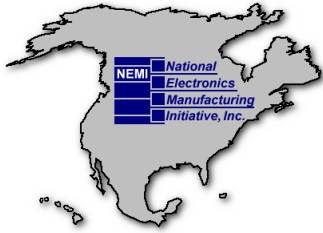


NEMI Lead Free Solder Program September 2000 Status



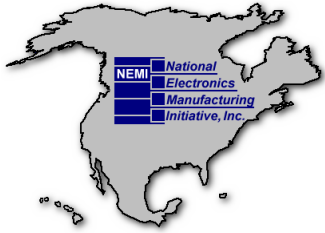
*Ron Gedney
V.P. Operations*



NEMI Lead Free Project

- **Initiated 1Q99**
- **Extensive search of available data (NCMS, ITRI-UK, IDEALS, etc.)**
- **May, 1999 Meeting in Chicago**
 - **Six solder vendors**
 - **Major OEMs, EMS and component suppliers**
 - **Decided:**
 - » **Standardize one paste**
 - » **Patent free if possible**
 - » **Ternary or lower alloy**
- **SOW developed and accepted 12/99**
- **22 company participants**

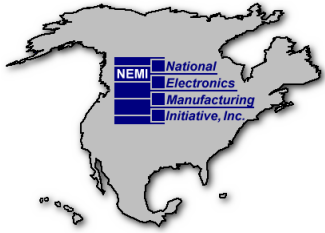
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NEMI Lead Free Project

- **Formed five sub-groups:**
 - **Alloy: choose alloy, pursue industry standard, gather data**
 - **Reliability: Selected testing, improve confidence levels**
 - **Components: Assess issues, develop data base**
 - **Process: Propose manufacturing process for new alloy**
 - **Legislative: Monitor world-wide legislation (joint with EIA)**

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NEMI Leaders

Project Chair:

Edwin Bradley, Motorola

Co-Chair:

Richard Charbonneau, StorageTek

Alloy Sub-Group:

Carol Handwerker, NIST

Process Sub-Group:

Jasbir Bath, Solectron

Reliability Sub-Group:

John Sohn, Lucent

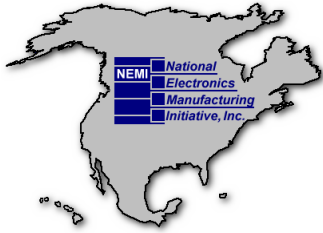
Components Sub-Group:

Richard Parker, Delphi Delco

Legislative Sub-Group:

Ron Gedney, NEMI

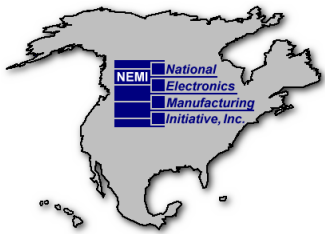
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NEMI Lead Free Project

- **Alloy Group Accomplishments:**
 - 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
 - Obtained Patent Search – on NEMI web site
 - Determined Eutectic
 - Chose Sn_{3.9}Ag_{0.6}Cu (+/-0.2%) for reflow; low cost Sn_{0.7}Cu for wave
 - Developed matrix of data desired
 - » Guide for University Research
 - Starting to work with Academia

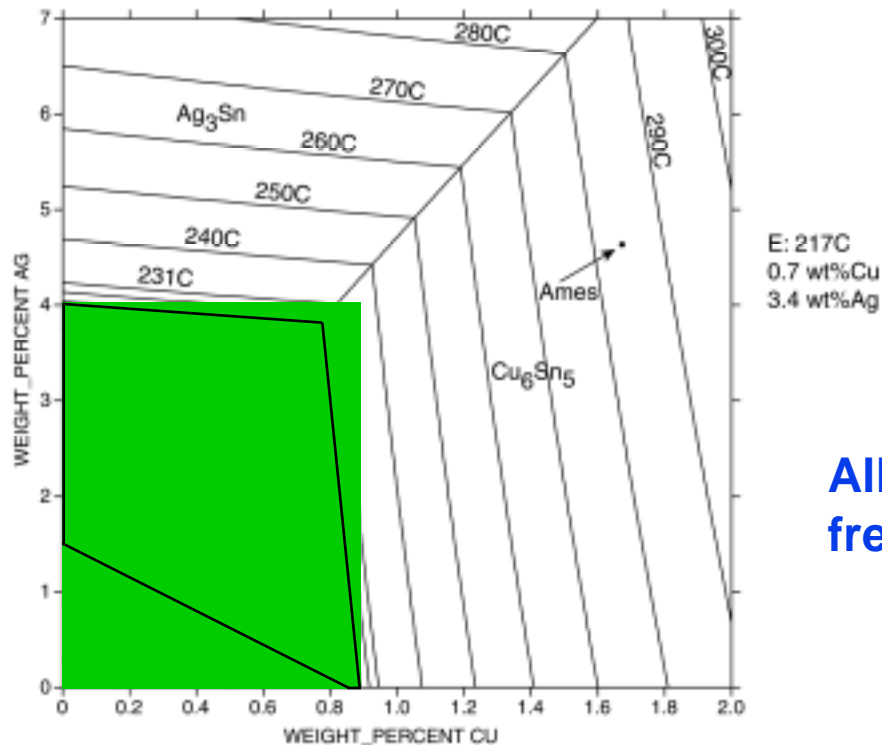
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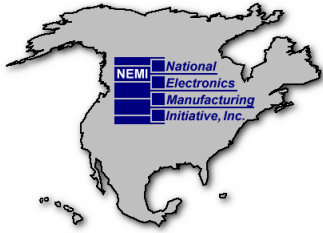
Eutectic of Sn-Ag-Cu solders

B. Boettinger, C. Handwerker of NIST performed studies to determine the true Sn-Ag-Cu eutectic.

Extrapolated Ternary Sn-Ag-Cu Liquidus Surface
 $L(\text{Liquid})=0$ (Thermodynamic modeling)



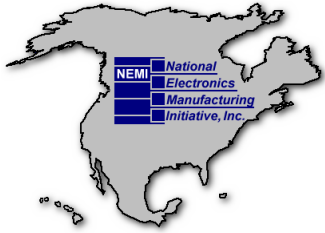
**Alloys in shaded area have
freezing range <10C.**



Lead Free Standards

- **NEMI Goal:**
 - choose ONE solder and recommend as the “industry standard”
- **Leverage of NEMI Member Companies**
 - NEMI membership represents a significant segment of the industry
 - » NEMI member companies employ over 1M workers
 - » NEMI member companies recorded \$300B in sales during 1999.
- **However, maximum benefit achieved through world wide agreement**
- **Update/create JEDEC standards**

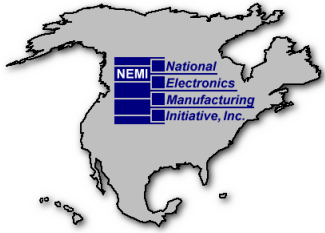
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Lead-Free Solder Database

- **Alloy Group has compiled list of material properties needed for modeling.**
- **List distributed to 50+ Universities soliciting information/guide for future work:**

A list of the relevant materials properties needed for the alloy database follows. Most of the mechanical tests would be undertaken using the most common strain rates. There is also a list of properties required to be determined for lead-free solderable coatings as PCB and component finishes.



Properties of Lead-Free Solders

Thermal, Electrical, and Wetting Properties

Sn3.9Ag0.6Cu Sn0.7Cu Sn3.5Ag Sn37Pb

Coefficient of Thermal Expansion (CTE)

Vol. Change on Freezing (%)

Specific Heat (JKg⁻¹K⁻¹)

Latent Heat (KiloJ Kg⁻¹)

Thermal Diffusivity (mm²/s)

Thermal Conductivity(Wm⁻¹K⁻¹)

Electrical Conductivity (%IACS)

Electrical Resistivity (micro Ohm cm)

Surface Tension(mNm⁻¹) at Temperature of solder/T(mp of solder)

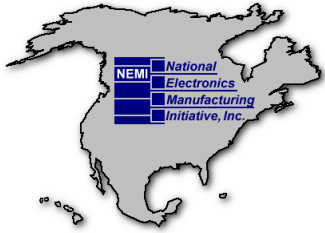
Surface Tension at (mNm⁻¹)) at Temperature of Solder/T(mp of solder)

Wetting Time @ 0 Force (sec) as a function of Temperature of solder/T(mp of solder)

Wetting Time @ 2/3 Force (sec) as a function of Temperature of solder/T(mp of solder)

Max Wetting Force (micro N) as a function of Temperature of solder/T(mp of solder)

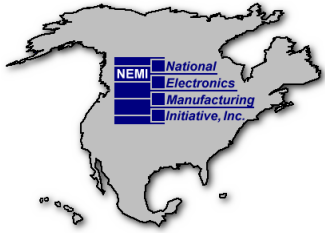
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Mechanical Properties

Ultimate Tensile Strength(MPa) at room T
Shear Strength (MPa)
(at particular strain rates, e.g. 10^{-3} to 10^7 /s)
Ring in Plug Shear (kg)
(at particular strain rates, e.g. 10^{-3} to 10^7 /s)
Elastic (Young's) Modulus (GPa) at 25°C
Elastic (Young's) Modulus (GPa) at 50°C
Elastic (Young's) Modulus (GPa) at 100°C
Total Elongation (%)
(at particular strain rates, e.g. 10^{-3} to 10^7 /s)
Uniform Elongation (%) at room T
(at particular strain rates, e.g. 10^{-3} to 10^7 /s)
Yield Strength (MPa) at room T
(at particular strain rates, e.g. 10^{-3} to 10^7 /s)
Work Hardening Coefficient
(at particular strain rates, e.g. 10^{-3} to 10^7 /s)
Creep Resistance (at particular strain rates)
Min.Creep Strain Rate @Stress of 10MPa (1/s) at room T
Min.Creep Strain Rate @Stress of 20MPa (1/s) 125°C
Hardness (HV)
Thermomechanical Fatigue Resistance
(at particular strain rates, e.g. 10^{-3} to 10^7 /s)
Isothermal Fatigue Data
(at particular strain rates e.g. 10^{-3} to 10^7 /s)
Thermal Fatigue Hysteresis behavior
(at particular strain rates e.g. 10^{-3} to 10^7 /s)

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Mechanical Properties (cont.)

Constitutive Behavior

(at particular strain rates)

Stress Rupture

(at particular strain rates)

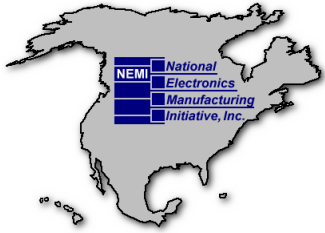
Acoustic measurements

Fracture Toughness (MPa - M^{1/2}) Room T

(at particular strain rates)

There is very little information on the properties of lead-free component and board surface finishes, their performance during assembly, and their effect on the thermomechanical fatigue properties of the assemblies. Useful data on lead-free surface finishes will include: solderability before and after aging (aging conditions: room temperature, dry aging, steam aging, temperature and humidity aging), whisker formation testing for tin coatings after aging at 50°C for at least 2 months and as a function of component lead/coupon deformation, microstructure (grain size, preferred crystal orientation), hardness, ductility or elongation, organic content in the deposit, and wear and contact resistance.

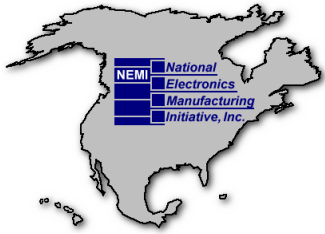
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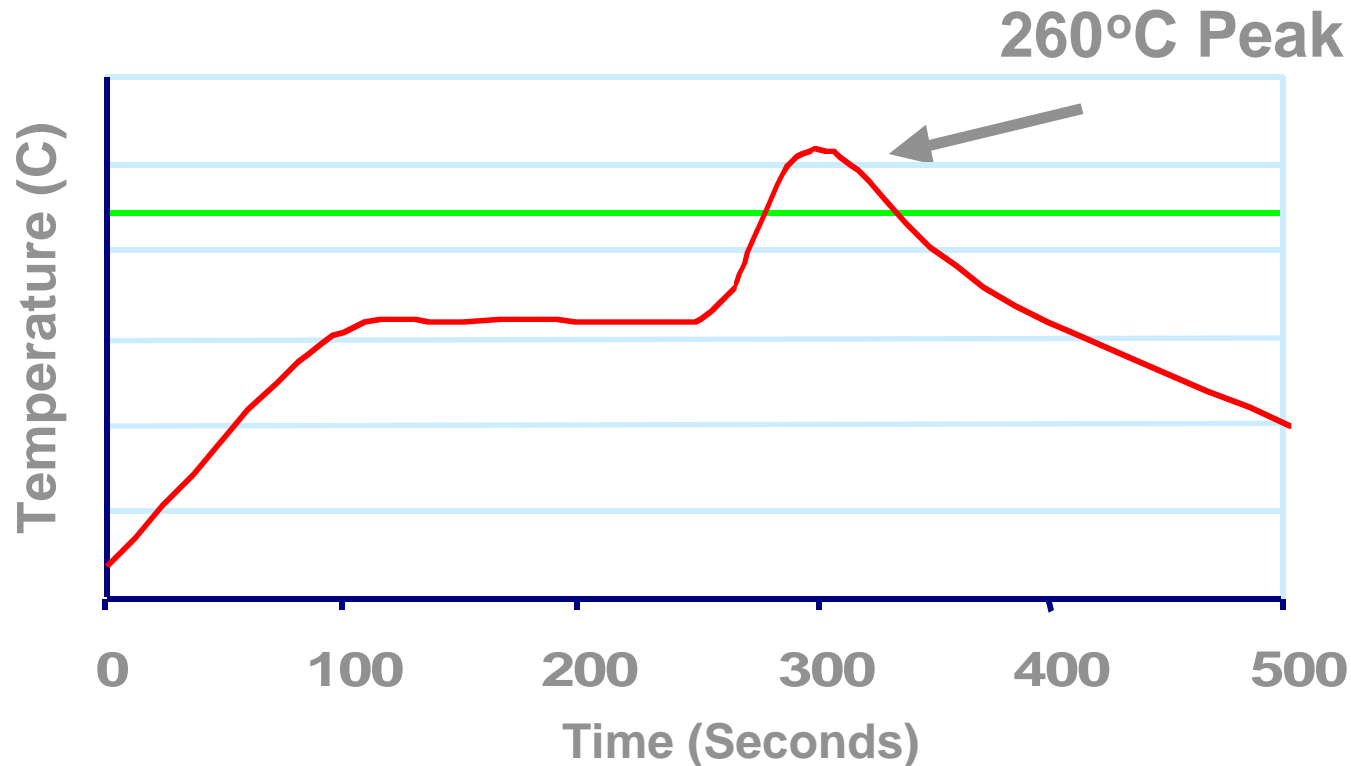
NEMI Lead Free Project

- **Component Group Accomplishments:**
 - **2Q99: Conducted Vendor Survey**
 - » **Majority of suppliers unaware/no plan**
 - **Developed and Published Worst Case Reflow Profile**
 - **Engaged ITRI for help in assessing PWB Finishes**
 - **Engaged with ITRI to determine effect on PWB Laminates**
 - **Second vendor survey underway**
 - **Major issue – plastic semiconductor packages**
 - » **Working with 5 major suppliers to quantify**
 - » **Initial MSL data results distributed to members**
 - **Obtain boards, components for reliability testing**

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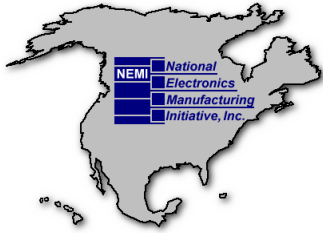


Primary Process Impact (Max)



Moisture & temperature sensitivity of components & PWBs to higher reflow temps. is major issue.

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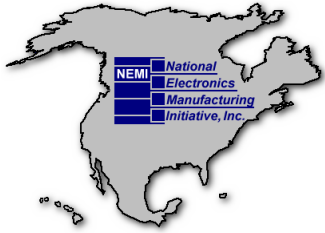


NEMI Lead Free Project

- **Reliability Group Accomplishments**

- Test Plan developed and in place
- All Test Cells committed/assigned to member companies
- Component Group arranged for test parts (on hand)
- Existing Test Board designs evaluated, new design where necessary
- Joint with ITRI, PWB suppliers have evaluated FR-4 materials for high temperature assembly.
- PWB suppliers guarantee laminate to pass tests.

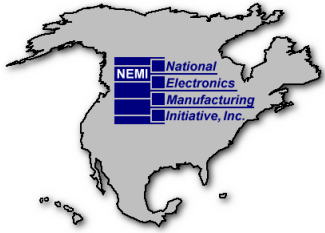
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NEMI Lead Free Project

- **Reliability Group (cont'd)**
 - **Test Boards in build; delivery expected Sept. 30, 2000**
 - **Universal Instruments to do board assembly**
 - **Process Group to supply solder paste and process to Universal**

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NEMI Lead Free Project

- **Reliability Tests:**

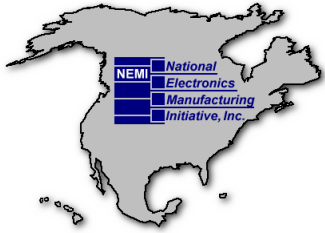
- **Four tests planned**

- » **Thermal Cycling**
 - » **Thermal shock**
 - » **Electrochemical Migration**
 - » **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**

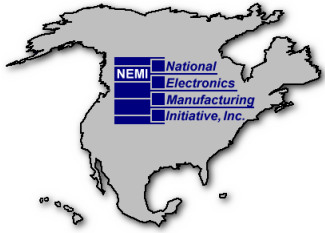
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NEMI Reliability Testing

- **Inspection before/after test to include:**
 - Visual
 - X-Ray
 - Acoustical
- **Member Companies will do Failure Analysis and Statistical Analysis**

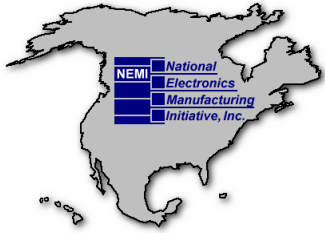
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NEMI Lead Free Project

- **Process Group Accomplishments:**
 - **Solder paste chosen for reliability evaluations**
 - » **Quantity of paste provided to Universal**
 - **Stencil ground rules & process defined**
 - » **Given to Universal Instruments for Assembly**
 - **Profile defined and transmitted to Universal**

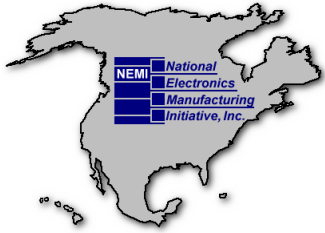
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NEMI Lead Free Project

- **Legislative Sub-group Accomplishments:**
 - **Published legislative status on NEMI web site**
 - **Prime inputs from member companies and Electronic Industries Alliance**
 - » **Links to EIA web site provided**

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NEMI Lead Free Project

- **Project defined and moving forward**
- **Responsibilities assigned**
- **Target date for completion 6-30-2000**
- **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

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