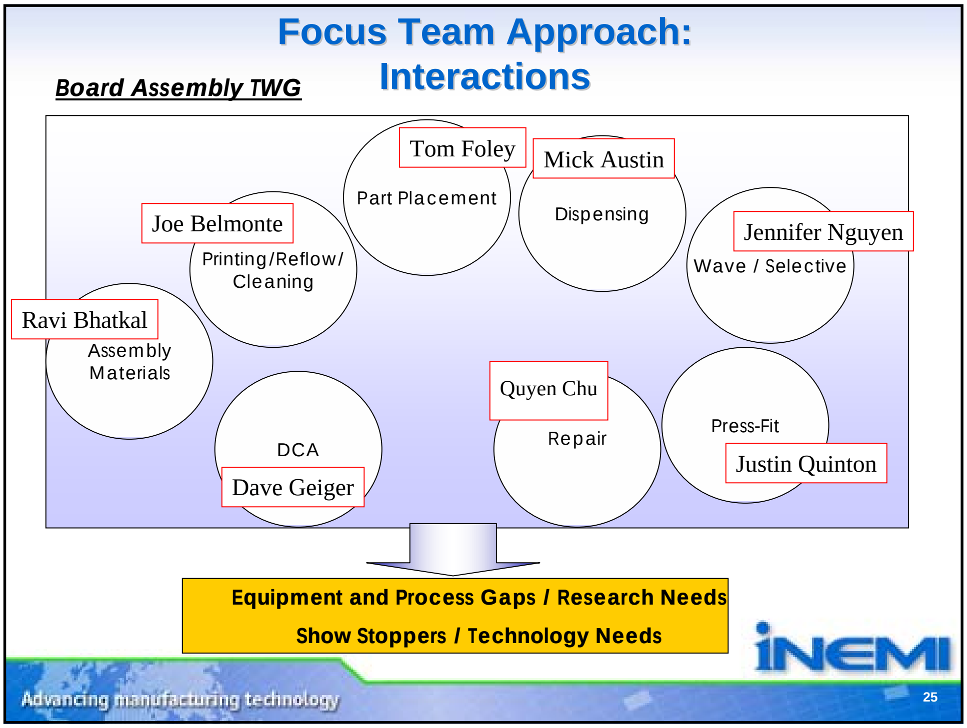

Focus Team Approach: Interactions

Board Assembly TWG

Equipment and Process Gaps / Research Needs

Show Stoppers / Technology Needs

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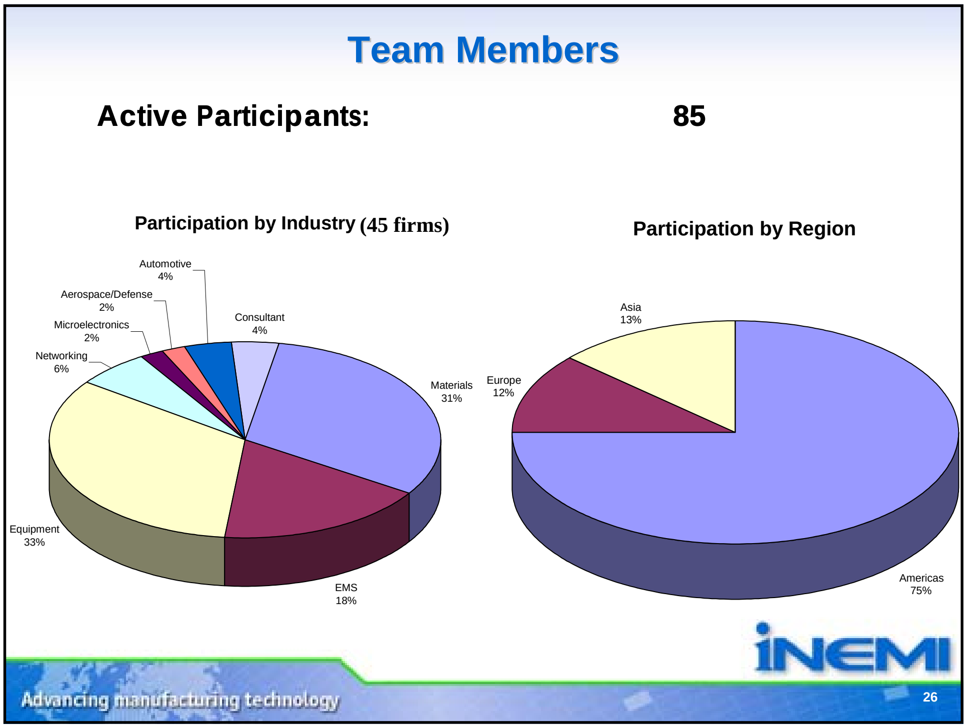

Team Members

Active Participants: 85

Participation by Industry (45 firms)

Participation by Region

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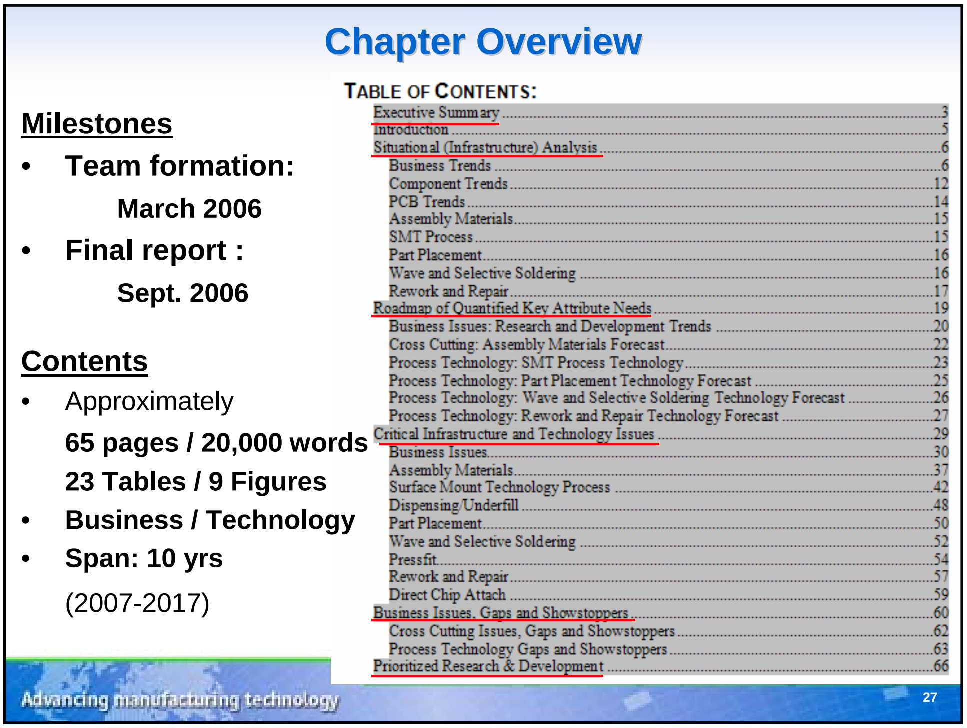

Chapter Overview

Milestones

- **Team formation:**

  March 2006
- **Final report :**

  Sept. 2006

Contents

- Approximately

  65 pages / 20,000 words

  23 Tables / 9 Figures
- **Business / Technology**
- **Span: 10 yrs**

  (2007-2017)

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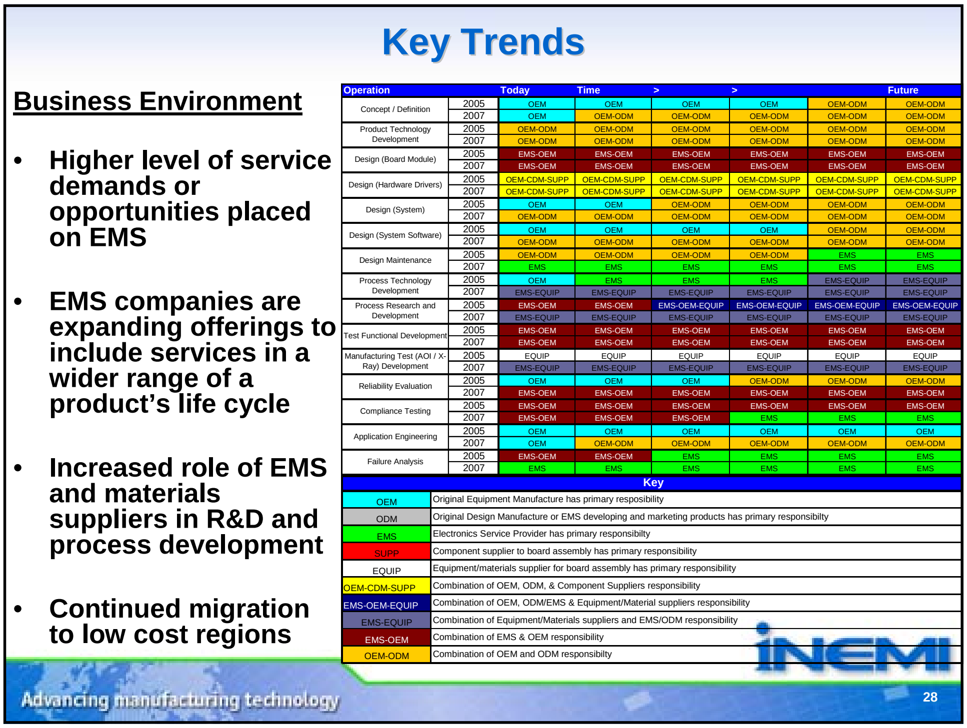

Key Trends

Business Environment

- **Higher level of service demands or opportunities placed on EMS**
- **EMS companies are expanding offerings to include services in a wider range of a product's life cycle**
- **Increased role of EMS and materials suppliers in R&D and process development**
- **Continued migration to low cost regions**

Operation		Today	Time	>	>		Future
Concept / Definition	2005	OEM	OEM	OEM	OEM	OEM-ODM	OEM-ODM
	2007	OEM	OEM-ODM	OEM-ODM	OEM-ODM	OEM-ODM	OEM-ODM
Product Technology Development	2005	OEM-ODM	OEM-ODM	OEM-ODM	OEM-ODM	OEM-ODM	OEM-ODM
	2007	OEM-ODM	OEM-ODM	OEM-ODM	OEM-ODM	OEM-ODM	OEM-ODM
Design (Board Module)	2005	EMS-OEM	EMS-OEM	EMS-OEM	EMS-OEM	EMS-OEM	EMS-OEM
	2007	EMS-OEM	EMS-OEM	EMS-OEM	EMS-OEM	EMS-OEM	EMS-OEM
Design (Hardware Drivers)	2005	OEM-CDM-SUPP	OEM-CDM-SUPP	OEM-CDM-SUPP	OEM-CDM-SUPP	OEM-CDM-SUPP	OEM-CDM-SUPP
	2007	OEM-CDM-SUPP	OEM-CDM-SUPP	OEM-CDM-SUPP	OEM-CDM-SUPP	OEM-CDM-SUPP	OEM-CDM-SUPP
Design (System)	2005	OEM	OEM	OEM-ODM	OEM-ODM	OEM-ODM	OEM-ODM
	2007	OEM-ODM	OEM-ODM	OEM-ODM	OEM-ODM	OEM-ODM	OEM-ODM
Design (System Software)	2005	OEM	OEM	OEM	OEM	OEM-ODM	OEM-ODM
	2007	OEM-ODM	OEM-ODM	OEM-ODM	OEM-ODM	OEM-ODM	OEM-ODM
Design Maintenance	2005	OEM-ODM	OEM-ODM	OEM-ODM	OEM-ODM	EMS	EMS
	2007	EMS	EMS	EMS	EMS	EMS	EMS
Process Technology Development	2005	OEM	EMS	EMS	EMS	EMS-EQUIP	EMS-EQUIP
	2007	EMS-EQUIP	EMS-EQUIP	EMS-EQUIP	EMS-EQUIP	EMS-EQUIP	EMS-EQUIP
Process Research and Development	2005	EMS-OEM	EMS-OEM	EMS-OEM-EQUIP	EMS-OEM-EQUIP	EMS-OEM-EQUIP	EMS-OEM-EQUIP
	2007	EMS-EQUIP	EMS-EQUIP	EMS-EQUIP	EMS-EQUIP	EMS-EQUIP	EMS-EQUIP
Test Functional Development	2005	EMS-OEM	EMS-OEM	EMS-OEM	EMS-OEM	EMS-OEM	EMS-OEM
	2007	EMS-OEM	EMS-OEM	EMS-OEM	EMS-OEM	EMS-OEM	EMS-OEM
Manufacturing Test (AOI / X-Ray) Development	2005	EQUIP	EQUIP	EQUIP	EQUIP	EQUIP	EQUIP
	2007	EMS-EQUIP	EMS-EQUIP	EMS-EQUIP	EMS-EQUIP	EMS-EQUIP	EMS-EQUIP
Reliability Evaluation	2005	OEM	OEM	OEM	OEM-ODM	OEM-ODM	OEM-ODM
	2007	EMS-OEM	EMS-OEM	EMS-OEM	EMS-OEM	EMS-OEM	EMS-OEM
Compliance Testing	2005	EMS-OEM	EMS-OEM	EMS-OEM	EMS-OEM	EMS-OEM	EMS-OEM
	2007	EMS-OEM	EMS-OEM	EMS-OEM	EMS	EMS	EMS
Application Engineering	2005	OEM	OEM	OEM	OEM	OEM	OEM
	2007	OEM	OEM-ODM	OEM-ODM	OEM-ODM	OEM-ODM	OEM-ODM
Failure Analysis	2005	EMS-OEM	EMS-OEM	EMS	EMS	EMS	EMS
	2007	EMS	EMS	EMS	EMS	EMS	EMS

Key	
OEM	Original Equipment Manufacture has primary resposibility
ODM	Original Design Manufacture or EMS developing and marketing products has primary responsibilty
EMS	Electronics Service Provider has primary responsibilty
SUPP	Component supplier to board assembly has primary responsibility
EQUIP	Equipment/materials supplier for board assembly has primary responsibility
OEM-CDM-SUPP	Combination of OEM, ODM, & Component Suppliers responsibility
EMS-OEM-EQUIP	Combination of OEM, ODM/EMS & Equipment/Material suppliers responsibility
EMS-EQUIP	Combination of Equipment/Materials suppliers and EMS/ODM responsibility
EMS-OEM	Combination of EMS & OEM responsibility
OEM-ODM	Combination of OEM and ODM responsibilty

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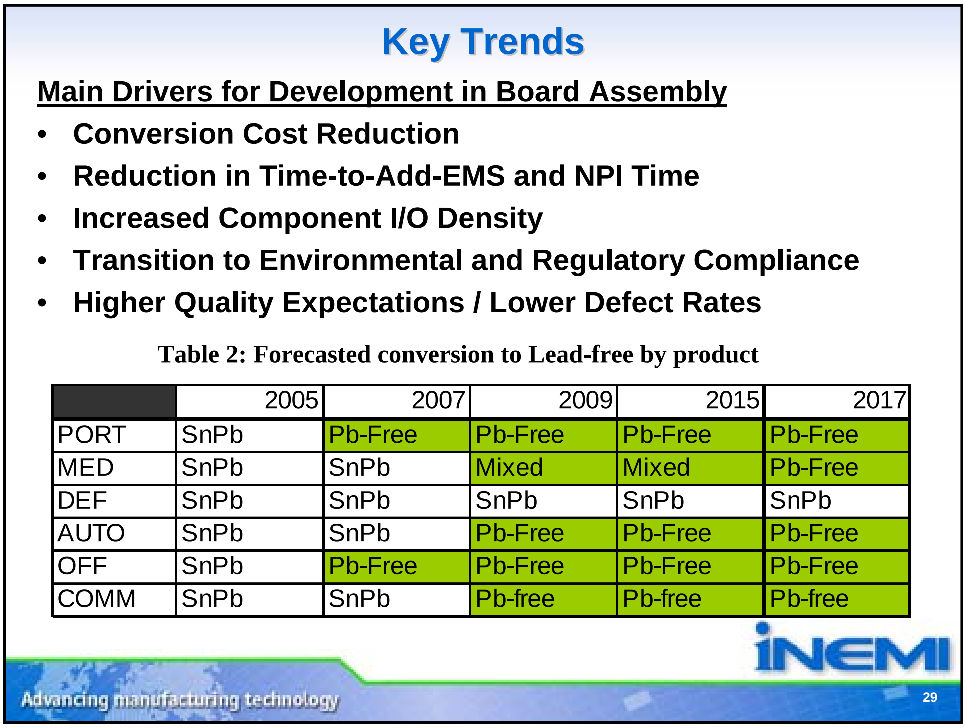


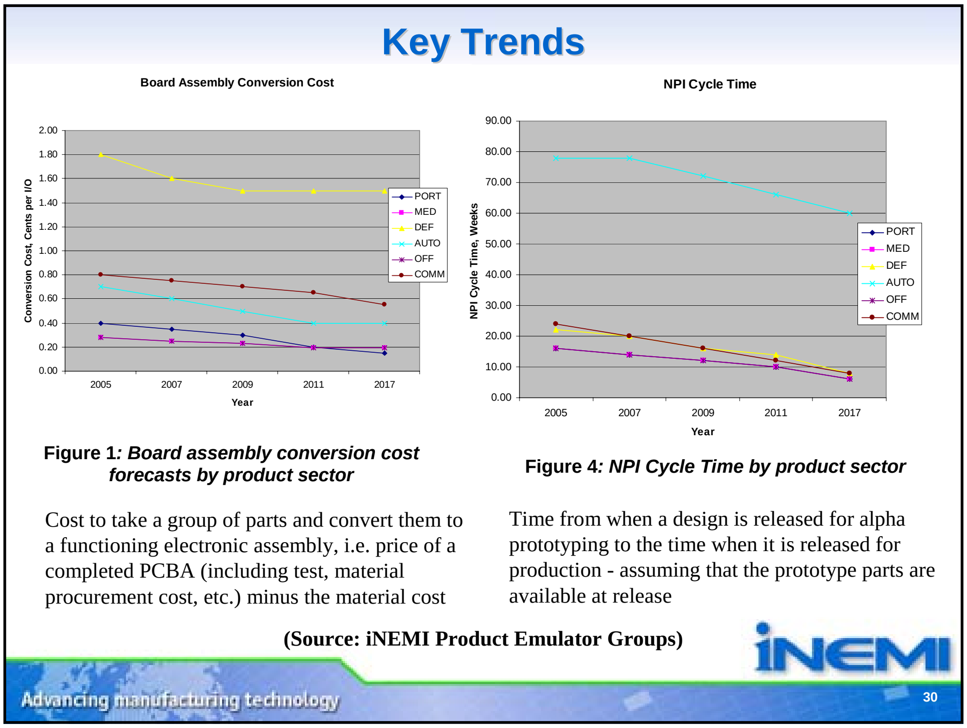
Key Trends

Main Drivers for Development in Board Assembly

- **Conversion Cost Reduction**
- **Reduction in Time-to-Add-EMS and NPI Time**
- **Increased Component I/O Density**
- **Transition to Environmental and Regulatory Compliance**
- **Higher Quality Expectations / Lower Defect Rates**

Table 2: Forecasted conversion to Lead-free by product

	2005	2007	2009	2015	2017
PORT	SnPb	Pb-Free	Pb-Free	Pb-Free	Pb-Free
MED	SnPb	SnPb	Mixed	Mixed	Pb-Free
DEF	SnPb	SnPb	SnPb	SnPb	SnPb
AUTO	SnPb	SnPb	Pb-Free	Pb-Free	Pb-Free
OFF	SnPb	Pb-Free	Pb-Free	Pb-Free	Pb-Free
COMM	SnPb	SnPb	Pb-free	Pb-free	Pb-free



Key Trends

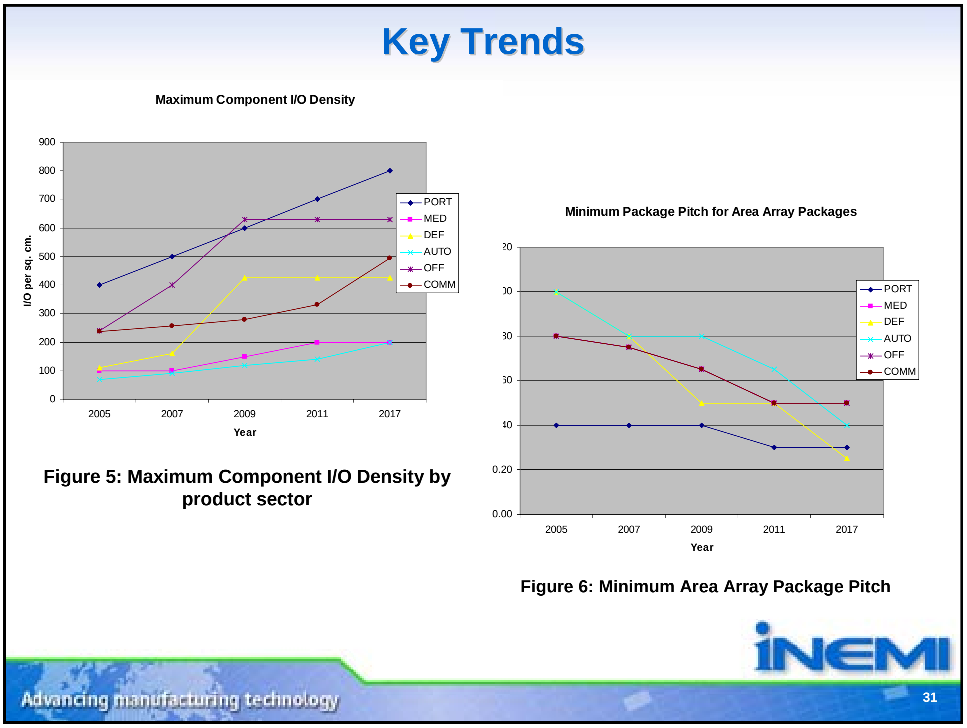
Figure 1*: Board assembly conversion cost forecasts by product sector*

Figure 4*: NPI Cycle Time by product sector*

Cost to take a group of parts and convert them to a functioning electronic assembly, i.e. price of a completed PCBA (including test, material procurement cost, etc.) minus the material cost

Time from when a design is released for alpha prototyping to the time when it is released for production - assuming that the prototype parts are available at release

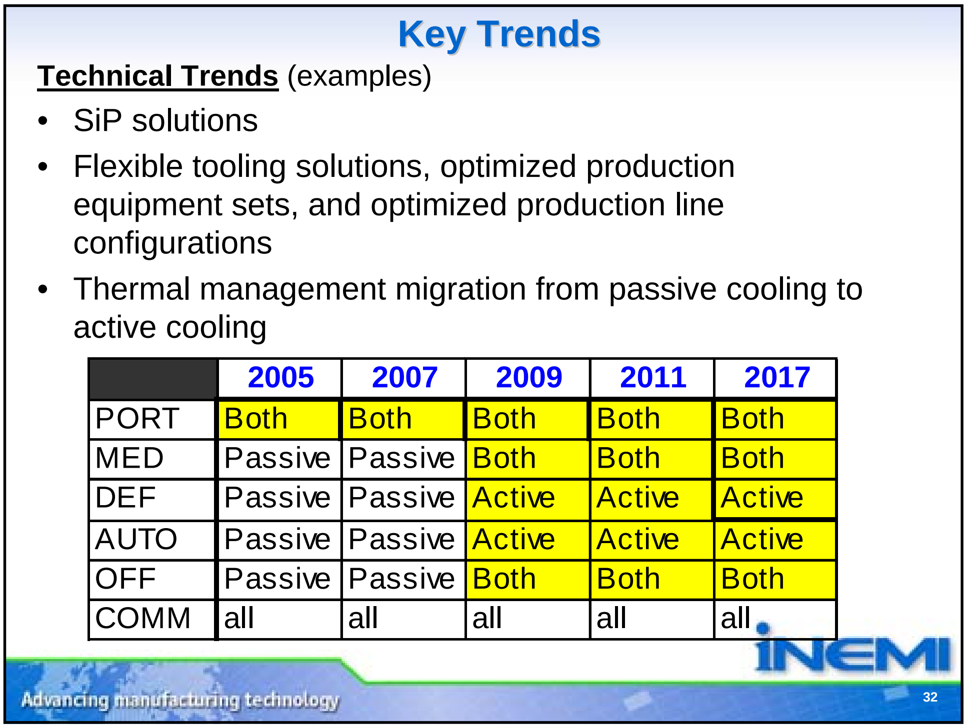
(Source: iNEMI Product Emulator Groups)



Key Trends

Figure 5: Maximum Component I/O Density by product sector

Figure 6: Minimum Area Array Package Pitch

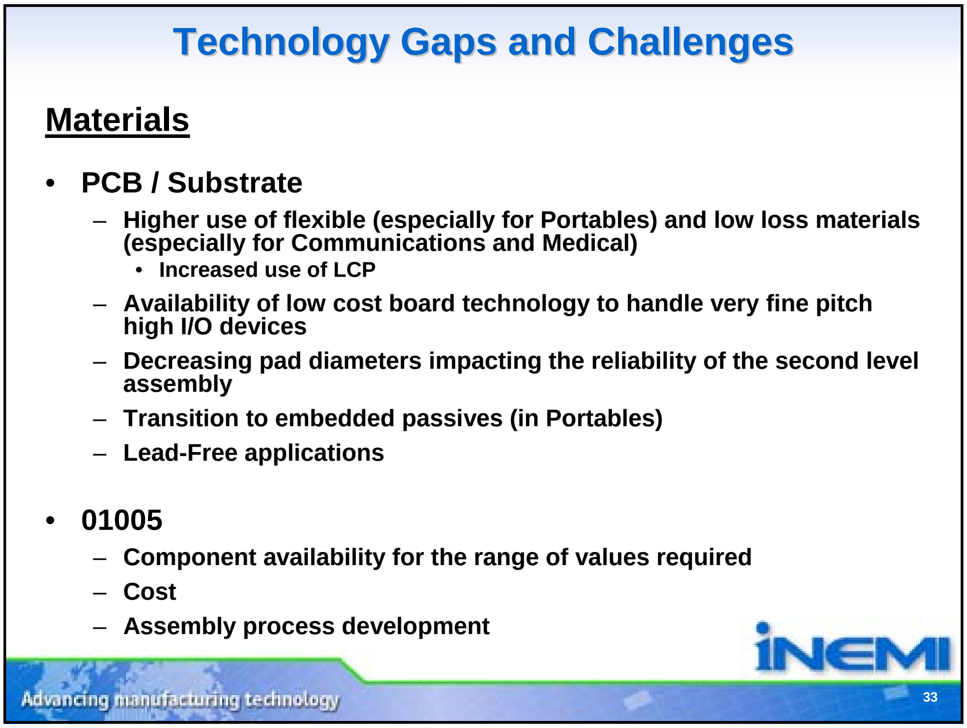


Key Trends

Technical Trends (examples)

- SiP solutions
- Flexible tooling solutions, optimized production equipment sets, and optimized production line configurations
- Thermal management migration from passive cooling to active cooling

	2005	2007	2009	2011	2017
PORT	Both	Both	Both	Both	Both
MED	Passive	Passive	Both	Both	Both
DEF	Passive	Passive	Active	Active	Active
AUTO	Passive	Passive	Active	Active	Active
OFF	Passive	Passive	Both	Both	Both
COMM	all	all	all	all	all

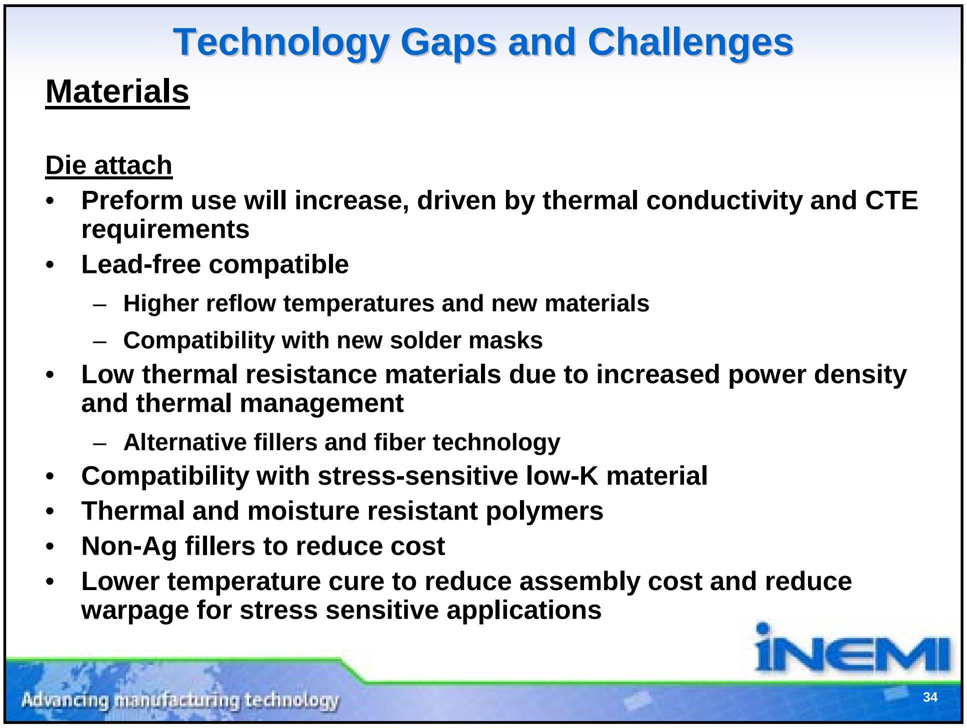


Technology Gaps and Challenges

Materials

- PCB / Substrate
  - Higher use of flexible (especially for Portables) and low loss materials (especially for Communications and Medical)
    - Increased use of LCP
  - Availability of low cost board technology to handle very fine pitch high I/O devices
  - Decreasing pad diameters impacting the reliability of the second level assembly
  - Transition to embedded passives (in Portables)
  - Lead-Free applications

- 01005
  - Component availability for the range of values required
  - Cost
  - Assembly process development

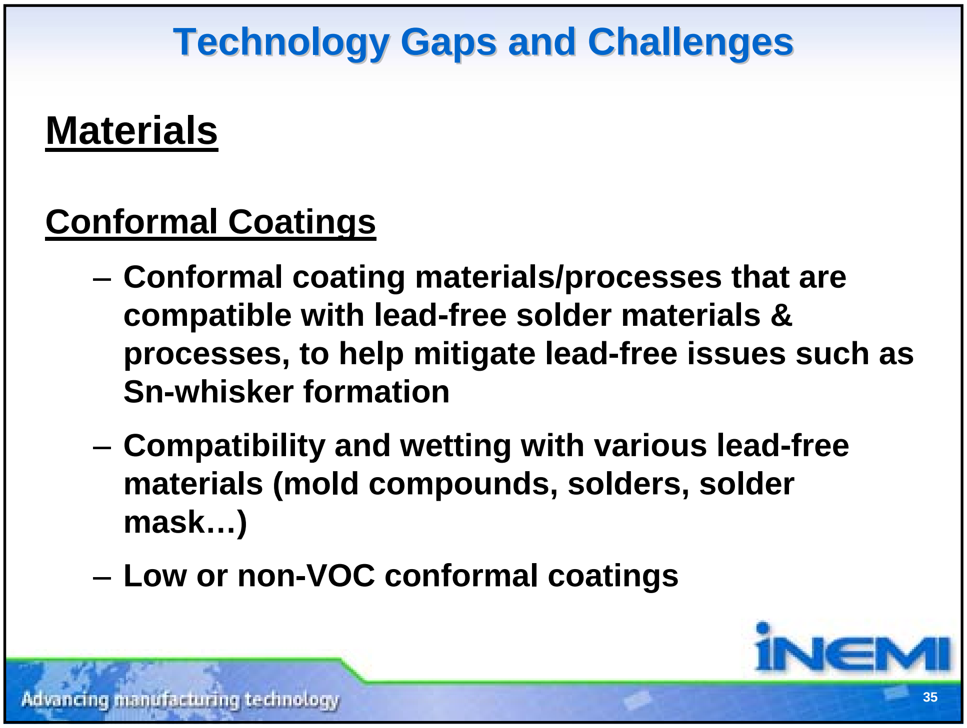


Technology Gaps and Challenges

Materials

Die attach

- Preform use will increase, driven by thermal conductivity and CTE requirements
- Lead-free compatible
  - Higher reflow temperatures and new materials
  - Compatibility with new solder masks
- Low thermal resistance materials due to increased power density and thermal management
  - Alternative fillers and fiber technology
- Compatibility with stress-sensitive low-K material
- Thermal and moisture resistant polymers
- Non-Ag fillers to reduce cost
- Lower temperature cure to reduce assembly cost and reduce warpage for stress sensitive applications

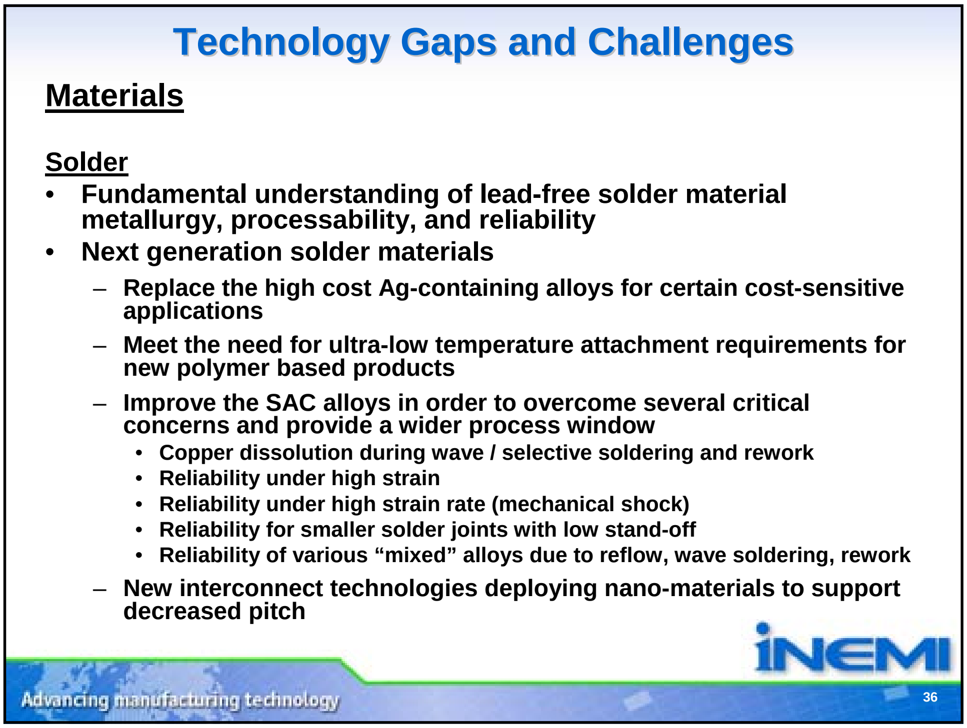


Technology Gaps and Challenges

Materials

Conformal Coatings

- – Conformal coating materials/processes that are compatible with lead-free solder materials & processes, to help mitigate lead-free issues such as Sn-whisker formation
- – Compatibility and wetting with various lead-free materials (mold compounds, solders, solder mask…)
- – Low or non-VOC conformal coatings

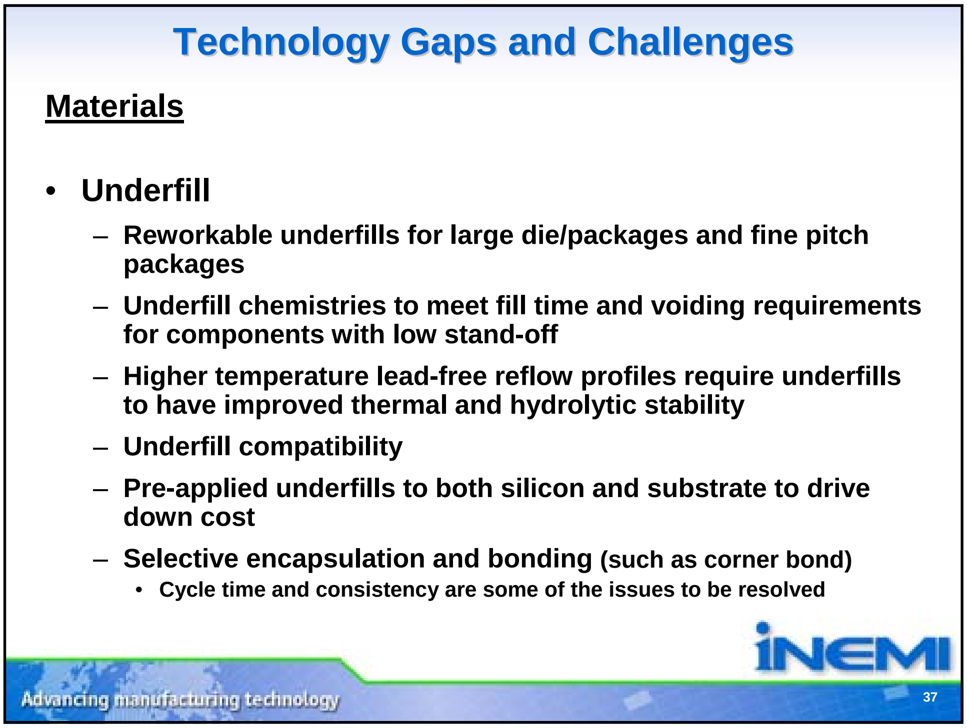


Technology Gaps and Challenges

Materials

Solder

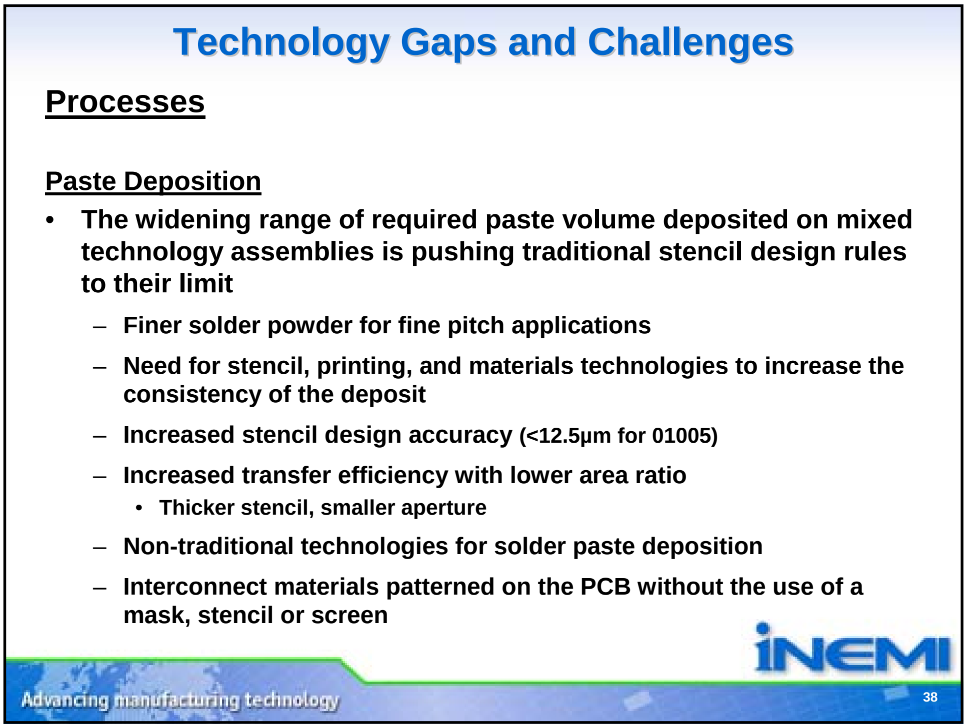
- Fundamental understanding of lead-free solder material metallurgy, processability, and reliability
- Next generation solder materials
  - – Replace the high cost Ag-containing alloys for certain cost-sensitive applications
  - – Meet the need for ultra-low temperature attachment requirements for new polymer based products
  - – Improve the SAC alloys in order to overcome several critical concerns and provide a wider process window
    - Copper dissolution during wave / selective soldering and rework
    - Reliability under high strain
    - Reliability under high strain rate (mechanical shock)
    - Reliability for smaller solder joints with low stand-off
    - Reliability of various “mixed” alloys due to reflow, wave soldering, rework
  - – New interconnect technologies deploying nano-materials to support decreased pitch



Technology Gaps and Challenges

Materials

- Underfill
  - Reworkable underfills for large die/packages and fine pitch packages
  - Underfill chemistries to meet fill time and voiding requirements for components with low stand-off
  - Higher temperature lead-free reflow profiles require underfills to have improved thermal and hydrolytic stability
  - Underfill compatibility
  - Pre-applied underfills to both silicon and substrate to drive down cost
  - Selective encapsulation and bonding (such as corner bond)
    - Cycle time and consistency are some of the issues to be resolved

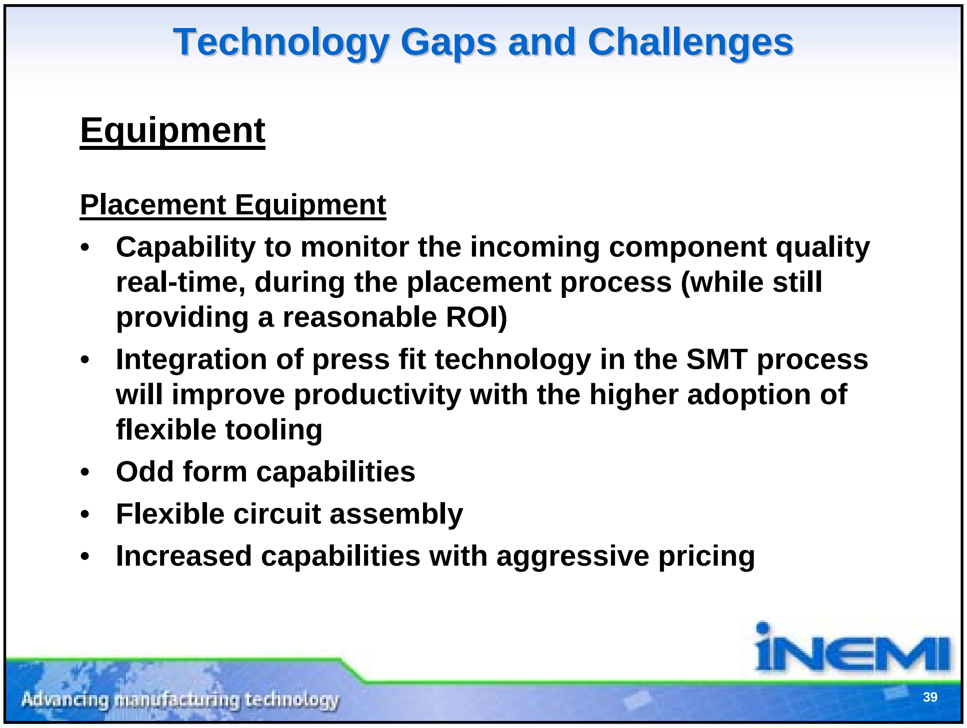


Technology Gaps and Challenges

Processes

Paste Deposition

- The widening range of required paste volume deposited on mixed technology assemblies is pushing traditional stencil design rules to their limit
  - Finer solder powder for fine pitch applications
  - Need for stencil, printing, and materials technologies to increase the consistency of the deposit
  - Increased stencil design accuracy (<12.5µm for 01005)
  - Increased transfer efficiency with lower area ratio
    - Thicker stencil, smaller aperture
  - Non-traditional technologies for solder paste deposition
  - Interconnect materials patterned on the PCB without the use of a mask, stencil or screen

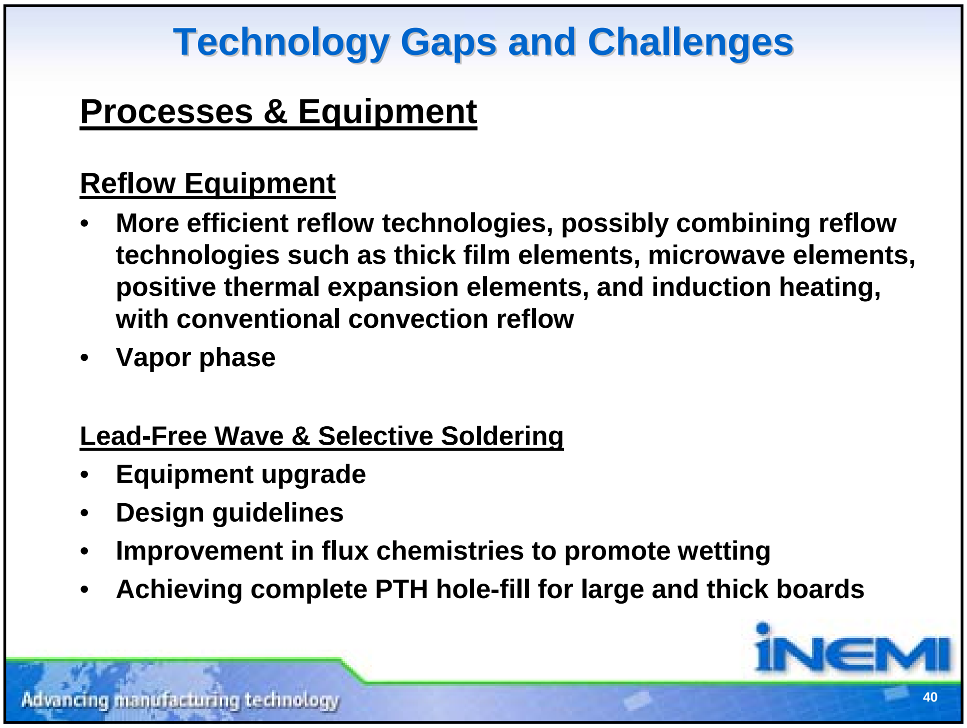


Technology Gaps and Challenges

Equipment

Placement Equipment

- Capability to monitor the incoming component quality real-time, during the placement process (while still providing a reasonable ROI)
- Integration of press fit technology in the SMT process will improve productivity with the higher adoption of flexible tooling
- Odd form capabilities
- Flexible circuit assembly
- Increased capabilities with aggressive pricing



Technology Gaps and Challenges

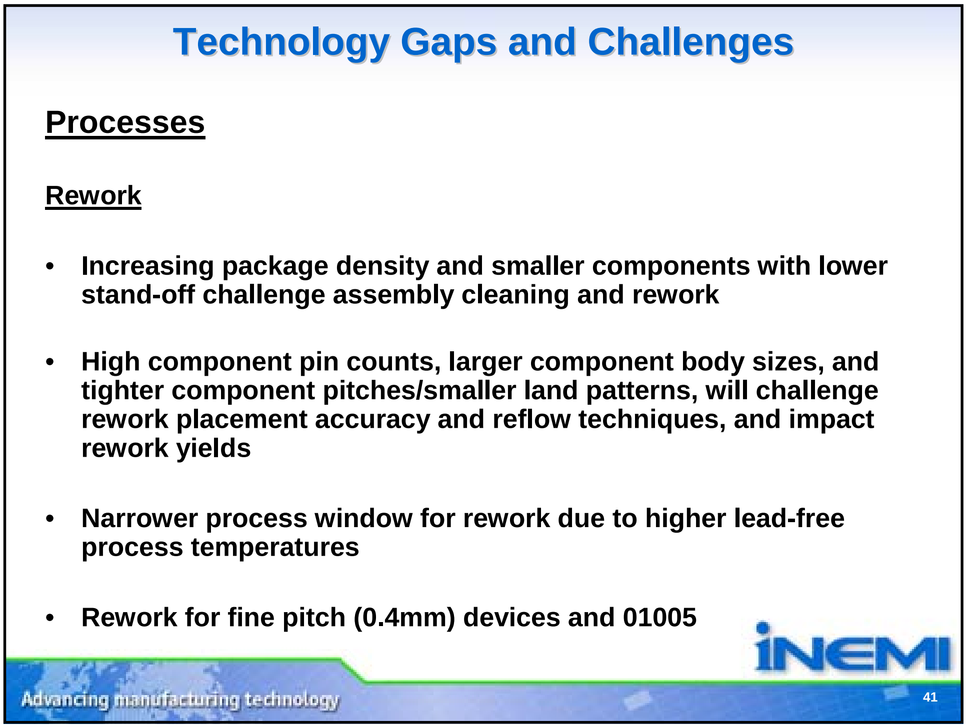
Processes & Equipment

Reflow Equipment

- More efficient reflow technologies, possibly combining reflow technologies such as thick film elements, microwave elements, positive thermal expansion elements, and induction heating, with conventional convection reflow
- Vapor phase

Lead-Free Wave & Selective Soldering

- Equipment upgrade
- Design guidelines
- Improvement in flux chemistries to promote wetting
- Achieving complete PTH hole-fill for large and thick boards

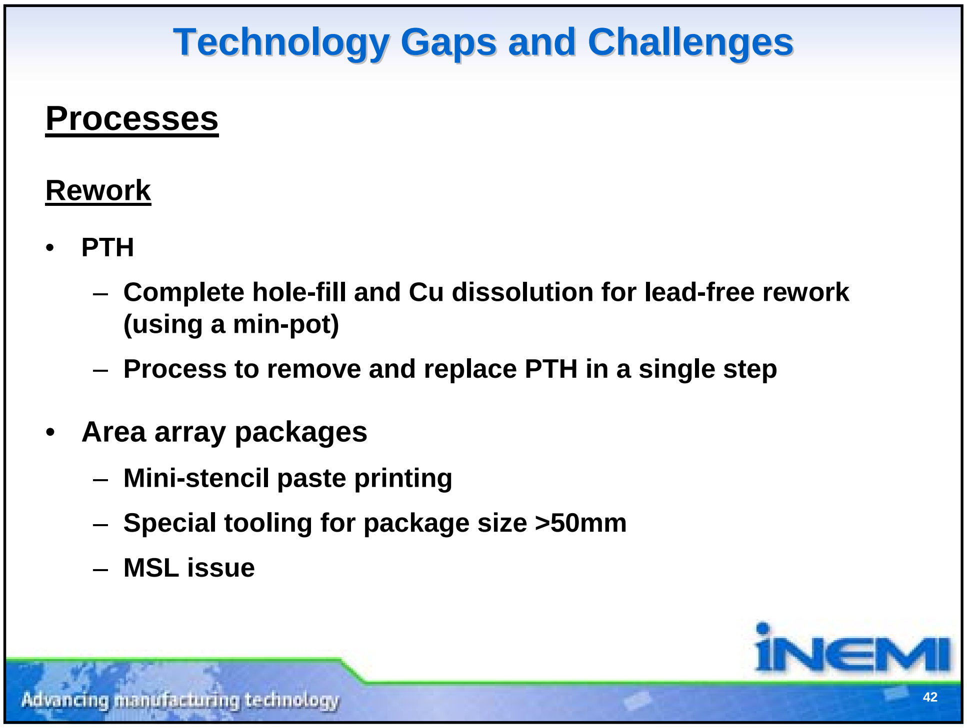


Technology Gaps and Challenges

Processes

Rework

- **Increasing package density and smaller components with lower stand-off challenge assembly cleaning and rework**
- **High component pin counts, larger component body sizes, and tighter component pitches/smaller land patterns, will challenge rework placement accuracy and reflow techniques, and impact rework yields**
- **Narrower process window for rework due to higher lead-free process temperatures**
- **Rework for fine pitch (0.4mm) devices and 01005**

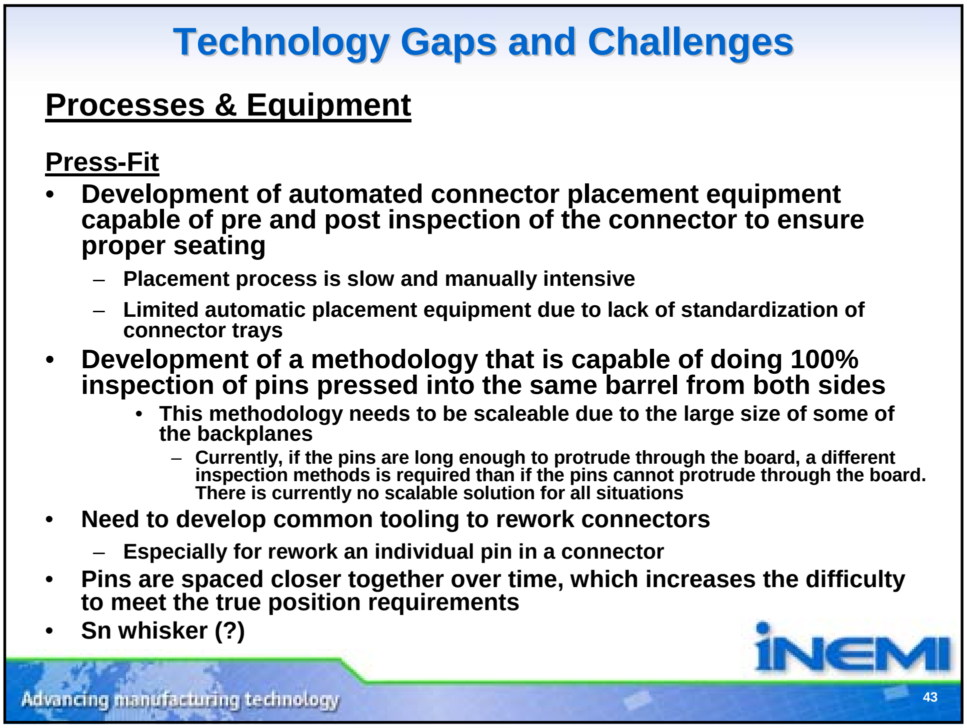


Technology Gaps and Challenges

Processes

Rework

- **PTH**
  - **Complete hole-fill and Cu dissolution for lead-free rework (using a min-pot)**
  - **Process to remove and replace PTH in a single step**
- **Area array packages**
  - **Mini-stencil paste printing**
  - **Special tooling for package size >50mm**
  - **MSL issue**

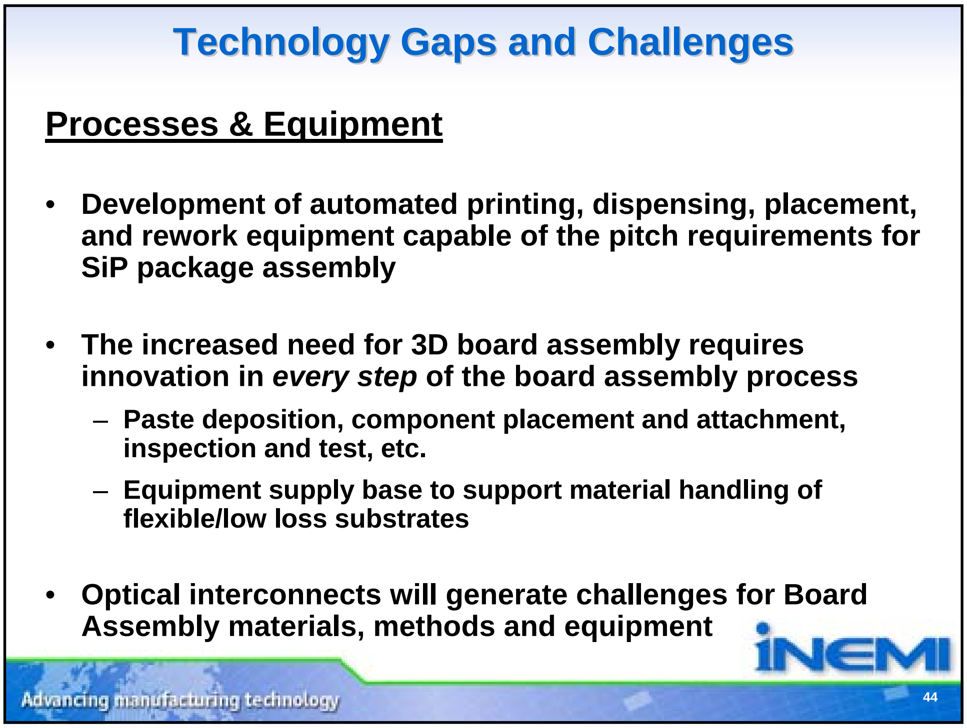


Technology Gaps and Challenges

Processes & Equipment

Press-Fit

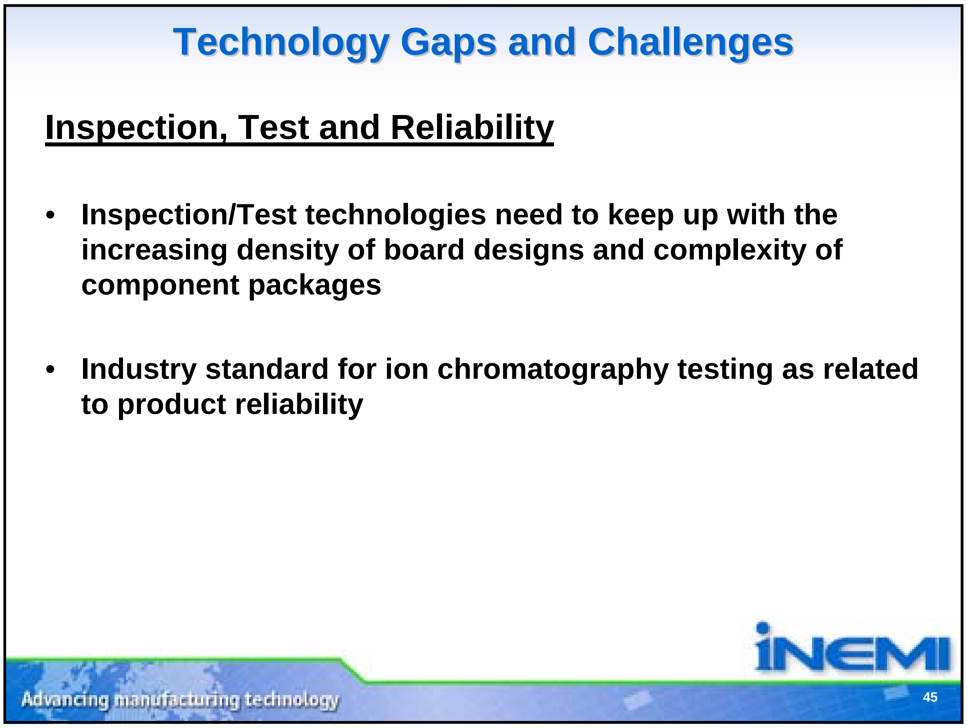
- Development of automated connector placement equipment capable of pre and post inspection of the connector to ensure proper seating
  - Placement process is slow and manually intensive
  - Limited automatic placement equipment due to lack of standardization of connector trays
- Development of a methodology that is capable of doing 100% inspection of pins pressed into the same barrel from both sides
  - This methodology needs to be scaleable due to the large size of some of the backplanes
    - Currently, if the pins are long enough to protrude through the board, a different inspection methods is required than if the pins cannot protrude through the board. There is currently no scalable solution for all situations
- Need to develop common tooling to rework connectors
  - Especially for rework an individual pin in a connector
- Pins are spaced closer together over time, which increases the difficulty to meet the true position requirements
- Sn whisker (?)



Technology Gaps and Challenges

Processes & Equipment

- Development of automated printing, dispensing, placement, and rework equipment capable of the pitch requirements for SiP package assembly
- The increased need for 3D board assembly requires innovation in *every step* of the board assembly process
  - Paste deposition, component placement and attachment, inspection and test, etc.
  - Equipment supply base to support material handling of flexible/low loss substrates
- Optical interconnects will generate challenges for Board Assembly materials, methods and equipment



Technology Gaps and Challenges

Inspection, Test and Reliability

- Inspection/Test technologies need to keep up with the increasing density of board designs and complexity of component packages
- Industry standard for ion chromatography testing as related to product reliability

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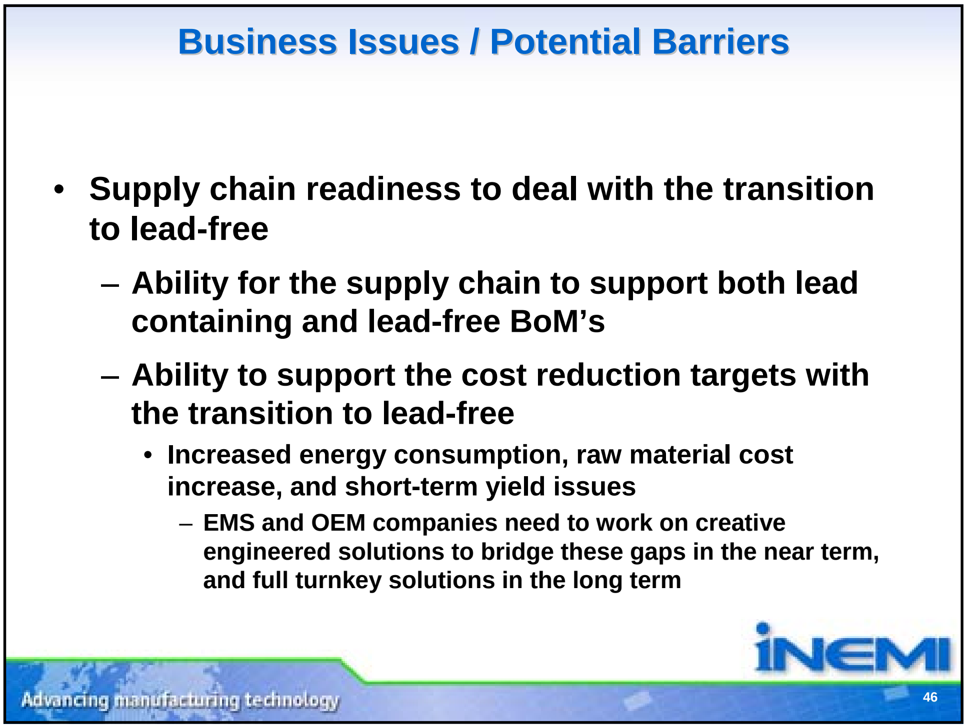

Business Issues / Potential Barriers

- Supply chain readiness to deal with the transition to lead-free
  - Ability for the supply chain to support both lead containing and lead-free BoM’s
  - Ability to support the cost reduction targets with the transition to lead-free
    - Increased energy consumption, raw material cost increase, and short-term yield issues
      - EMS and OEM companies need to work on creative engineered solutions to bridge these gaps in the near term, and full turnkey solutions in the long term

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Business Issues / Potential Barriers

- Emerging technologies
  - With R&D transitioning to low cost geographies, government, academia and industry consortia will need to formulate ways to adopt and develop emerging technologies (such as nano-technology) into the board assembly process, in the global outsourcing environment
- DFM in the global outsourcing environment requires closer interactions and collaboration across the supply chain
  - Industry standards need to be further developed to facilitate and streamline information flow

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