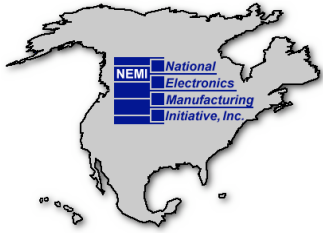


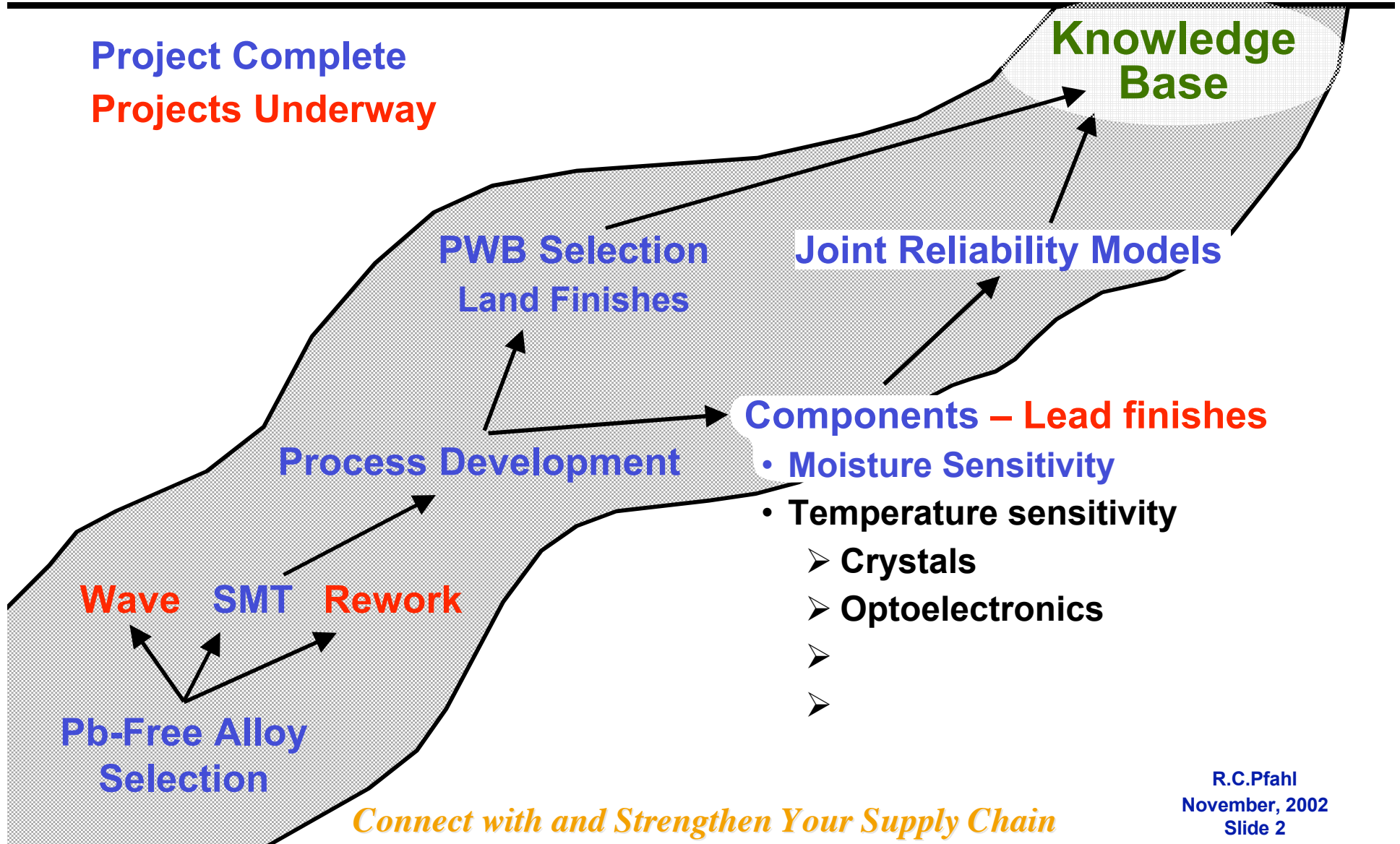


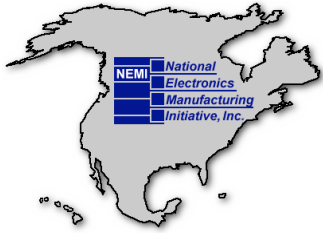
Status of Pb-Free Activities in North America

***Dr. Robert Pfahl,
Chair, NEMI Environmentally
Conscious Electronics TWG***



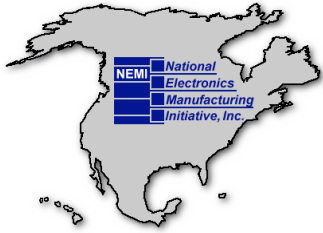
North American Pb-Free Activities (NEMI) Lead-Free Roadmap





Roadmap of Lead Free Assembly

- **Driving forces for Lead Free Assembly are many**
 - ✓ Market
 - ✓ Regulation
 - ✓ Reputation
- **Impact of these forces varies depending on**
 - ✓ Product segment (e.g. consumer, business, automotive)
 - ✓ Regional focus
 - ✓ Company strategy
- **NEMI Strategy is to ensure supply chain readiness for Lead Free Assembly**
- **Actual crossover is a business decision (based on above factors)**



NEMI Pb-Free Project Participants

OEMs/EMS

Agilent
Alcatel Canada
Celestica
Compaq(HP)
Delphi/Delco
IBM
Intel
Kodak
Lucent
Motorola
SCI
Solectron
StorageTek

Solder Suppliers

Alpha Metals
Heraeus
Indium
Kester

Components

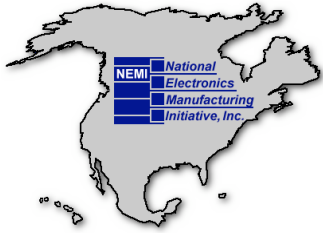
ChipPac
Intel
Motorola
Texas Instruments

FCI USA Electronics

Govt. & Other

NIST
SUNY-B/IEEC
ITRI (US)
IPC
BTU
Universal
Vitronics-Soltec

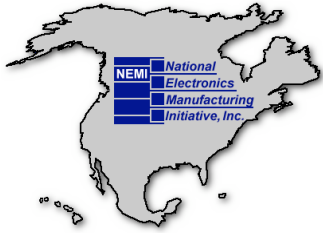
Connect with and Strengthen Your Supply Chain



Major Project Activities

- **Solder Alloy** – Carol Handwerker, NIST
 - ✓ Alloy Material Property development
 - ✓ Interface w/academia, government agencies
- **Components/PCBs** – Rich Parker, Delphi
 - ✓ Effect of High temperature reflow
 - ✓ Pb-free terminations
- **Process Development** – Jasbir Bath, Solectron
 - ✓ Generic process for Reliability test boards
 - ✓ Process characterization benchmark
- **Solder Reliability** – John Sohn, NEMI
 - ✓ Transparent test procedure
 - ✓ Common data to share with industry
- **Tin Whiskers** – Swami Prasad, ChipPAC

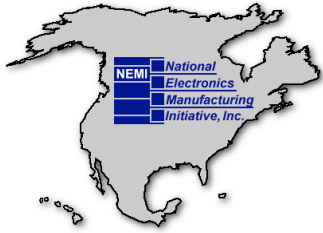
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Solder Alloy Project

Mission: Provide critical data and analyses needed for making decisions with respect to solder alloys, manufacturing, and assembly reliability.

- ✓ **NEMI chose Sn-3.9Ag-0.6Cu, rest of world moving close to that choice**
 - **Worked with NIST to characterize alloy phase diagram.**
- ✓ **Developed “best practices” experimental procedures to measure the mechanical, thermal, electrical and wetting properties of lead-free solders**
- ✓ **Developed Solder Reliability Modeling Guidelines**
 - **Critical review of reported deformation data and models**



Selection Criteria

- If possible, stay with ternary alloys (or less). Quaternary alloys can present control difficulties.
- The new alloy should be near eutectic (e.g., no large pasty range during cool-down).
- Avoid using a patented alloy if possible, so industry freedom of action is guaranteed.
- Using the best knowledge available, do not choose an alloy that will have environmental issues in the future.

Alloy Systems Considered

Sn-58Bi

Sn-Zn-Bi

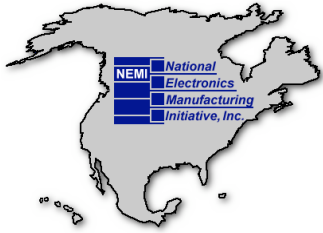
Sn-Ag-Bi

Sn-Ag-Cu

Sn-Ag

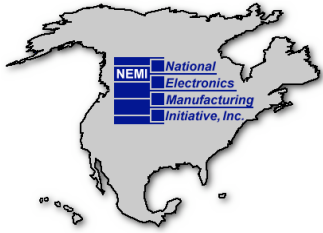
Sn-Cu

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Alloy Team Accomplishments

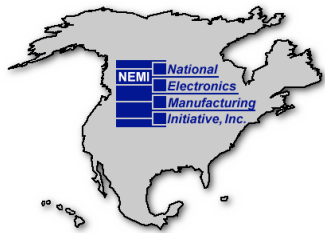
- ✓ **Lead-free solder reference database available.**
- ✓ **Determined ternary eutectic melting temperature of Sn-3.9Ag-0.6Cu.**
- ✓ **Investigated patent and materials property issues for Task Force selection of Sn-3.9Ag-0.6Cu for reflow and Sn-0.7Cu for wave.**
- ✓ **Examined sensitivity of melting behavior of Sn-Ag-Cu to composition and temperature in response to request from team members.**
- ✓ **Held workshop on modeling and data needs for lead-free solders with workshop report being used as roadmap for developing and analyzing data.**
- ✓ **Public domain properties and reference databases available on NIST website.**
- ✓ **Database developed for archiving information on NEMI thermal cycling test vehicles needed for FEA.**



Component Project

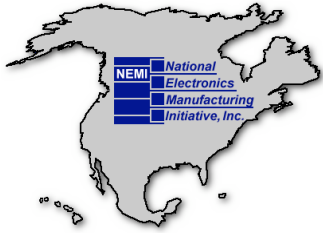
Mission: Identify and recommend the best materials for the supplier industry to use, which meet the Pb-free requirements set by the main task group.

- ✓ **Characterized component survivability at elevated reflow temps.**
 - Some degradation, but materials available to meet needs.
- ✓ **Characterized the optimum operating profile of maximum time, temperature and environment exposures.**
- ✓ **Recommendation for component temperatures**
 - JEDEC used our data for revised J-STD-020B standard, consistent with our position: $250^{\circ}\text{C} -5/+0$



Conclusions

- Large ICs stayed below **240°C peak** temperatures
 - ✓ Smaller ICs and discrete parts stayed below 250°C peak temperature
 - ✓ Manufacturing tolerances were not added to the 240°C goal:
 - Oven repeatability
 - Thermocouple repeatability (mounting, tolerance, equipment)
 - Machine to machine reproducibility
- With appropriate management of reflow process, 240C max achievable for large IC's, 250C max for small IC's on Boards \square 0.92" thick



Process Development Project

Mission: Demonstrate manufacturing processes for lead-free soldering of printed wiring board assemblies

- ✓ Most thorough study of lead-free assembly to date
- ✓ Processes developed on existing tools and equipment
- ✓ Transferred to 3rd party for Reliability hardware build
- ✓ No major problems encountered during builds
- ✓ Agilent demonstrated Feasibility X-Ray inspection for Pb-Free
- ✓ Employed Acoustic microscopy before/after reflow
 - No damage due to reflow
- ✓ Evaluated automated optical inspection tooling
- ✓ Solder paste performance – Excellent printability and wetting

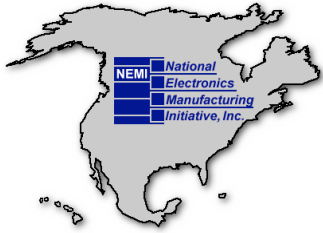
Demonstrated high quality Pb-free solder joints for reliability testing

R.C.Pfahl

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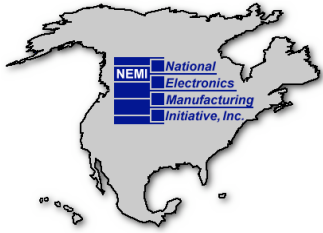
November, 2002

Slide 11



Conclusions and Recommendations

- **Lead-free solder assemblies successfully manufactured with existing assembly process equipment**
- **Materials used for lead-free soldering: Adequate**
 - ✓ Solderability of lead-free solder paste is reduced compared with tin-lead.
 - ✓ Voiding tends to increase with lead-free solder paste especially with tin-lead components.
- **Equipment Used: Most existing production equipment is adequate for SMT lead-free assembly**
- **Inspection Equipment: X-Ray and Acoustic Inspection tools adequate. More work needed on AOI**



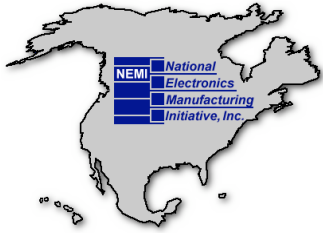
Reliability Project

Mission: Perform reliability testing for selected solders, components, and board finishes using an approved test vehicle.

- ✓ Thorough experiment covering various components, solder/lead combinations, failure analysis, statistical analysis.
- ✓ Reliability tests
 - Thermal Cycling (-40 to 125°C, 0-100°C)
 - Three-point Bend Testing of BGAs
 - Electrochemical Migration
- ✓ Very Detailed Failure analysis and root cause of TC failures
 - Red dye penetrant
 - Metallurgical cross-section and analysis

Demonstrated Pb-free Joints are more reliable than Tin-lead

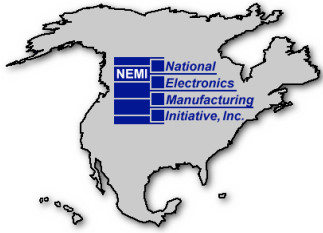
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NEMI Pb-free Reliability Project Conclusions

- **Thermal Cycling (-40 to + 125°C and 0 to 100°C)**
 - ✓ LF (balls/comp finish - paste alloy) combinations performed equivalent to or better than Pb benchmark
 - ✓ Not as clear with mixed cell combinations
 - Most performed equivalent to the Pb benchmark
 - Two combinations performed worse
 - One combination performed better
- **3 Point Bend testing: no differences observed between the different combinations**
- **No Electrochemical Migration issues seen with LF alloy when evaluated per IPC-TM-650 Method 2.6.14.1**
- **Established technical feasibility of Pb-free processing and reliability of Pb-free solder joints.**

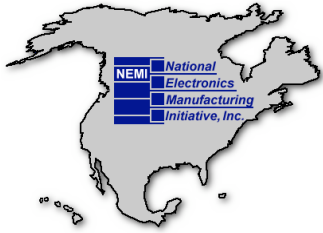
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Tin Whisker Project

Mission:

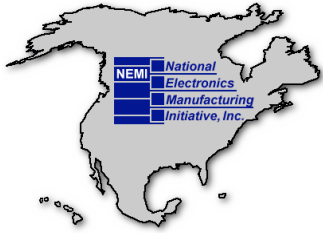
- **Determine underlying mechanisms of whisker formation**
- **Develop an accelerated test to determine the potential for whisker formation**
- **Determine the acceleration factors to predict long term tendency to whisker**
- **Recommend industry standard test to IPC/JEDEC**



Follow-on Work

- **Much work still needed to implement/understand SnAgCu solders. Projects underway on**
 - ✓ **Board Laminates & ability to withstand higher temp.**
 - ✓ **Board finishes for SnAgCu soldering**
 - ✓ **Component lead finishes**
 - **Tin whisker accelerated stress testing***
 - **Fundamental understanding of tin whisker formation**
 - ✓ **Component replacement & rework**
 - **Thin (0.060") and thick (0.130") Boards**
 - ✓ **Wave Solder for Pin-in-hole components**
 - ✓ **Reliability modeling of SnAgCu solder joints**
- * **Sharing results with JEITA & ITRI UK.**

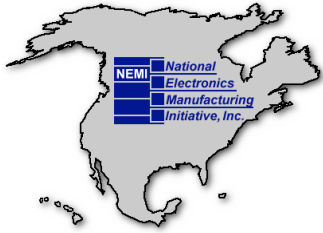
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NEMI Pb-Free Project Summary

- ✓ **Recommended specific Pb-Free SnAgCu alloy to industry**
- ✓ **Demonstrated manufacturability of Pb-free process with SnAgCu alloy – It is Doable! Motorola has product in production today with NEMI alloy.**
- ✓ **Demonstrated Reliability of Pb-free interconnection process with both SnPb and Pb-free component lead coatings – It is better than/equal to SnPb solder**
- ✓ **Industry can produce PWB's for Pb-free soldering**
- ✓ **Recommended modifications to JSTD 020 for Pb-free – Now released.**
- ✓ **Providing extensive data base to support conclusions**
- ✓ **Undertaking follow-on work to close knowledge gaps**
 - **Re-work, wave soldering (PIH interconnect)**
 - **Tin Whisker test methodology**
 - **Tin Whisker fundamental understanding**

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NEMI Pb-Free Project

- **We believe NEMI has moved the industry forward in knowledge and understanding of Pb-free materials and processes.**
- **Continuing to work to fill in knowledge Gaps**
- **Building the knowledge base equivalent to today's SnPb solder will not be done overnight.**