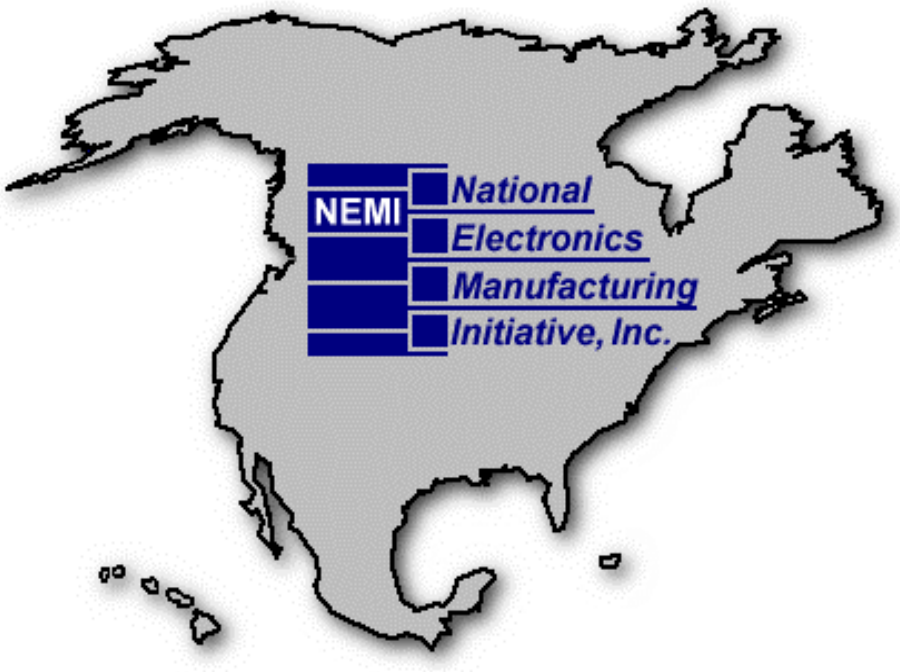


Lead Free Alloy Team Status

Carol Handwerker
National Institute of Standards and Technology
Alloy Team Leader
01-17-01

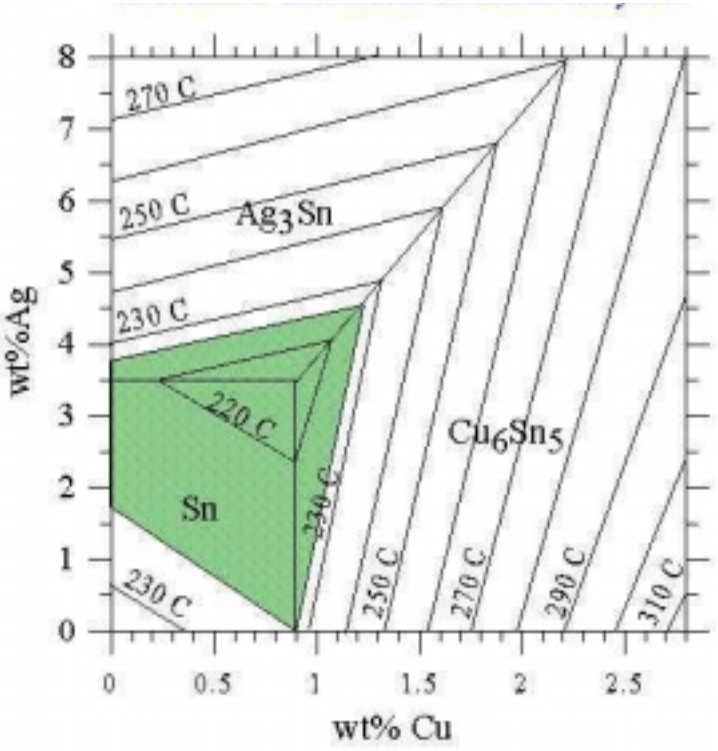
Alloy Team Tasks

- Literature Search; Assessed available data, including Europe and Far East - continuing
- Determined no drop-in replacement for Pb/Sn eutectic
- Criteria: Eutectic solder; max three metals (ternary), patent free if possible
- Chose Sn-Ag-Cu Family
- Obtained Patent Search
- Determined Ternary Eutectic
- Chose Sn-3.9Ag-0.6Cu (+/-0.2%)for reflow; low cost Sn-0.7Cu for wave
- Developed matrix of data desired
- Developing Guide for University Research
- Starting to work with Academia/ Research Institutes (Sandia National Labs, NIST Boulder)

Eutectic of Sn-Ag-Cu solder system

- **Bill Boettinger, Kilwon Moon, Ursula Kattner, Carol Handwerker of NIST performed studies to determine the true Sn-Ag-Cu eutectic composition**

Ternary Liquidus Surface based on data from NIST, Marquette U., and Northwestern U



Ternary Eutectic Composition
Sn - 3.5 Ag - 0.9 Cu
at 217°C

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

NEMI Alloy group action plans

- Developing “best practices” experimental procedures to measure the mechanical, thermal, electrical and wetting properties mentioned. (Input from NEMI, Sandia National Labs, ITRI-UK). This document will be distributed to interested universities/ organizations via Internet.
- Developing solder database of existing mechanical properties of lead-free alloys. Adding on information to the database as appropriate.
- Organizing workshop on modeling and data for lead-free solders at TMS meeting. (New Orleans Convention Center, New Orleans, LA, 8:30am-4:30 pm on Thursday, 15th February, 2001)

Lead-Free Solder Database

- A list of the relevant materials properties needed for the alloy database has been developed.
- There is also a list of properties required to be determined for lead-free solderable coatings as PCB and component finishes.
- For eutectic Sn-37Pb, there is a need for comparison data for the same measurement techniques used for the lead-free alloys. Priorities for Sn-37Pb are the same as for the lead-free alloys.

Thermal, Electrical and Wetting Properties

(1 = High Priority, 2 = Medium 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, 2 = Medium 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 (continued)

Alloys: Sn3.9Ag0.6Cu, Sn0.7Cu, Sn3.5Ag, Sn37Pb

(1 = High Priority, 2 = Medium 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

Data Gathering and Distribution

Continuing survey of literature: ***group responsibility***

Example:

Development of Lead (Pb) and Halogen free Peripheral Leaded and PBGA components to meet MSL3 260°C peak reflow

Woosley, Swan, Chong, Matsushita, Koschmieder, Simmons - Motorola
presented at
Electronics Goes Green - International Conference
Fraunhofer Institute, Berlin, 13 Sept 2000

Workshop Goals

The goal of this workshop is to bring together modelers and experimentalists to

- define the state-of-the-art in reliability modeling and mechanical property measurements of solder joints made with lead-free solders
- determine the "necessary and sufficient" experimental data modelers need
- describe the changes needed to improve modeling and data, including failure criteria
- develop a consensus on the best test methods for collecting needed data
- complete the assessment of missing high priority data

8:30 **Welcome** - Review of workshop objectives. Preview of strawman test methods - Carol Handwerker - NIST

8:45 **NEMI Task Force Overview** - Ron Gedney -NEMI- and Jasbir Bath - Solectron

9:15 **NSF Manufacturing Program** - Delcie Durham - NSF

9:45 **NIST Advanced Technology Program** - Carol Handwerker - NIST

10:00 Ahmer Syed - Amkor
Overview of Reliability Models and Data Needs
What are the various types of reliability models for lead-free solders?
What is common in all of the reliability models available for lead-free solders?
Are these models sufficient to describe the properties?
What data are needed for these models, for the modeling community?
If we collect the data that the modelers request, will it be enough to make accurate predictions of reliability?

10:40 Leon Keer - Northwestern University
Constitutive and Damage Accumulation Modeling
What data are needed for these models, for the modeling community?
If we collect the data that the modelers using request, will it be enough to make accurate predictions of reliability?

11:20 Chris Bailey - University of Greenwich
Manufacturing and Reliability Modeling
Interaction between manufacturing models and reliability models
Sensitivity of reliability to solder joint shape and complex stress states

1:00 Darrel Frear - Motorola
Experiments needed to characterize solder joint behavior
What is the set of experiments needed to completely characterize solder joint behavior as input into reliability modeling ?
Strengths and weaknesses in existing techniques
What improvements are necessary?

1:40 Alek Zublewicz - Motorola (in conjunction with Don Henderson -IBM)
Experiments needed to characterize solder joint behavior
What is the set of experiments needed to completely characterize solder joint behavior as input into reliability modeling ?
Strengths and weaknesses in existing techniques
What improvements are necessary?
Alek will emphasize microstructural information needed.

2:20 **Discussion of Modeling and Data/Database Needs**
2 breakout sessions - Ahmer Syed/Jasbir Bath and Darrel Frear/Carol Handwerker)

3:00 Break

3:15 Continued: **Discussion of modeling and data/database needs**

4:00 Reports from breakout sessions - define needs and opportunities; action items

4:30 Adjourn