iNEMI

International Electronics Manufacturing Initiative

Board Assembly Roadmap

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Advancing manufacturing technology

Agenda

- Chapter Overview
- Key Trends
- Technology Gaps & Challenges
- Disruptive Technologies
- Business Issues / Potential Barriers
- Summary

Chapter Overview

Milestones

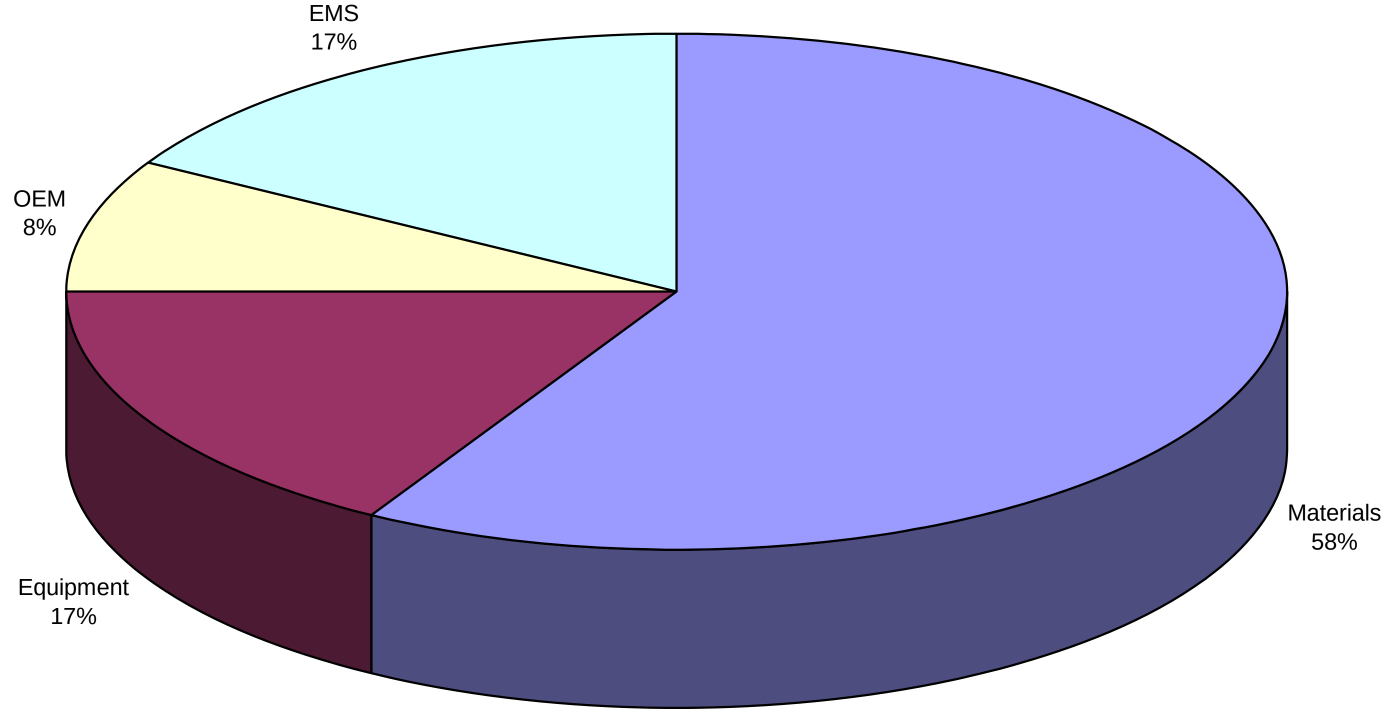
- Team formation:
  March 2008
- Final report :
  Sept. 2008

Contents

- Approximately
  71 pages / 26,000 words
  22 Tables / 8 Figures
- Business / Technology
- Span: 10 yrs
  (2009-2019)

Contents

Chapter Participation



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/ODM and materials/equipment suppliers in R&D and process development
- Continued migration to low cost regions
- The demands on cost reduction, and consequent low margins in this segment, are driving consolidation among EMS companies
- Thermal Management migration from passive cooling to active cooling
- Lower escape and defect rates

Key Trends

Main Drivers for Development in Board Assembly

- **Aggressive reduction of conversion cost**
- **Transition to environmental and regulatory requirements**
- **Reduction in New Product Introduction (NPI) Time**
- **Increased Component I/O Density**

NPI Capabilities Enhancement Priorities

Short-term Priorities (1 – 3 years)

- Elimination of hard tooling from current manufacturing processes
- Elimination (or easy identification) of counterfeit parts from the supply chain

Medium-term Priorities (3 – 7 years)

- Modeling and simulation tools need to push towards the reduction / elimination of Functional Verification steps.
- DfX rule systems need to be consolidated but be flexible enough to accommodate new component and assembly technologies - industry standards are valuable but only if they can have a much shorter development and revision cycle than what is supported today.

Long-term Priorities (8+ years)

- NPI cycle time can be improved with a change to deposited materials which could replace discrete components. This could also be accompanied by different delivery methods.
- Material developments may help qualify high reliability applications.
- New interconnect technologies may provide flexible routing options, reducing or eliminating PCB fabrication cycle time.

Key Trends

Technical Trends (examples of solutions)

SiP solutions

- Embedded components
- Flexible tooling solutions
- Optimized production equipment sets
- Optimized production line configurations

Impact of Embedded Passive Implementations

Embedded Passive Type	Board Assembly Impact
Second Level Substrate	Handling / Manufacturing Process which does not adversely impact the embedded passive performance
	Reduction in the number of placement machines
	Need for placement equipment with higher flexibility
	Known good substrate
	Increased board thickness due to additional layers
	Increased thermal mass of substrates
Package Level Substrate	Need for placement equipment with higher flexibility
	Known good substrate
	Advancements in board handling due to increased adoption of ceramic substrates
	Increased thermal mass of substrates
Interconnect Level	Equipment for integration of the passives on the termination
	Known good die
	Interconnect technologies for the passives on the termination
	Reliability understanding of integration of the passives on the interconnect

Assembly Materials Technology Needs

Parameter	Definition	2007	2009	2011	2019
Bar Solder	Lead-free % US	30%	50%	75%	95%
	Lead-free % WW	75%	90%	95%	95%
	Alloy	SAC/Sn-Cu	SAC/Sn-Cu	SAC/Sn-Cu	SAC /Sn-Cu
	Alloy			Low Temp	Low Temp
Solder Pastes	Lead-free % US	30%	50%	75%	90%
	Lead-free % WW	60%	80%	85%	90%
	Alloy	SAC	Lower Silver SAC	Lower Silver SAC/Low Temp.	Lower Silver SAC/Low Temp. Lower Silver SAC/Low Temp.Temp
	Halogen-free	85%	90%	95%	95%
	Recycle ratio	5%	10%	25%	25%
Wave Solder Flux	VOC Free	40%	50%	60%	90%
	Halogen free	95%	95%	95%	95%
Die Attach Preforms	Thermal conductivity critical	85%	90%	90%	90%
	Matched CTE capability	5%	7%	25%	50%
Die Attach Adhesives	Lead-free compatibility JEDEC +260 reflow, small die, paste	JEDEC L1 @260	JEDEC L1 @260	JEDEC L1 @260	JEDEC L1 @260
	Lead-free compatibility JEDEC +260 reflow, large die, paste	JEDEC L2 @260	JEDEC L1 @260	JEDEC L1 @260	JEDEC L1 @260
	High thermal (polymer based) paste	>30 W/m-K	>50 W/m-K	>100 W/m-K	>100 W/m-K
	Compatibility with Low-k ILD, paste	JEDEC L2 @260 90 nm tech	JEDEC L1 @260 65 nm tech	JEDEC L1 @260 45 nm tech	JEDEC L1 @260 32 and below nm tech
	Pre-applied polymer DA to silicon	JEDEC L3 @260	JEDEC L2 @260	JEDEC L2A @260	JEDEC L1 @260

Assembly Materials Technology Needs(2)

Underfills	Lead-free FC in package (Laminate) BGA balls only	JEDEC L3 @ 260, BGA balls only	JEDEC L2 @ 260, BGA balls only	JEDEC L1 @260, FC bump and BGA balls	JEDEC L1 @260, FC bump and BGA balls
	Lead-free FC in package (ceramic), BGA balls only	JEDEC L1 @260, BGA balls only	JEDEC L1 @260, BGA balls only	JEDEC L1 @260, FC bump and BGA balls	JEDEC L1 @260, FC bump and BGA balls
	Low K ILD	JEDEC L3 @260 90 nm tech	JEDEC L2 @260 65 nm tech	JEDEC L2 @260 45 nm tech	JEDEC L2 @260 45 nm tech
	Pre-applied FC	JEDEC L3 @260	JEDEC L2 @260	JEDEC L2A @260	JEDEC L2A @260
	Large Die	25 mm Low K	25 mm low K	30 mm low K	30 mm low K
	CSP	Pre-applied Lead-free	Reworkable 5%	Reworkable 25%	Reworkable 25%
Conformal Coatings	Lead-free	Compatible with Lead-free residues	Compatible with Lead-free residues	Compatible with Lead-free residues	Compatible with Lead-free residues
	VOC	VOC-Free	VOC-Free	VOC-Free	VOC-Free
Nano-materials	As fillers	Small Commercial Quantities	Large Quantities?		

Key	
Current Capability	
In Development	
Research Needed	

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
  - Substrate technologies also need to be able to keep up with the increasing density of board designs and miniaturization.
  - The issues of CTE (coefficient of thermal expansion) mismatch at the 2nd level interconnect, package warpage and resulting assembly problems
  - Decreasing pad diameters impacting the reliability of the second level assembly
  - Transition to embedded passives (in Portables)
  - Halogen Fire Retardant - free development process impacts?
- **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
    - Controlled release of alloy alternatives (process impact warning)
  - 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

Reflow Technology Forecast

Parameter	Metric	2007	2009	2011	2013	2019
Temperature Delta Performance Lead-free Processing Maintenance	Cross Conveyor Uniformity at Peak temperature - LF profile (°C)	7	7	5	4	4
	Along Conveyor Uniformity at Peek temperature - LF profile (°C)	10	10	7	5	5
	Peak Temperature Repeatability of a given thermal couple (°C)	5	5	4	3	3
Inert Capability	Scfh (ppm levels)	100	100	100	100	100
Cooling rates	Solder joint reliability	4°/sec	6°/sec	6°/sec	6°/sec	6°/sec
Flux Management	Flux collection	Self Cleaning	Self Cleaning	Advanced flux chemistry and better containment	Advanced flux chemistry and better containment	Elimination of flux management
Cost of Operation, Energy & Consumption	Reduction in operating costs	70%	60%	50%	40%	40%
Traceability	Ability to link process parameters and changeovers to equipment	GEM/ SECS	Data logging XML connectivity SPC	Auto collection of data and warnings	Closed loop control	Tracking of all products and materials processed
Change over time	Total time from one product to the next with significant temperature profile change	25 minutes	20 minutes	17 minutes	15 minutes	10 minutes

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 mini-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
- Need to develop common tooling to rework connectors
  - Especially for rework on individual pins in a connector
- Pins are spaced closer together over time, which increases the difficulty to meet the true position requirements
- Sn whisker mediation in fine pitch connectors

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**

Disruptive Technologies and Events

Environmental Drivers

- **New interconnect materials development driven by REACH regulations**
- **New industry (iNEMI) pro-activity toward HFR-free and other issues**
- **Development of alternative materials (nano solder, conductive adhesives) and processes (warm assembly, nano-velcro) driven by energy consumption and carbon footprint considerations**

Convergence of Packaging and Assembly

- **Will drive changes in industry supply chain**

Printing Process

- **The need for finer pitch, smaller volume deposits, combined with non-planar surfaces, may drive alternative deposition schemes (movement from stencil printing to dispensing / jetting).**
- **Divergence of package sizes will drive new assembly approaches**
- **Cutting edge, fine pitch packages are developed for Portable products, but the same packages will get used for larger boards in other segments. Sometimes, a 0.4 mm pitch component will be next to a large CCGA. This will place extreme divergence in print volume requirements leading to hybrid assembly approaches.**

Disruptive Technologies and Events

Energy Costs Will Drive New Process and Materials Development as well as Geographic Footprint for Assembly

- **With dramatic changes in the energy infrastructure, significant changes will occur in the development and deployment of low energy consuming materials and processes.**
- **Manufacturing site location considerations will factor in costs of energy and transportation.**

Embedded PCBs

- **Embedding active, passive, and optical components in PCBs, in various formats (e.g. bare die, packaged parts, and modules), will present challenges for the PCB fabrication and assembly processes, and will inevitably impact the configuration of the supply chain.**
- **Process development, test, reliability, yield, and cost are some of the issues to be addressed.**

Printed Electronics

- **Printed Electronics, a topic to be addressed in a separate chapter of this Roadmap, will have direct impact on many elements of the Board Assembly supply chain, including equipment, materials, and processes.**

Business Issues / Potential Barriers

- Supply chain readiness to deal with the transition to lead-free/HFR-free/REACH/?
  - 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/HFR-free
    - Increased energy consumption, raw material cost increase, and yield issues
      - EMS and OEM companies need to work on creative engineered solutions to bridge these gaps

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

Summary

- Miniaturization is a key driver in electronics industry:
  - IC Packaging
  - Board Assembly
  - Increased functionality of End Product
- End product manufacturing is increasingly commoditized:
  - Migration to low cost geographies
  - Relentless cost pressures
  - Low margin business
- New technologies are required to keep pace:
  - Green materials
  - Nanomaterials (e.g. temp. reduction of Pb-free solders)
  - Warm Assembly
- Have covered only highlights from 1 of 20 roadmaps
- Many more details in full Roadmap

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