Bi-Sn Based Low Temperature Soldering Process and Reliability

Call for Project Formation
August 17-18, 2015

Initiative Leaders: Raiyo Aspandiar, Mokler, Scott, Intel; iNEMI Staff: Haley Fu
Agenda

• Participants Introduction
• iNEMI Project Process
• Project Formation Team Objective
• Project Preliminary Definition
  – Initial Proposal
  – IS / IS NOT analysis
  – Discussion
• Next Step & Meetings
iNEMI Project Process
Successful iNEMI Projects

• Address knowledge gap(s) of industry:
  – Common problem
  – Best solved by working together
  – Timed success that aligns to business needs
  – Best manifested on complex far reaching issues
  – Often includes reliability testing & verification

• Requires teamwork across multiple levels of the supply chain:
  – Ensures efficient alignment of goals and investments of the varied team players;
  – Supports the company’s commercial interests.

• Delivers a coordinated industry wide response and capability set.
  – OEM/ODM/EMS/Suppliers at multiple levels.
The Project Development Process - 5 Steps

0. INPUT
1. SELECTION
2. DEFINITION
3. PLANNING
4. EXECUTION / REVIEW
5. CLOSURE

“Initiative” Open for Industry input

“Project” Limited to committed Members
Definition

- Organization
- Stakeholders
- Background
- Objectives
- Deliverables
- Benefits
- Skills required
- Risks
- Scope
- Costs

Decision after Review

- Is it still valid?
- Is the market forecast valid?
- Do we have resources?
- What is current priority?
- What are the consequences of aborting now?

APPROVAL TO PROCEED
Planning

- Time estimates
- Initial schedule
- Resource analysis
- Optimization
- Risk review
- Issue resolution
- Prepare to implement

Decision after Review

- Is the schedule acceptable to participating member companies?
- Are resources committed?
- Do we still want to do it?
- Is current priority correct?

APPROVAL TO PROCEED
Output of Planning Process

- Project Leadership
- SOW (Statement of Work)
  - Document Describing the Project
- PS (Project Statement)
  - Document Defining:
    - What each Firm Will Contribute
    - The rules for the Project
    - Firm Commitment from Management

SOW and PS are described at www.inemi.org
Project Formation Team
Objective
Project Formation Team Objective

- Plan the project with manageable/achievable scope to benefit the membership/industry
  - Define the project goals and scope
  - Identify tasks and resources required
  - Plan the project schedule
  - Develop the SOW and PS
  - Identify key players to form the project team
Outline of Statement of Work (SOW)

1. Background to work
2. Scope of project
3. Purpose of project
4. What the project IS/IS NOT
5. Business Impact
6. Previous/current related work
7. Outcome of project
8. Prospective Participants
   - (Generic – nonspecific list)
9. Project Schedule with Milestones
10. Resources required from project participants
11. Project monitoring plan
12. General and administrative guidelines
Project Proposal

The Starting Point
Problem Statements

- ODMs are striving to lower Energy Usage
  - Higher energy costs are driving ODMs to reduce power usage in manufacturing process
  - One major target is reflow ovens -- lowering temperatures in reflow ovens can save significant amount of energy

- SMT Solder Joint Yield Losses are increasing due to the burgeoning of ultra-thin electronic packages and boards
  - Lowering soldering temperatures lowers package and board warpage and hence mitigates the solder joint yield loss
Proposed Mitigation To Problems

• Use of low temperature solders and solder pastes
  – Will enable lowering the peak reflow temperatures which in turn will
  – Lower energy usage costs
  – Lower package and board warpage during reflow soldering
Low Temperature Solders

- There are a variety of compositions and melting ranges for Potential Low Temperature Solders in Electronics Manufacturing.

- Bi-Sn system solders are being proposed for this Project.
  - More processing and economic benefits than Medium Temperature Solders.

Medium Temperature Solders [SnAgCu +Bi,In]
- melt in the 210 to 220°C range

Low Temperature Solders [Bi/Sn/X, X=Ag,Cu,Ni]
- melt in the 139 to 175°C range
Bi-Sn based solders have high strain rate sensitivity. At high strain rate, the solder is very brittle due to the bismuth phase within its two-phase microstructure. This leads to high risk of brittle fracture of Bi-Sn based solder joints under mechanical shock and drop conditions for electronic products.
Potential Solution Paths to Mitigate Risks of Bi-Sn Brittle Solder Joints

Resin Reinforced Bi-Sn Solder Paste

- Resin added to the solder paste cures during reflow and provides reinforcement under mechanical stresses

Ductile Bi-Sn Metallurgy Solder Paste

- Addition of Elemental Dopants increases ductility of Bi-Sn solder by modifying microstructure
- Hypoeutectic Bi-Sn compositions (40 vs 57 wt% Bi) with added dopants
Failure Modes after Shock Tests
For BGA Solder Joints

Mixed SAC/BiSn Solder Joint
Formed using Bi-Sn-Ag Solder Paste

SAC305 Solder Paste
Formed using SAC305 Solder Paste

Cracking along the solder/IMC interface and in the solder

Cracking in the solder and along the solder/IMC interface

Pad Cratering (crack laminate)
Project Proposal

- **Objective:**
  - To assess the two solution paths available for mitigating mechanical drop / shock and thermal cycle risks associated with Bi-Sn based solder pastes for SMT assembly

- **Scope**
  - **Solder Pastes**
    - ductile Bi-Sn metallurgy
    - Resin Reinforced Bi-Sn based
    - SAC305 (for comparison)
    - standard BiSnAg (for comparison)
  - **Components**
    - High density BGAs
    - BTCs (such as QFNs)
    - Other
  - **Board Surface Finishes**
    - OSP (1st option)
    - ENIG
    - ENEPIG
  - **SMT Process Development**
    - Stencil Printing
    - Reflow Soldering
    - Rework Process
  - **Shock/Drop and Thermal Evaluation using Test Vehicle Designs**
    - Shock/Drop is the 1st priority and thermal is the 2nd
    - Per JEDEC or other standards
  - **Product Validation**
    - Boards Assembled with Best performing solder pastes from each category
    - Subjected to selected Product level functional and mechanical shock/drop tests
## Proposed Steps

<table>
<thead>
<tr>
<th>Step #</th>
<th>Description</th>
<th>Expected Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Select Solder Pastes Available from Suppliers in Both Categories - Ductile Bi-Sn - Resin Reinforced Bi-Sn</td>
<td>List of Solder Pastes with TDS containing Recommended Reflow Profiles, and SDS</td>
</tr>
<tr>
<td>2</td>
<td>Select Components to be Tested</td>
<td>List of Components with their design documents</td>
</tr>
<tr>
<td>3</td>
<td>Design Shock Test Boards</td>
<td>Board Design Files and Requirement Documents of Shock Test Boards</td>
</tr>
<tr>
<td>4</td>
<td>Identify Sites for Board Assembly, Shock Test and Failure Analysis</td>
<td>List of Members Sites where Shock Test Boards will be assembled, Shock Tests conducted and Failure Analysis performed</td>
</tr>
<tr>
<td>5</td>
<td>Develop SMT Process - Printing - Reflow soldering</td>
<td>Optimized Stencil Printing Parameters and Reflow Profiles for each solder paste being evaluated</td>
</tr>
<tr>
<td>6</td>
<td>Assemble Boards</td>
<td>Assembled Boards from each selected member board assembly site</td>
</tr>
<tr>
<td>7</td>
<td>Mechanical Shock/Drop Test Boards</td>
<td>All test boards subjected to Shock/Drop per Plan and Weibull Plots generated</td>
</tr>
<tr>
<td>8</td>
<td>Conduct Failure Analysis</td>
<td>Solder Joint Failure locations, modes of failure and microstructural aspects</td>
</tr>
<tr>
<td>9</td>
<td>Publish Preliminary Report</td>
<td>Completed Report on Mechanical Shock/Drop Test Results</td>
</tr>
<tr>
<td>Step #</td>
<td>Description</td>
<td>Expected Outcome</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>10</td>
<td>Select Best Performing Solder Pastes from Mechanical Shock/Drop Test in each category - Ductile Bi-Sn - Resin Reinforced Bi-Sn</td>
<td>List of one each Ductile Bi-Sn and Resin Reinforced Bi-Sn Solder Paste to be used for Product Validation Steps</td>
</tr>
<tr>
<td>11</td>
<td>Select Product Design to be Validated and manufacturing site for assembly and for Validation Tests</td>
<td>Detailed information of Product Board, and BOM with planned Product Validation Tests</td>
</tr>
<tr>
<td>12</td>
<td>Procure BOM and assemble Product at selected Manufacturing Site</td>
<td>Assembled Product Boards</td>
</tr>
<tr>
<td>13</td>
<td>Test Boards through standard Product Functionality and Reliability</td>
<td>Results of Functionality and Reliability with Yields and Failures documented</td>
</tr>
<tr>
<td>14</td>
<td>Conduct Failure Analysis</td>
<td>Solder Joint Failure locations, modes of failure and microstructural aspects</td>
</tr>
<tr>
<td>15</td>
<td>Publish Final Report</td>
<td>Completed Report on all Project Outputs</td>
</tr>
</tbody>
</table>
## Standard Bi-Sn-Ag Metallurgy
### Low Temperature Solder Pastes

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Manufacturer’s Part Number</th>
<th>Metallurgical Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIM</td>
<td>NC273LT</td>
<td>Bi57Sn42Ag1</td>
</tr>
<tr>
<td>Alent</td>
<td>CVP-520</td>
<td>Bi57.6Sn42Ag0.4</td>
</tr>
<tr>
<td>Indium</td>
<td>5.7LT</td>
<td>Bi57Sn42Ag1</td>
</tr>
<tr>
<td>Koki</td>
<td>T4AB48-M742</td>
<td>Bi57.6Sn42Ag0.4</td>
</tr>
<tr>
<td>Inventec</td>
<td>Ecorel Free 140-18</td>
<td>Bi57.6Sn42Ag0.4</td>
</tr>
<tr>
<td>Senju</td>
<td>ECO Solder Paste SHF L25-LT140ZH</td>
<td>Sn59-40Bi-0.5Sb-0.5Cu</td>
</tr>
<tr>
<td>Shenmao</td>
<td>PF602-P68</td>
<td>Bi58-Sn42</td>
</tr>
<tr>
<td>Tamura</td>
<td>TLF-401-11</td>
<td>BiS8-Sn42</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Manufacturer’s Part Number and Alloy</td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
<td>---------------------------------------------------------------------------</td>
<td></td>
</tr>
</tbody>
</table>
| Alent                    | ✓ Timberwolf  
|                          | ✓ Bi-Sn eutectic + Epoxy Resin                                             |
| Hitachi Chemical         | ✓ UP-300 (standard resin content)  
|                          | ✓ Bi-Sn Eutectic + Proprietary Resin                                        |
|                          | ✓ UP-400 (higher resin content)  
|                          | ✓ Bi-Sn Eutectic + Proprietary Resin                                        |
| Indium Corp of America   | ✓ 723-62-2  
|                          | ✓ Indalloy 281 Bi-Sn Eutectic + Proprietary Resin                           |
| Panasonic                | ✓ CV6511B  
|                          | ✓ Bi-Sn eutectic + Proprietary Resin                                        |
| Senju                    | ✓ L20-JPP-J10(S6)-T7R  
|                          | ✓ Bi-Sn eutectic + Proprietary Resin                                        |
| Tamura                   | ✓ SAM10-401-27  
|                          | ✓ BiSn Eutectic Metallurgy                                                 |
| Yincaе                   | ✓ SMT138E  
<p>|                          | ✓ Solderable Ag containing Epoxy paste                                      |</p>
<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Manufacturer’s Part Number and Alloy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alent</td>
<td>✓ OM-535</td>
</tr>
<tr>
<td></td>
<td>✓ SBX02 (Bi-Sn-0.4Ag –X₃–X₄) eutectic patented Alloy</td>
</tr>
<tr>
<td>Senju</td>
<td>✓ L27-LT142ZH</td>
</tr>
<tr>
<td></td>
<td>✓ Patented Sn-Bi-X₁–X₂ hypo-eutectic patented alloy</td>
</tr>
</tbody>
</table>
## Prospective iNEMI Member Participants

<table>
<thead>
<tr>
<th>Solder Paste Suppliers</th>
<th>ODMs/EMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hitachi Chemical</td>
<td>Celestica</td>
</tr>
<tr>
<td>Henkel</td>
<td>Flextronix</td>
</tr>
<tr>
<td>Indium</td>
<td>Sanmina</td>
</tr>
<tr>
<td>Nihon</td>
<td>Wistron</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OEMs</th>
<th>Research Institutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dell</td>
<td>Calce</td>
</tr>
<tr>
<td>HP</td>
<td>RIT</td>
</tr>
<tr>
<td>Intel</td>
<td>SUNY Binghampton</td>
</tr>
<tr>
<td>Lenovo</td>
<td></td>
</tr>
<tr>
<td>Microsoft</td>
<td></td>
</tr>
</tbody>
</table>

Welcome your active participation and leadership!
Discussion
Is/Is Not Analysis

The Starting Point
## IS / IS NOT Analysis

<table>
<thead>
<tr>
<th>This Project IS:</th>
<th>This Project IS NOT:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide initial analysis of what the Project IS and IS NOT</td>
<td></td>
</tr>
</tbody>
</table>
Guidelines for SOW Development
Outline of Statement of Work (SOW)

1. Background to work
2. Scope of project
3. Purpose of project
4. What the project IS/IS NOT
5. Business Impact
6. Previous/current related work
7. Outcome of project
8. Prospective Participants
   - (Generic – nonspecific list)
9. Project Schedule with Milestones
10. Resources required from project participants
11. Project monitoring plan
12. General and administrative guidelines
iNEMI Statement of Work – Basic Information

• **Scope of Work** – definition of what is to be done
  – Describe what work will be done
  – State the major goals of the project at the end of project deliverables
  – Provide an approximate timeframe for major phases of the project and for completion

• **Purpose of Project**
  – Explain how the project aligns to the roadmap and what gaps will be filled
  – Will the project provide a complete solution or be part of a complex solution?
  – List anticipated benefits to participants, to the iNEMI membership in general, and the industry
• **Business Impact**
  – Provide information on what impact this project will have on
    • Participating organization
    • iNEMI member companies
    • Industry as a whole

• **Outcome of Project**
  – List addressed issues that are expected to addressed and/or resolved, e.g., identify gaps, report(s) on results of any testing, etc.
  – List expected deliverables and project milestones
  – Sharing Project Results: To be determined by the project team on what information will be shared outside of the team.

**NOTE:** All changes to SOW must be approved by TC
Statement of Work – Resources

- Detailed list of resource needs and expenditures expected for the project, including:
  - Human resources
  - Equipment
  - Money
- List of committed resources from participating companies
- State source of funding for any components, assembly, design, and testing needs
  - Funding alternatives include
    - Participant donation
    - Supplier donation
    - iNEMI direct funding
Statement of Work – Materials and Processes

• Identify materials to be used
• Describe any processes to be used, including applicable standards and specifications
• Identify specific suppliers or technologies required and reasons for the requirement
• When custom components are necessary, state which project participant is responsible for assuming this cost
• Standard processes and materials should be used whenever possible to reduce costs, improve yields, and assure widest applicability of results within the industry
• Justification is needed if non-standard materials or processes are to be used
• Specify and describe any non-standard materials or processes (Specification Projects)
• State anticipated number of parts to be tested
• Use IPC 9701 0-100C as baseline ATC unless justification can be given for alternate test parameters
• For test vehicle design and fabrication, recommend using reference components that have been ATC tested on previous projects be used to provide a baseline and facilitate comparison of results
• Use standard design practices and commonly used software to reduce costs and widen applicability of results
• At what stages will testing be done along with time needed
Statement of Work – Schedules With Milestones

• Project plan with
  – Identified tasks
  – Intermediate check points
  – End dates

• A detailed timeline, including each project activity

• Content and dates for:
  – Technical reviews (2 per year)
  – Progress reports
Statement of Work – Project Monitoring Plans

• Plan to ensure open lines of communication among participants?
  – Provide planned teleconference schedule
  – Request progress reports as tasks are completed
• Practice risk analysis by anticipating problems and having alternate solutions ready
• Use opportunity analysis to identify new areas or topics that might be addressed in additional projects
  – To prevent scope of the current project from expanding
  – keep project focused on original goals
• Review project requirements with suppliers before the project begins
• Provide monthly updates to TIG and TC coach
• Provide information as needed to assist in completing Project Summary Chart
Possible Project Phases

• Definition (Phase 1)
  – Draft test plan
  – Fix test parameter
  – DOE Design
  – Test Vehicle Design
  – Phase 1 Interim/Final Report
  – Revised SOW for Phase 2
  – ...

• Fabrication (Phase 2)
  – Test vehicle fabrication
  – Test vehicle verification
  – Test vehicle assembly
  – Phase 2 Interim/Final Report
  – Revised SOW for Phase 3
  – ...

• Testing and Analysis (Phase 3)
  – Perform tests
  – Analyze test results
  – Phase 3 Final Report
    • Summary
    • Lessons Learned
  – Final Summary Report
  – ...

• Summary

• Lessons Learned
Initiative Timeline - Next Meetings

• 1st meeting – kick off and introduction
• 2nd meeting – Is/Is not analysis, preliminary definition
• 3rd-5th meeting – experiment design (materials; reliability; test method options; test vehicles; etc.)
• 6th meeting – review the draft SOW, potential resource requirement and high level schedule
• 7th meeting - refine the SOW, prepare the PS;
• Submit to TC for approval (2 weeks)
• Target to open for sign-up before the end of September

Propose meeting at:
8am China on Tuesday
5pm PDT US on Monday