Pb-Free Technology Development & Deployment

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Advancing manufacturing technology

iNEMI and the Environment: 1998-Present
Pb-Free Projects

- Since 1996 iNEMI has proactively roadmapped the technology needs to produce Environmentally Conscious Electronics (ECE)
- iNEMI members have provided the technical and supply chain leadership to meet the two new EU directives on Electronic Products.
  - iNEMI and NIST performed the research to identify the preferred solder to replace Sn-Pb
  - iNEMI developed the processes and standards for the conversion
  - iNEMI developed the standards for environmental data transfer
  - iNEMI is currently addressing remaining knowledge gaps for mission critical applications.

Pb-Free Electronics

- Participants:
  - iNEMI Members including:
    - OEMs
    - EMS Firms
    - Suppliers
    - NIST
- Environmental Objective
  1. Develop standard alloy to replace eutectic Sn-Pb
  2. Meet EU RoHS requirements
- Unique Characteristics
  - Driven by legislative action
  - Driven by customer requirements
  - Industry wide deadline for regulatory requirements

Pb-Free Electronics - Actions Required

- Research to identify viable alternatives
- Reliability studies on alternatives
- Selection of single alloy
- Process Development
- Material development (paste and flux)
- Application Development
- Supply chain readiness
- Identify the reliability risk of potential "whisker" growth from pure tin platings on components

Transition to Pb-free Assembly

- 1998 Roadmap Identified the Gap
- Phase I Project developed the alloy, process, components and reliability from 1999-2002
- Phase II Project expanded the technology base to include rework, wave-soldering, and reliability of lead finishes
- Phase III Project teams addressed these supply chain transition issues identified in the 2002 Roadmap
- Phase IV Projects worked to optimize and standardize manufacturing processes
- Phase V Projects are currently addressing the needs for High Reliability Products

Results:

- The iNEMI efforts accelerated the establishment of SAC alloys as the standard and reduced the effort in each member company.

Phase I 1999-2002

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Results:

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Pb-Free Assembly
Chair: Edwin Bradley, PhD Motorola
Co-Chair: Rick Charbonneau

Pb-Free Assembly Project Results

– iNEMI declares victory for Pb-free alloy
- In 2000, iNEMI team recommended Sn3.9Ag0.6Cu for reflow solder
- Many other compositions had been proposed, but debate shifted from a wide variation of materials to discussion of best SnAgCu alloy
- Although compositions vary, the iNEMI-recommended alloy is representative of the acceptable range of lead-free alloys
  - Provides a model system for industry that has been well-characterized by iNEMI & NIST
  - Members are using the alloy in production
- iNEMI's focus on a single lead-free alloy helped accelerate industry convergence on standard solder formulations & manufacturing processes

Phase II 2000-2003

- **Phase II projects expanded the technology base to include assembly and rework of large complex PWB assemblies.**

Pb-Free Assembly & Rework

Chairs: Jerry Gleason, HP
Charlie Reynolds, IBM
Team Leaders: Jasbir Bath, Solectron,
Quyen Chu, Jabil Circuit
Mathew Kelly, Celestica
Ken Lyjak, IBM
Patrick Roubaud, HP

- **Three Phase II projects addressed potential reliability concerns over the growth of tin whiskers in Pb-free plated tin coatings.**

Tin Whisker Projects

- **Accelerated Test Project** – Investigated Standardized Test Methods

Tin Whisker Accel. Tests
Chair: Heidi Reynolds, Sun Microsystems
Co-Chairs: Jack McCullen, Intel
Mark Kwoka, Intersil

- **User Group** – Developed Mitigation Strategies & Acceptance Criteria

Tin Whisker Users Group
Chairs: Joe Smetana, Alcatel
Richard Coyle, Lucent

- **Modelling Project** – Investigated Fundamental Mechanisms of Initiation & Growth

Tin Whisker Modeling
Chair: George Galyon, IBM
Co-Chair: Maureen Williams, NIST

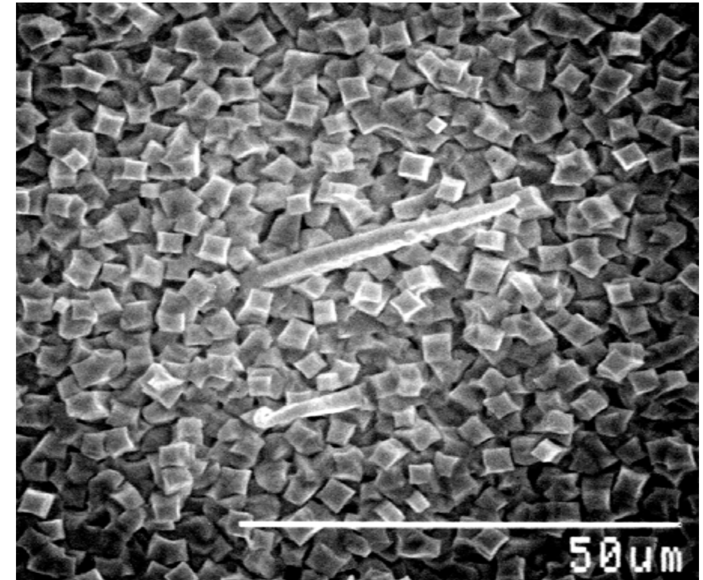
Tin Whisker Accelerated Test Results

Objective:

Devise industry standard tests for predicting tin whiskers

Status:

- **The group has carried out three factorial experiments looking for test methods involving :**
  - **Temperature**
  - **Humidity**
  - **Thermal cycling**
- **Third test completed 10,000 hrs. Reported at ECTC May 31, 2005**
- **Fourth test completed to verify voltage bias effect. Reported at ECTC May 30, 2006**
- **Fifth test to gain better understanding of temp./humidity completed. Reported at ECTC May 30, 2006**
- **Developed and submitted tin whisker "test protocol" to IPC/JEDEC for consideration as an industry standard:**
  - **iNEMI project chair drove standard JESD 22-A121.01, released May, 2005**
  - **Group is coordinating with JEITA (Japan) and ITRI/E4 (Europe) to establish unified whisker test methods worldwide.**



Example of tin whisker

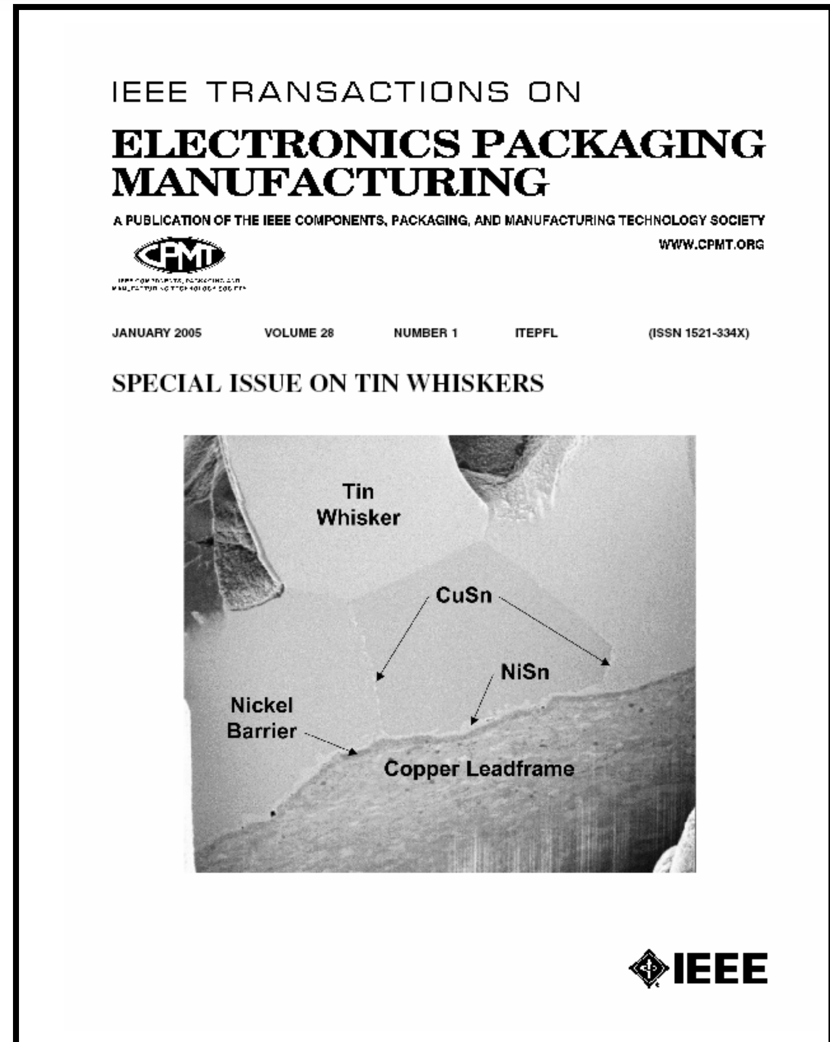
Tin Whisker Modeling Results

Objective:

To determine the mechanism of tin whisker formation and growth in order to predict behavior, design mitigation methods, and develop acceleration tests.

Status:

- **1st Workshop (iNEMI/NIST/TMS) at Metals, Minerals and Materials Society conference San Diego (6/03)**
- **Interim report produced (6/03).**
- **2nd Workshop (iNEMI/CPMT/ECTC) held at ECTC in Las Vegas (6/04).**
- **IEEE Mfg. Transactions special edition published.**
- **3rd Workshop (iNEMI/ECTC) held at ECTC in Orlando (5/31/05).**
- **4th Workshop held at ECTC in San Diego (5/30/06).**
- **5th Workshop held at ECTC in Reno (5/29/07).**



Tin Whisker User Group Results

Objective:

Develop recommendations for lead-free surface finishes on components that would minimize risk of failures from tin whiskers in high-reliability electronic applications.

- 11 large corporate users of components
  - –Concerned with long-term reliability (>8 years)
- Developed recommendations for Acceptance Testing & Mitigation Practices for tin whiskers on high-reliability products
  - –Rev. 2 sent to JEDEC/IPC recommending joint standard (8/04)
  - –Rev. 3 released (5/05)
  - –Revised and updated (12/06)
- Worked with JEDEC/IPC on Acceptance Test and Guidance Specifications
  - JESD 201 (Acceptance Test) released by JEDEC (Feb. ’06)
  - Tin Whisker Theory and Mitigation Practices Guideline – JP002 – released by IPC & JEDEC.
- Cooperating with JEITA on IEC Specification

iNEMI

Published Results from first Phases

LEAD- FREE ELECTRONICS

iNEMI Projects Lead to Successful Manufacturing

Edited by

Edwin Bradley • Carol A. Handwerker • Jasbir Bath

Richard D. Parker • Ronald W. Gedney

- Published by IEEE
- Edited by Edwin Bradley (Motorola), Carol Handwerker (NIST/Purdue University), Jasbir Bath (Solectron), Richard Parker (Delphi Electronics & Safety) and Ron Gedney (iNEMI, retired).
- Available for purchase

iNEMI

Phase III 2002-2006

- 2002 Roadmap identified a number of business Issues to convert to a Pb-free supply chain.

RoHS Transition Task Group
Chair: Dave McCarron, Dell
Projects:
Component Supply Chain Readiness
Component and Board Marking
Assembly Process Specifications
Materials Declarations

- Five Phase III project teams addressed these supply chain transition issues.
  - Component Supply Chain Readiness
  - Component and Board Marking
  - Assembly Process Specifications
  - Materials Declarations
  - Mat. Declaration Data Exchange

Mat. Declaration Data Exchange
Chair: Richard Kubin, E2open
Co-chair: Marissa Yao, Intel

Materials Declaration Data Exchange

Objectives:

- Work with international standards bodies to help define and validate standards for the exchange of Material Composition data between all elements of the value chain
  - Support requirements of the WEEE and RoHS Directives
  - Work closely with the Materials Declarations Project

Scope:

- Create a roadmap to identify standards, as well as the IT infrastructure, required to support the B2B exchange of material composition data.

Status:

- Launched iNEMI project on July 17, 2004
- Transitioned to an IPC standards committee
- Draft standard IPC-1752 completed two rounds of feedback
- Released March, 2006

Phase IV 2003-2008

- 2003 Gap Analysis identified a number of reliability and optimization Issues to convert to a Pb-free supply chain.
- Four Phase IV projects established to close the following technology gaps:
  - Mixed assemblies (Pb-free BGA's in a SnPb assembly process) Completed
  - Wave/selective solder
  - Pb-free component surface finishes
  - Pb-free rework optimization

Pb-free Conversion: Current Situation

- *High Volume Market has converted*
- *High Rel. Market has not converted*

RoHS Supply Chain Readiness

- Industry has used SnPb solder for over 50 years:
  - Processes well characterized
  - Reliability understood
- Elimination of Pb from solder caused significant supply chain impact.
- Collaborative efforts through industry groups such as iNEMI are helping the industry to make the transition:
  - Common understanding of issues
  - Common solutions
  - Leveraging the combined resources of many companies

Industry Readiness

- 9 of 11 Telecommunications OEMs Polled took Pb-free Exemption for Solder In Network Infrastructure Equipment
- A dual component supply chain has resulted
  - Pb-free components for high volume consumer market
  - Traditional SnPb components for
    - Telecommunications
    - Servers
    - Military products
    - Medical electronics
- Reliability of Pb-Free Components with Eutectic Solder has not been fully demonstrated for long life products.
- Some Telecom service providers are now demanding that mission critical equipment remain with SnPb solder.
- Suppliers are not willing to provide traditional components to small high reliability market.

iNEMI High Rel Task Group

Objectives

- Gain a common understanding of the supply chain challenges facing High Reliability OEMs/EMS providers who are:
  - Taking Pb exemption (e.g. telecom switching, high end servers, etc.)
  - Out of Scope of RoHS (e.g. measurement equipment, medical)
- Share experiences between OEMs/EMS providers on current state of supply base
- Define the gaps that this Pb-free move leaves for the high reliability products.
- Influence supply base to meet on-going needs of these industry segments (especially BGAs).
- Consumer Electronics drive the cost and the market
  - The high rel. market must develop a viable scenario to take advantage of consumer components and meet their reliability requirements.

Scenarios

- **Long term solution is to reduce reliability risk of Pb-free components and assembly.**
  - **The economic incentive is compelling**
  - **Well worth technology investment**
  - **Could take several years to complete but this is cumulative, so strides made today are useable.**
- **What can we do in the short term to help encourage the availability of SnPb compatible BGAs?**
- **What can we do in the mid term to close remaining knowledge gaps that the High Rel. segments face?**
- **What can be done longer term to better understand and predict reliability of electronics hardware using Pb-free components and assembly?**

Additional Issues

- Transition in Reliability Concerns
  - Initial concerns with SAC alloys were thermal cycling
  - Current concern is mechanical failure
  - Improved mechanical shock performance is a driver for new alloy introduction.

- Proliferation of Pb-Free metallurgies is significantly complicating the issue of closing knowledge gaps!
  - Alloys behave differently
  - Can effect form/fit/function
    - supplier A part does not behave like supplier B part in mfg. and/or use.
  - Users are demanding new part numbers from their suppliers

New Projects to Address Gaps

- Early Failure Study for Pb-free Assemblies
  - Some data suggests that there may be early failures from SAC joints that do not follow normal Weibull distributions.
  - This project hopes to determine if this hypothesis is true and, if so, what are the underlying causes of these early failures.

- Alternative Alloys Project
  - As a number of new alloys are being introduced, it is adding complexity to manufacturing and reliability understanding.
  - This project plans to collect industry available data on new alloys and to propose methodologies to deal with the mix and match of alloys within manufacturing.

Conclusions

- For a decade iNEMI has identified the technology requirements to address Pb-free environmental regulation.
- iNEMI members have provided the technical and supply chain leadership to meet Pb-free directives on Electronic Products:
  - Led by OEM and EMS member companies
  - Participation by all critical links of supply chain
- The iNEMI efforts accelerated the establishment of SAC alloys as the standard and reduced the effort in and risk to each member company.

Conclusions
The iNEMI Model

- **The iNEMI Pb-free Efforts Serve as a Model as to what iNEMI and its members can achieve in addressing future industry wide technology challenges.**
  - identified the technology requirements
  - Provided the technical and supply chain leadership to meet these requirements
  - Verify the reliability of the alternative solutions.
  - Reduce the development cost and effort for each firm
  - Reduce the risk to individual firms and the entire industry

iNEMI and the Environment: 2006-Present
iNEMI Halogen-Free Projects

Halogen-Free PCB Project

- Phase 1 (Design) Feb ’06 – Sep ‘06 (Complete)
- Phase 2 (Test) Jul ‘07 – Mar ’08
- Phase 3 (Results) Nov ’07 – Apr ’08
- Release Results Apr ‘08 (iNEMI members)
  Apr ’08 (APEX - Public)
- Phase 4 (Next Steps)
  - Open iNEMI meeting at APEX to discuss Phase 4 - Next Steps
  - Wednesday, April 2, 2008 from 1:00pm -3:30pm

Conclusion

The iNEMI Pb-free Efforts Serve as a Model as to what iNEMI and its members can achieve in addressing future industry wide technology challenges:

- Addresses knowledge gap of industry
  - Common problem
  - Best solved by working together
  - Often a pre-cursor to standards development
- Brings together a segment of supply chain to provide industry-wide response
  - OEMs
  - EMS providers
  - Materials, equipment, software, and/or component suppliers
- Direct alignment with member companies' commercial interests.

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