



International Electronics Manufacturing Initiative

# **iNEMI Projects for Pb-free Electronics**



*Meeting the requirements of the EU RoHS Directive*

*Bob Pfahl*

- **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 family to replace Sn-Pb**
  - **iNEMI developed processes and standards for the conversion**
  - **iNEMI developed the standards for environmental data transfer**

- **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**

- Research to identify viable alternatives
- Reliability studies on alternatives
- Selection of single alloy
- Process Development
- Material development (paste and flux)
- Application Development and optimization
- Identify the reliability risk of potential “whisker” growth from pure tin platings on components
- Reliability of solutions are still being verified
- **New areas requiring development still being identified**

# Environmentally Conscious Electronics Projects

## Pb-Free Assembly

Chair: Edwin Bradley, PhD Motorola  
Co-Chair: Rick Charbonneau

*Complete*

## Pb-Free Assembly & Rework

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

*Complete*

## RoHS Transition Task Group

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

*Complete*

## Mat. Declaration Data Exchange

Chair: Richard Kubin, E2open  
Co-chair: Marissa Yao, Intel

*Complete*

## Tin Whisker Accel. Tests

Chair: Heidi Reynolds, Sun Microsystems  
Co-Chairs: Jack McCullen, Intel  
Mark Kwoka, Intersil

## Tin Whisker Users Group

Chairs: Joe Smetana, Alcatel  
Richard Coyle, Lucent

## Tin Whisker Modeling

Chair: George Galyon, IBM  
Co-Chair: Maureen Williams, NIST

## Pb-Free BGAs in SnPb Assy

Chair: Robert Kinyanjui, Sanmina-SCI

## Pb-Free Wave Soldering

Chair: Denis Barbini, Vitronics Soltec  
Co-chair: Paul Wang, Microsoft

## Pb-Free Substrate Finishes

Chair: Keith Newman, Sun Microsystems  
Co-chair: Charan, Gurumurthy, Intel

## High Reliability RoHS Task Force

## iNEMI declares victory for Pb-free alloy

- In 2000, iNEMI team recommended Sn3.9Ag0.6Cu for reflow solder
- Many other compositions have been proposed, but debate has 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 backwards compatible, single lead-free alloy helped accelerate industry convergence on standard solder formulations & manufacturing processes
- Further work by IPC Solder Products Value Council drove single alloy for industry standardization.



**Objective:**

**Develop baseline manufacturing process for medium to high-end IT products in time to meet EU RoHS requirements**

**Scope:**

**Extend the previous project's work (based on SnAgCu solder) into new areas:**

- High I/O count packages**
- Large thick PWBs**
- Rework**
- MSL limits (for large complex PWBs)**

**Status:**

- Indications are that existing rework process needs additional development to meet maximum temperature requirements for lead-free packages and laminates**
- Group has revised process and tools to stay under the maximum temperature goal of 260°C**
- Reliability testing complete**
- Final report released to iNEMI members.**

- **Solder Alloy**  
All work based on iNEMI SAC Alloy
- **Components**  
Component temperatures of 230C - 260C max on boards 135 mil. thick were observed  
PWB material selection is critical (for thick, complex boards)!  
JEDEC revised J-STD-020C standard (260°C max. component temp.)
- **Process**  
Manufactured with existing assembly process equipment  
Developed rework capability for SAC (more effort needed)
- **Reliability**  
Demonstrated reliability of high I/O count devices on complex boards (with & without rework)  
No impact – electrolytic NiAu vs. Immersion Ag

- **Accelerated Test Project** – Investigating Standardized Test Methods
- **Modelling Project** – Investigating Fundamental Mechanisms of Initiation & Growth
- **User Group** – Developing Mitigation Strategies & Acceptance Criteria

**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

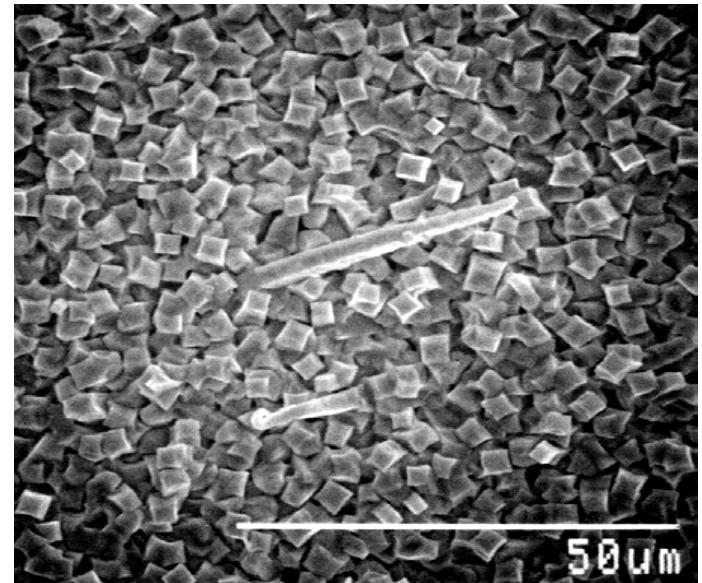
Third test completed 10,000 hrs. Reported at ECTC May 31, 2005

Fourth test underway to verify voltage bias effect (completed 3,000 hrs.)

Fifth test to gain better understanding of temp./humidity underway

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*

## Objective:

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

## Status:

**1<sup>st</sup> Workshop (iNEMI/NIST/TMS) at Metals, Minerals and Materials Society conference San Diego (6/03)**

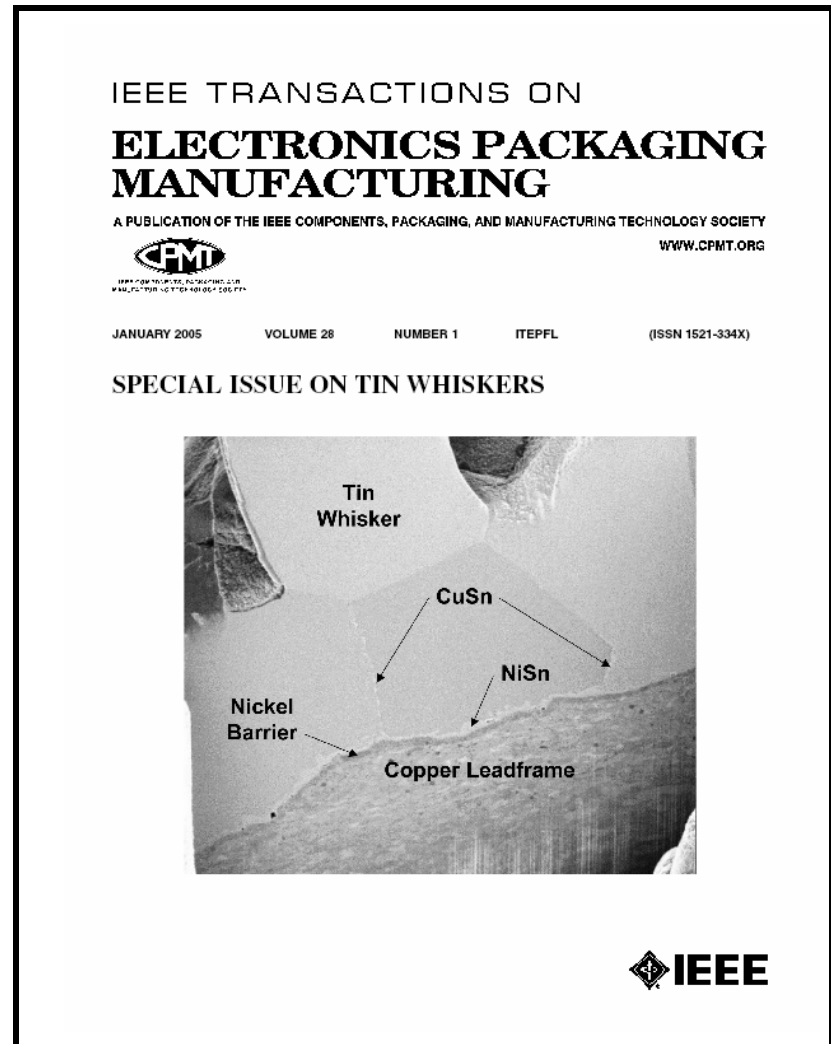
**Interim report produced (6/03).**

**2<sup>nd</sup> Workshop (iNEMI/CPMT/ECTC) held at ECTC in Las Vegas (6/04).**

**IEEE Mfg. Transactions special edition published.**

**3<sup>rd</sup> Workshop (iNEMI/ECTC) held at ECTC in Orlando (5/31/05).**

**4<sup>th</sup> Workshop held at ECTC in San Diego (5/30/2006)**



**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)
- **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**

## **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**

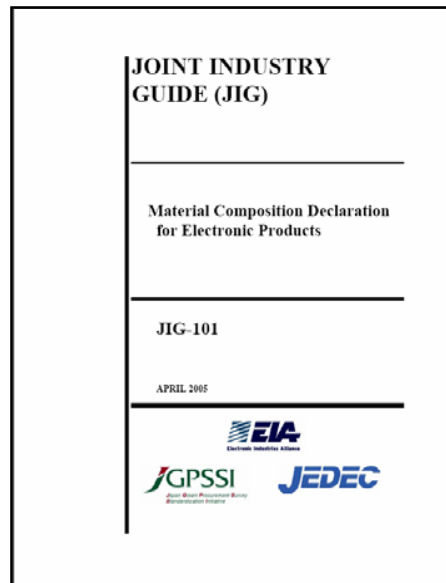
## **Scope:**

- **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**

## Joint Industry Guide



**Targeted lists of materials and substances for disclosure**

**The composition amount or "threshold level"**

**15 Level A Material/Substance categories  
(including the 6 RoHS substances)**

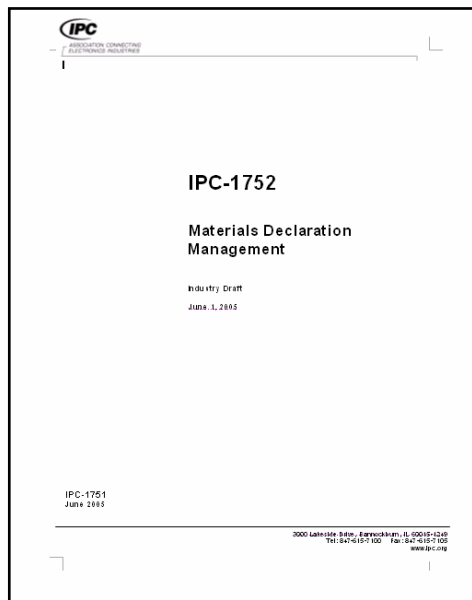
**9 Level B Material/Substance categories**

**Over 2000 specific substance CAS numbers!**

**Formally released as an EIA/JEDEC standard on  
May 25, 2005**

☞ **Provides "What" needs to be declared**

## *IPC-1752 Materials Declaration Management*



**References RoHS and JIG for substance reporting requirements**

**Provides a standard data model, XML schema and human readable presentation format (PDF)**

**XML schema will be aligned with RosettaNet 2A13/2A15 PIPs**

**2 versions of the form:**

- **IPC-1752-1: RoHS at homogeneous and JIG substance reporting at the part level**
- **IPC-1752-2: RoHS and substance reporting at the homogeneous material level**

**Free download [www.ipc.org/IPC-175X](http://www.ipc.org/IPC-175X)**

*Provides standard on “How” to declare*

**Objective:**

- **Understand process parameters for assembly of Pb-free BGA's in a PbSn reflow/wave environment. Companies that have exemption from RoHS face this alternative due to supply chain transition to lead-free**

**Scope:**

- **Provide the general industry with a “generic” process guideline and risk assessment for assembling lead-free BGAs in a SnPb assembly process**

**Status:**

- **Project officially Started May, 2005**
- **Phase I process development completed**
- **Phase II will include reliability evaluations**

- **Observed microstructures in agreement with predictions based on the calculated solidification path: especially, the Scheil calculations.**
- **SAC-Pb formed final frozen phases: (Sn) + (Pb) +  $\epsilon$  with melting point: ~177 °C (calculated), & micro-pores observed in same area.**
  - » Further investigation of porosity effects may be required
  - » Results from different phase fractions compared to equilibrium microstructures.
- **Characterized joints at 205 °C, 225 °C, and 240 °C reflow temp.**
- **At 205 °C reflow temperature, there are significant differences in microstructure between the melted SAC-Pb and non-melted SAC. In addition, the primary  $\epsilon$  phase will grow to an abnormal IMC size if the reflow temperature is not sufficient to melt it. These features may be unfavorable to the reliability of the solder joint.**
- **The growth of the  $\text{Cu}_6\text{Sn}_5$  IMC has less influence on the microstructures than that of the  $\text{Ag}_3\text{Sn}$  IMC.**

**Objective:**

- **Characterize the impact lead free alloys exert on the wave and/or selective soldering process as well as identifying the impact this has on product reliability**

**Scope:**

- **Develop an appropriate wave soldering test vehicle with a number of board level parameters which includes through hole components and surface mount devices**

**Status:**

- **Project officially started May, 2005**
- **Phase 1 – Characterize process parameters & materials**
- **Phase 2 – Characterize joint performance**

**Objective:**

- **Evaluate and recommend best practices, rework equipment requirements, and procedures for best of breed lead-free rework processing in a manufacturing environment**

**Scope:**

1. **Rework tolerances and repeatability (Rework equipment manufacturers)**
2. **Optimized heat transfer into reworked boards (Rework equipment manufacturers)**
3. **Work to reduce adjacent (top and bottom) component temperatures with development from rework equipment suppliers**
4. **Specific rework practices:**
  - BGA Socket and FCBGA component rework**
  - Lead-free mini-pot wave connector rework**

## **Objective:**

- **Evaluate the effects of alternative surface finishes for circuit boards and package substrates on Pb-free solder joint reliability during mechanical stress testing – do comparative reliability testing on Pb-free components assembled on test boards**

## **Scope:**

**Conduct comparative four-point bend testing, drop testing and board-level thermal cycling of Pb-free components assembled on test boards, as well as comparative solder ball shear/pull testing on BGA and CSP components for various finishes.**

## **Status:**

- **Project officially started May, 2005**
- **PWB Design & Fabrication of the Test vehicle completed.**
- **Time-zero component characterization (cross-section, X-ray, CSAM, coplanarity, etc.) of components completed.**
- **Extensive low/high speed solder ball shear and pull testing completed.**

**Pb-free surface finishes include:****PWB Laminate**

- **OSP (Entek+ CU106AXHT)**
- **Immersion Ag (Alpha Star i-Ag)**

**BGA Substrates**

- **Electrolytic Ni/Au**
- **ENIG**
- **Ni/Pd/Au**
- **Cu (SOC, OSP & i-Sn)**

**Lead-frames**

- **Matte Sn**
- **Matte Sn/Ni**
- **Ni/Pd/Au**

- **Members are OEMs and EMS providers producing high-reliability products**
- **Many taking RoHS Pb exemption (RoHS5 Products)**
- **Issued three position papers**
  - **RoHS5 & RoHS6 Subassembly Modules (6/12/06)**
  - **Pb-Free Manufacturing Requirements for High-Complexity, Thermally Challenging Electronic Assemblies (2/16/06)**
  - **Recommendations to Electronics Industry Component Supply Base (8/19/05)**
- **Firms experiencing difficulty in sourcing Pb containing components**

- Series of 18 articles ran monthly in *Circuits Assembly* and *Printed Circuit Design & Manufacture* magazines.
- Available at:  
[http://www.inemi.org/cms/newsroom/Articles/Pb-Free\\_Watch.html](http://www.inemi.org/cms/newsroom/Articles/Pb-Free_Watch.html)



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

- **Industry is prepared to meet legislative requirements**
  - **Selected Single Alloy**
  - **Developed Materials, Processes, Standards**
- **Significantly greater cost and increased risk to industry than initially thought**
- **Closing remaining knowledge gaps could take several more years of investment/investigation**
- **Those that took “exemption” to maintain reliability are discovering that they may have to take greater risks because of a lack of components**
- **Regulations delayed or stopped industry programs of potentially greater impact, for example recycling of plastics**
- **Industry needs to be more proactive in the future**

**[www.inemi.org](http://www.inemi.org)**

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