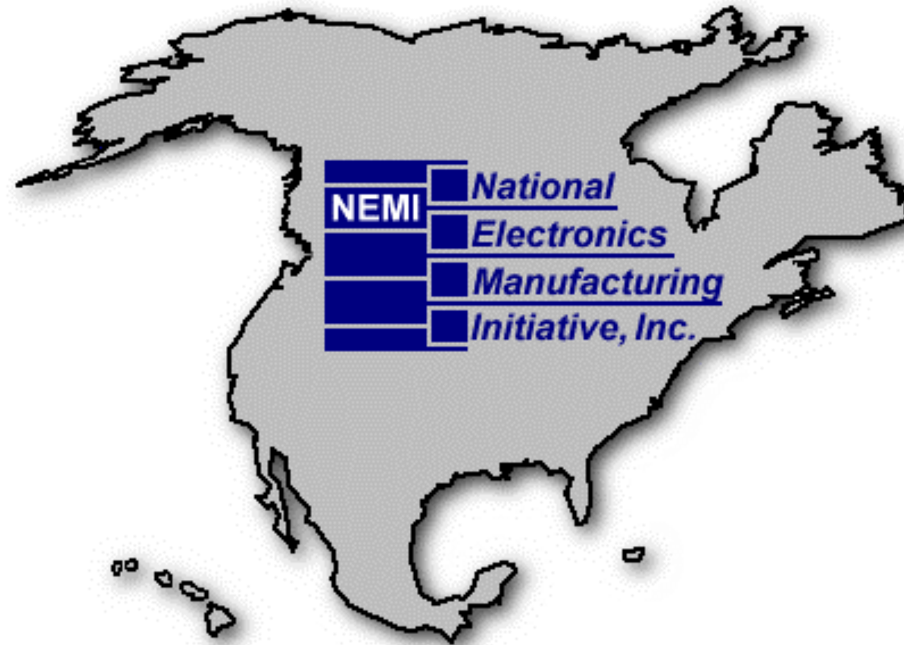


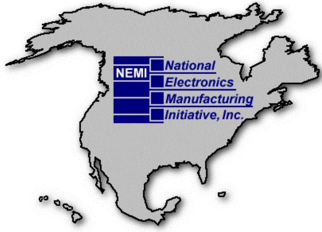
NEMI overview and NEMI Pb-free Task Group Activities

Ron Gedney- NEMI   Jasbir Bath-Solectron

Workshop on Modeling and Data Needs for Lead-free Solders

New Orleans, LA

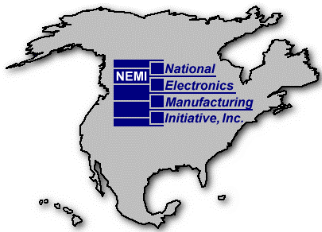
February 15th, 2001



What Does NEMI Do?

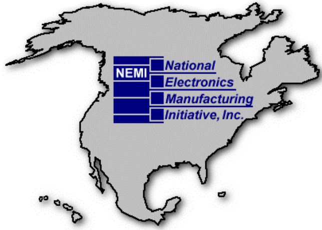
Focus: Electronics Manufacturing Technology above Silicon

- Roadmaps the needs of the North American electronics industry.
- Conducts Industry Forums on Emerging Topics
- Identifies gaps in the North American infrastructure.
- Provides Industry leadership to address gaps.
- Establishes implementation projects to eliminate these gaps.
- Stimulates R&D projects to fill these gaps.
- Stimulates standards activities to speed the introduction of new technology.



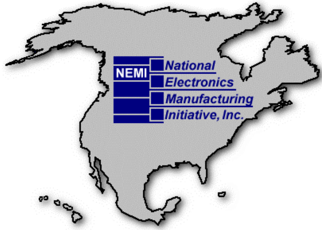
Current NEMI Membership

- 3M
- Adept Technology, Inc.
- Agile Software
- Alcatel Canada
- American Electronics Association (AEA)
- AMP Incorporated
- AMR Research
- Asymtek
- BTU International
- Celestica, Inc.
- ChipPac, Inc.
- Cimetrix, Inc.
- Compaq Computer Corporation
- Cookson Electronics
  - Alpha Metals
  - Speedline Technologies
- CTS Corporation
- CyberOptics Corporation
- Defense Advanced Research Projects Agency (DARPA)
- Delphi Delco Electronics Corporation
- Dexter Corporation
- Dover Technologies International
  - Everett Charles
  - Universal Instruments
  - Vitronics Soltec
- DuPont Electronic Materials
- Eastman Kodak Company
- Electro Scientific Industries (ESI)
- Electronic Industries Association (EIA)
- Extricity, Inc.
- GenRad, Inc
- Georgia Institute of Technology
- GSI Lumonics
- IEEC (Binghamton Univ.)
- Ingenuus
- Indium Corp.
- IBM Corp.
- IPC
- Intel Corporation
- Interconnection Technology Research Institute (ITRI)
- Johnson Manufacturing Company
- Kester Solder
- Kulicke and Soffa Industries, Inc.
- Lucent Technologies, Inc.
- Merix Corporation
- Meta Group
- Motorola
- National Center for Manufacturing Sciences (NCMS)
- National Institute of Standards and Technology (NIST)
- Netfish Technologies, Inc.
- Nortel Networks
- Plexus Corp.
- PTC Corp.
- Sanmina
- SCI Systems
- Shipley Company
- Solectron Corporation
- Storage Technology Corporation
- Technomatix-Unicam, Inc.
- Texas Instruments
- Virginia's Center for Innovative Technology (CIT)



Uniqueness of the NEMI Roadmap

- The NEMI Roadmap is Customer driven, not technology driven.
- Product Sector Champions (the voice of the customer)
  - Project future needs
  - Focus on being competitive in World Market.
- Technology Working Groups (TWGs)
  - Predict evolution of technology/business practices
  - Identify gaps and showstoppers in technology/infrastructure
  - Focus on needs rather than provide solutions.
- Roadmaps deal with manufacturing rather than end products.
- Roadmap findings are used by Industry, Academia, and Government to focus development & deployment programs.

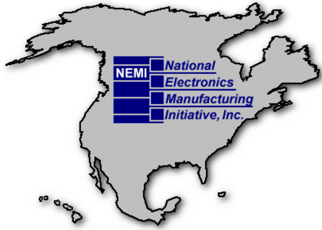


Roadmap Development

Product Sector Needs Vs. Technology Evolution

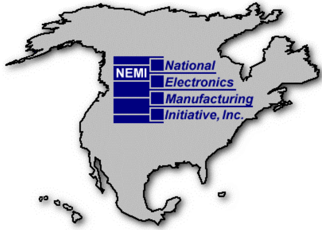
TWGs	Product Sectors
Digital Silicon Technology	Low Cost
Business Processes **Supply Chain, FIS, etc.**	Hand Held
Design Technologies Modeling, Thermal, etc	Cost / Performance
Manufacturing Technologies Board Assy, Test, etc.	Harsh Environment
Comp./Subsyst. Technologies Packaging, Substrates, Displays, etc.	High Performance

Connect with and Strengthen Your Supply Chain



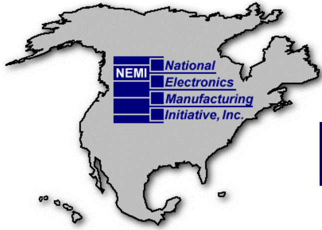
North America Electronics Goal

- N. American OEMs/EMSs need to prepare processes to be able to deliver Pb-free products in 2001 with an 'eye' to total Pb-elimination by 2004.
  - Japan driving "Green"consumer products.
    - Timetables seem to be holding (2001-2003)
  - NEMI companies received serious inquiries.
  - EU legislation to ban lead in 2008.
    - Countries can shorten timeframe.



NEMI lead-free program

- Initiated 1999
- Extensive search of available data (NCMS, ITRI-UK, IDEALS, etc.
- May, 1999 Meeting in Chicago
  - Six solder vendors
  - Major OEM's, EMS and component suppliers
  - Decided:
    - Standardize one paste alloy
    - Patent free if possible
    - Ternary or lower alloy
- SOW developed and accepted 12/99
- 22 company participants (now 28)

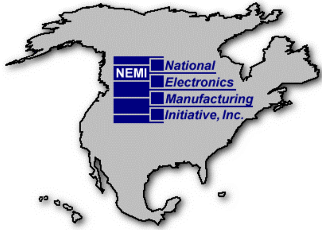


Lead-free Task Group Participants

OEMs/EMSs	
Alcatel Canada	Jana Cousineau
Celestica	Bruce Houghton
	Marianne Romansky
	Polina Snugovsky
Compaq	Elizabeth Bennedetto
Delphi/Delco	Rich Parker
IBM	Kevin Knadle
	Don Henderson
	Chuck Woychik
Intel	Raiyo Aspandiar
Kodak	Svetlana Reznik
Lucent	John Sohn
	Rajan Deshmukh
Motorola	Edwin Bradley
	Srinivas Chada
	Alek Zubelewicz
SCI	Frank Grano
Solectron	Jasbir Bath
StorageTek	Rick Charbonneau
	Brian Hunter

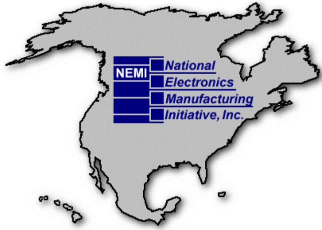
Solder Suppliers	
Alpha	Bruce Moloznik
Heraeus	Brian Bauer
Indium	Ning-Cheng Lee
Johnson Mfg.	Al Gickler
Kester Solder	Dennis Bernier
Components	
ChipPac	Swami Prasad
Intel	Jack McCullen
Motorola	Nick Lycoudes
Texas Instruments	Edgar Zuniga
FCI	Jim Kopec

Govt. Agencies/Other	
NIST	Carol Handwerker
SUNY-B/IEEC	Mike DiPietro
ITRI (US)	Jack Fisher
IPC	Chris Jorgensen
Universal Instr.	Len Poch
Vitronics-Soltec	Dennis Barbini



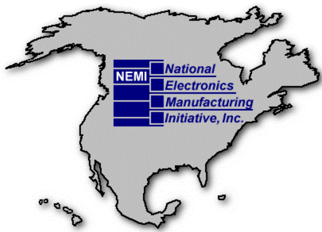
Lead Free Standards

- Leverage of NEMI Member Companies
  - NEMI member companies employ over 1M workers
  - NEMI member companies recorded $300B in sales during 1999.
    - representing a significant segment of the industry
  - However, maximum benefit achieved through world wide agreement .
  - Support World-wide Standards (SEMI, HDPUG, IPC)
- Update/create JEDEC standards.



Major Task Group Objectives

- Demonstrate capability to deliver products in volume by 2001 with Pb-free interconnects.
- Facilitate a common Pb-free solder alloy composition for N.American electronics assembly.
- Work with component and PCB suppliers to develop specifications necessary to meet high temperature reflow conditions.
- Develop criteria that industry can use to evaluate Pb-free processes.
- Monitor environmental legislation to adjust activities if necessary.



Task Group Structure

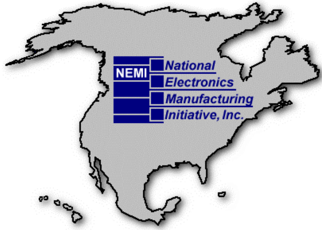
NEMI Pb-free Interconnect Group
Edwin Bradley, *Motorola*
Rick Charbonneau, *StorageTek*

Alloy Selection
Carol Handwerker, *NIST*

Solder Reliability
John Sohn, *Lucent*

Components
Rich Parker, Delphi

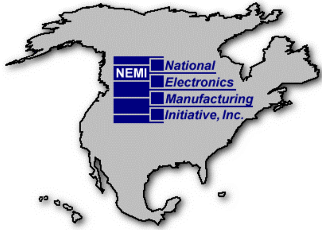
Process Dev
Jasbir Bath, Solectron



NEMI Lead Free Alloy Group

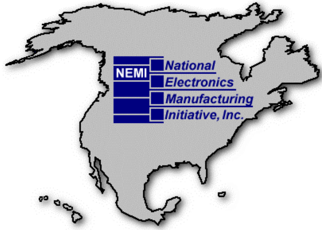
– Chair: Carol Handwerker(NIST), Co-Chair Alex Zubewelicz(Motorola):

- Literature Search; Assessed available data, including Europe and Far East.
- Determined no drop-in replacement for PbSn
- Criteria: Eutectic solder; max three metals (ternary), patent free if possible
- Chose SnAgCu Family
- Obtained Patent Search
- Determined Eutectic
- Chose Sn3.9Ag0.6Cu (+/-0.2%)for reflow; low cost Sn0.7Cu for wave
- Developed matrix of data desired
- Developing Guide for University Research
- Starting to work with Academia/ Research Institutes (Sandia National Labs, NIST Boulder)



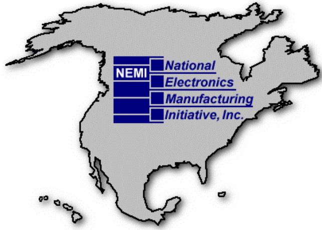
Thermal, Electrical and Wetting Properties (1-High Priority, 3-Low Priority)

Thermal, Electrical, and Wetting Properties	Sn3.9Ag0.6Cu	Sn0.7Cu	Sn3.5Ag	Sn37Pb*
Coefficient of Thermal Expansion (CTE)	2	2	2	
Vol. Change on Freezing (%)	3	3	3	
Specific Heat (JKg-1K-1)	3	3	3	
Latent Heat (KiloJ Kg-1)	3	3	3	
Thermal Diffusivity (mm2/s)	3	3	3	
Thermal Conductivity(Wm-1K-1)	3	3	3	
Electrical Conductivity (%IACS)	3	3	3	
Electrical Resistivity (micro Ohm cm)	3	3	3	
Surface Tension(mNm-1) at Temperature of solder/T(mp of solder)	3	3	3	
Surface Tension at (mNm-1)) at Temperature of Solder/T(mp of solder)	3	3	3	
Wetting Time @ 0 Force (sec) as a function of Temperature of solder/T(mp of solder)	3	3	3	
Wetting Time @ 2/3 Force (sec) as a function of Temperature of solder/T(mp of solder)	3	3	3	
Max Wetting Force (micro N) as a function of Temperature of solder/T(mp of solder)	3	3	3	



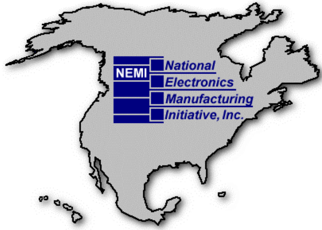
Mechanical properties (1-high priority, 3-low priority)

Mechanical Properties	Sn3.9Ag0.6Cu	Sn0.7Cu	Sn3.5Ag
Ultimate Tensile Strength(MPa) at room T	1	1	1
Shear Strength (MPa) (at particular strain rates, e.g. 10^{-3} to 10^{-7} /s)	1	1	1
Ring in Plug Shear (kg) (at particular strain rates, e.g. 10^{-3} to 10^{-7} /s)	3	3	3
Elastic (Young's) Modulus (GPa) at 25°C	3	3	3
Elastic (Young's) Modulus (GPa) at 50°C	3	3	3
Elastic (Young's) Modulus (GPa) at 100°C	3	3	3
Total Elongation (%) (at particular strain rates, e.g. 10^{-3} to 10^{-7} /s)	1	1	1
Uniform Elongation (%) at room T (at particular strain rates, e.g. 10^{-3} to 10^{-7} /s)	1	1	1
Yield Strength (MPa) at room T (at particular strain rates, e.g. 10^{-3} to 10^{-7} /s)	1	1	1
Work Hardening Coefficient (at particular strain rates, e.g. 10^{-3} to 10^{-7} /s)	1	1	1
Creep Resistance (at particular strain rates)	1	1	1
Min.Creep Strain Rate @Stress of 20MPa (1/s) at room T	1	1	1
Min.Creep Strain Rate @Stress of 20MPa (1/s) 125°C	1	1	1
Hardness (HV)	3	3	3



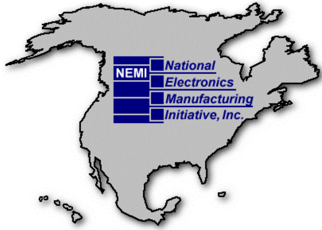
Mechanical Properties (cont)- Sn3.9Ag0.6Cu, Sn0.7Cu, Sn3.5Ag, Sn37Pb. (1-high priority, 3-low priority)

Thermomechanical Fatigue Resistance (at particular strain rates, e.g. 10^{-3} to 10^{-7}/s)	1	1	1
Isothermal Fatigue Data (at particular strain rates e.g. 10^{-3} to 10^{-7}/s)	1	1	1
Thermal Fatigue Hysteresis behavior (at particular strain rates e.g. 10^{-3} to 10^{-7}/s)	1	1	1
Constitutive Behavior (at particular strain rates)	1	1	1
Stress Rupture (at particular strain rates)	2	2	2
Acoustic measurements	3	3	3
Fracture Toughness(MPa- M1/2) Room T (at particular strain rates)	2	2	2



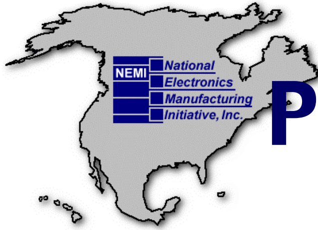
NEMI Alloy group action plans

- Developing experimental procedures to measure the mechanical, thermal, electrical and wetting properties mentioned. (Input from NEMI members and other institutions (Sandia National Labs, ITRI-UK). This document will be distributed to interested universities/ organizations.
- Developing solder database of existing mechanical properties of lead-free alloys. Adding on information to the database which is appropriate
- Developing and defining modeling and data base needs for selected lead-free solders



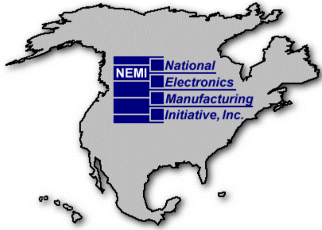
NEMI Lead Free Component Group

- Component Group (Chair: Rich Parker, Delphi-Delco)
  - 2Q99 – Supplier Survey Majority of suppliers unaware/no plan– this is changing
  - Developed and Published Worst Case Reflow Profile(260°C peak reflow)
  - Engaged ITRI(US) for help in assessing lead-free PWB Finishes and determine effect on PWB Laminates on increased temperature
  - Second vendor survey underway
  - Major issue – plastic semiconductor packages (popcorning, temperature)
    - Working with 4 major suppliers to quantify
  - Obtain boards, components for reliability testing



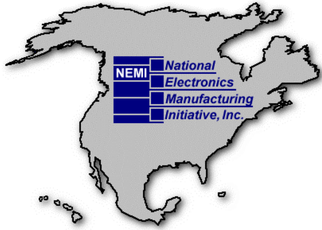
Primary Process Impact (260°C Max)

- -Moisture & temperature sensitivity of components & PWBs to higher reflow temps. is a major issue.
- Provide thermal profiles that represent a typical worst case processing temperature exposure for component testing purposes, for reflow and wave soldering processes.
- Based on temperature deltas of 5-20° C across a PCB substrate
  - Completed for reflow (255 C +5,-0)
  - Need data for wave soldering (265-270 C potentially)



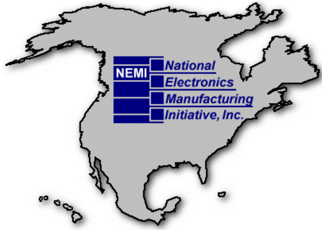
NEMI No-Lead Soldering Project: Component Subgroup Objectives

- Identify acceptable Pb-Free component / PWB termination finishes to be used by component and PWB manufactures. Identify risks or potential issues with the surface finishes available.
  - Sub team formed, Srini Chada(Motorola)
  - Part of survey sent to team for distribution to suppliers
    - ~35 surveys returned and are being compiled
  - Potential Candidates: NiPd, Ni/Pd/Au, Ni/Pt, SnNi, Sn, Sn/Ag, SnCu, SnBi, CuAu

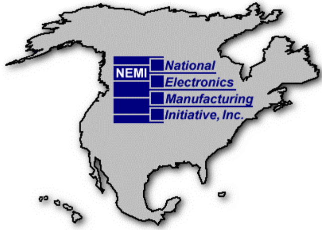


Component Subgroup Objectives (cont.)

- **Sanction and encourage testing for all types of components by component suppliers.**
  - Sub team formed, (Nick Lycoudes, Motorola)
  - Determine the impact to moisture susceptibility levels for IC packages.
- **Moisture Sensitivity Level (MSL) Rating:**
  - MSL typically degrades by one level for every 5 to 10 ºC increase of PRT(Peak Reflow Temperature)
  - Degradation of MSL may increase with increasing profile dwell above 200 °C
  - Assess life cycle reduction driven by increased thermal profile
    - Difficult to obtain this level of information.
      - Assumptions for packaged IC's: If they pass moisture susceptibility testing, life tests will be OK.

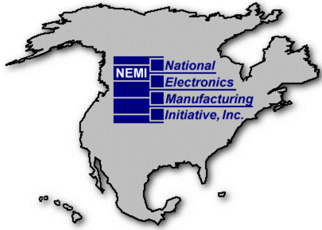


- **Reliability Group (Chair, John Sohn, Lucent)**
  - Test Plan developed and in place
  - All Test Cells committed/assigned to member companies (Motorola, Lucent, Kodak, Solectron, Celestica, SCI Systems)
  - Joint with ITRI, PWB suppliers have evaluated FR-4 materials for high temperature assembly.
  - PWB suppliers guarantee laminate to pass tests.



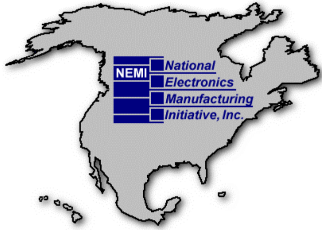
NEMI Lead Free Project

- **Reliability Tests:**
  - Three tests planned
    - Thermal Cycling
    - Electrochemical Migration(solder pastes)
    - 3 point bend
  - Three device Lead Finish/Paste Combinations:
    - 1. SnAgCu balls with SnAgCu paste
    - 2. SnPb balls with SnPb Paste (STD)
    - 3. SnPb Balls with SnAgCu Paste



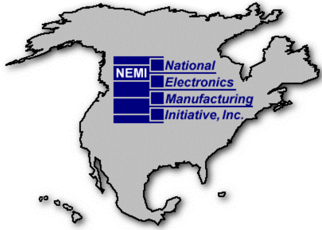
Solder Reliability Sub-Group

- Develop Relative Performance Data for Identified Alloys
  - Literature Review
  - Internal Testing
  - Complement other tests: HDPUG, NCMS
- Identify and Propose Changes to Industry Reliability Standards



Solder Reliability Sub-Group (Reliability testing)

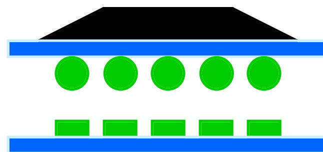
- <u>Thermal Cycling</u>: Thermal ramp rate 12ϒC/min in a test chamber with a tightly controlled thermal profile, using JEDEC JESD22-A104-A test method with –40ϒC to +125ϒC and 0ϒC to +100ϒC temperature regimes.
- <u>Bend Tests</u>: 3 point bend to simulate the damage that occurs from out of plane deformation during drop, test, or assembly. Especially related to BGA components. (Compaq)

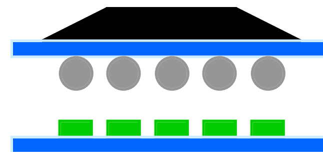


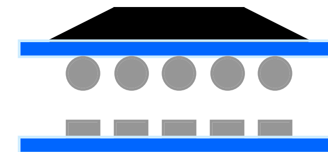
Solder Reliability Sub-Group (Components. Alloys, Finishes)

Components(lead-free and tin-lead: lead-free alloys/finishes listed below):

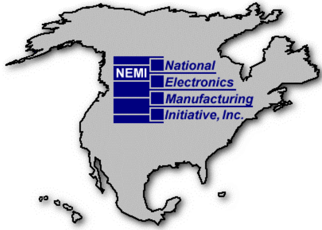
Type 1 TSOP (NiPd)	CSP(SnAgCu)
2512 resistor(pure tin)	CSP II(SnAgCu)
CerBGA(SnAgCu)	PBGA(SnAgCu)





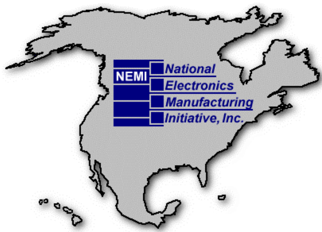


Connect with and Strengthen Your Supply Chain



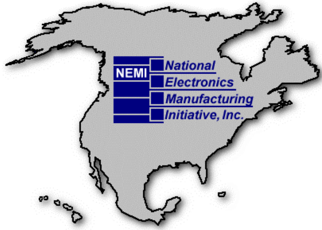
Lead-free Process Group

- Evaluate 5 tin-lead and 5 tin-silver-copper pastes by printability inspection and visual and X-ray inspection after reflow. Choose one tin-lead and one tin-silver-copper no-clean paste for the NEMI builds. (Solectron)
- Manufacture test boards for reliability sub-group (Universal Instruments/ DEK/ Vitronics Soltec)
- X-ray inspection of boards(Agilent Technologies)
- Sonoscan inspection of BGA and TSSOP component boards for delamination/anomalies.
- AOI inspection of TSSOP and resistor lead-free and tin-lead boards (Orbotech)
- Machine Rework evaluation of lead-free CSP and PBGA component boards (SRT/GenRad)
- Manufacturability report on boards built and analysis undertaken.



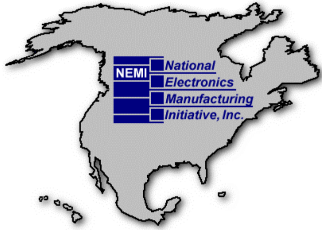
NEMI Lead Free Project

- Target date for completion 8/30/2001
- Implementation decision up to member companies
- Substantial investment will still be required
  - Individual companies must qualify to their own standards and requirements
  - Additional manufacturing equipment/facilities needed
  - Suppliers must change finishes/internal designs
  - Additional alloy characterization will be needed



Communications

- IPC Works, Oct. 1999 presentation and helped organize technical session.
- SUNY Binghamton Lead-free Symposium, Dec. 1999
- Circuits Assembly Article, Dec. 1999.
  - General project summary.
- Advanced Packaging article, Feb. 2000.
  - Alloy selection published, more detailed project summary.
- Panel Discussion at APEX 2000.
- Circuit Assembly, May, 2000.
  - Specific Pb-free alloy paper.
- Circuitree article, July 2000.
- HDPUG/SEMI meeting, Oct. 2000.
- UC-SMART meeting, UC Berkeley, Dec.2000
- Organized APEX 2001 Pb-free session.
- NEMI lead-free forum. APEX 2001



Overall Summary

- Recommended Sn-3.9Ag-0.6Cu (+/-0.2) for reflow, Sn-0.7Cu for wave in Oct. 1999.
- In middle of test plan for solder reliability to complement other consortia tests.
- Working with JEDEC committee leadership on development of appropriate component specs.
- Defined reflow profile for component evaluations.
- Working with ITRI(U.S.) on PCB issues.
- Plan to complete project in August, 2001.