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Advancing manufacturing technology
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iNEMI Statement of Work (SOW)
Board Assembly TIG
iNEMI Characterization of Pb-Free Alloy Alternatives Project

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Basic Project Information

Scope of Work

- **The major goals of the project include continuation of some Phase 1 goals and the addition of several follow-on objectives. Overall, goals for this project include the following.**
  - Continue to provide guidance to the industry that will help make Pb-free alloy choice easier to manage.
  - Provide technical information to the industry to reduce the complexity in selecting Pb-free alloys.
  - Develop a set of material test requirements for new Pb-free solder alloys.
    - Work with IPC and the IPC Solder Products Value Council to establish standard test methods for alloy properties and reliability evaluations.
    - Identify test methods to reduce impact on manufacturing processes.
  - Provide thermal cycle reliability data on a variety of commercially and scientifically important alloys.
  - Provide data from which thermal fatigue acceleration models can be derived for a range of alloys.

Purpose of Project

Significant innovations in Pb-free solder alloy compositions are being driven by volume manufacturing and field experiences. As a result, the industry has seen an increase in the number of Pb-free solder alloy choices beyond the common near-eutectic ternary Sn-Ag-Cu (SAC) alloys. The increasing number of Pb-free alloys provides opportunities to address shortcomings of near-eutectic SAC alloys, such as:

- Poor mechanical shock performance
- Alloy cost
- Copper dissolution
- Poor mechanical behavior of joints in bending

At the same time, the increase in alloy choice presents challenges in managing the supply chain and introduces a variety of logistical and technical risks, such as a potential decrease in thermal fatigue resistance.

The lack of information on the thermal fatigue performance for many new Pb-free alloys has motivated the Alloy Alternatives team to plan accelerated thermal cycle experiments. The project team has considered many possible sets of experiments in order to answer a variety of questions. In the end, the team has decided to:

- Validate the impact of Ag concentration in the range of 0 to 4% on thermal fatigue resistance.
- Evaluate the impact of commercially common dopants, such as Ni, on thermal fatigue performance.
- Assess how alloy composition affects the acceleration behavior.
- Provide basic thermal fatigue data for several of the most common alternate alloys on the market today, benchmarking them against eutectic Sn-Pb and SAC305.
- Depending on the availability of cells in the DoE, provide an opportunity to assess the performance of some new commercial and experimental alloys.

Currently, we are in the process of finalizing details of the accelerated thermal cycle test plan, including which alloys to test and which thermal cycle profiles to investigate such that meaningful acceleration factor data will result. If we are successful in executing these plans, the data could be of major benefit to the industry, especially since such large studies are nearly impossible for a single company to undertake. We expect thermal cycle testing to begin March 2010 and testing to be completed August 2010, but precise dates will depend on experimental details still to be determined.

One situation that creates uncertainty in the industry regarding new alloys, and which may slow the adoption of improved materials, is the lack of defined information requirements for alloy acceptance. The acceptability of any alloy may vary from product class to product class, and possibly from company to company. However, the methodology and data requirements may be largely the same, regardless of product requirements or company.

Development of standard test requirements and methods has begun with a review of the approach being developed by Hewlett-Packard. In this project, the iNEMI team will evaluate the merits of this approach and consider possible modifications that may be necessary in order to meet the needs of the broader electronics industry. A dialogue also will take place between the Alloy Alternatives team and the Solder Products Value Council (SPVC), with the ultimate goal of providing a formal starting point for the development of an IPC standard, or set of standards, addressing testing of new Pb-free alloys.

The iNEMI team presented to the JEDEC JC-14 committee concerns about part numbers and customer notification when BGA/CSP suppliers change ball alloys. We noted that a Pb-free BGA ball alloy change may have an impact on printed circuit assembly (PCA) manufacturing due to the higher melting point of some alloys. In particular, the change to low Ag ball alloys may require a change to PCA manufacturing processes. One recommendation was that the committee should consider mandating, or at least recommending, that new part numbers be issued when a BGA supplier changes the solder ball alloy. A new task group was formed to consider this issue and our recommendation. The Alloy Alternatives team will continue to drive creation of an appropriate standard.

The work done on this project will be part of the solution to the problem of complexity resulting from the presence of many new Pb-free solder alloy alternatives available within the industry. Anticipated benefits to the industry include:

- Better information, through standardized testing, from which to make alloy acceptance decisions.
- Another substantial benefit will be in providing thermal fatigue data for new alloys, including a better understanding of the impacts of Ag concentration and micro-alloy additions on performance and acceleration behavior.
- These data and the improvements in key standards will help industry to manage alloy proliferation.
- A formal, technical white paper will be generated with the intent of publishing this information in a peer reviewed journal.

Previous Related Work

- Planning and activity in Phase 2 centers around two focus areas determined in Phase 1: driving industry standards, in particular alloy test methods, and thermal fatigue behavior. As shown in Table 1, thermal fatigue and alloy test methods were identified as high priority knowledge gaps to be filled.

Table 1. Key knowledge gaps regarding the performance and impact of new Pb-free alloys

Gap or Concern
High Priority
Advantages and disadvantages of specific alloys
Composition limits for micro-alloy additions, ranges of effectiveness
Standard method to assess new alloys; standard data requirements
Consistency of testing methods, including test vehicles & assembly, test parameters, etc.
Establish the microstructural characteristics of specific alloys
Long-term reliability data for new alloys, particularly low Ag & micro-alloyed
Lack of thermal cycle data for evaluating new alloys; benchmark to Sn-Pb and SAC 305/405
Medium Priority
Assessment of new alloys for use in “mission critical, long life” products
Impact of rework on microstructure and properties
Mixed Sn-Pb/Pb-free assembly, including rework
Impact of alloy composition on work hardening rates & other flow properties; effect of strain rate and temperature
Impact of alloy composition on bend/flex limits (moderate strain rate; ICT, handling, card insertion, etc.)
Thermal fatigue accelerations factors (not yet fully established for SAC 305/405)
Impact of aging on microstructure and mechanical properties
Low Priority
Solder process margins required for new alloys used in various product classifications
Mixing of different BGA ball alloys and paste alloys for various component and board designs

Prospective Participants

Mike Davisson	Agilent
Paul Petri	Agilent
Mike Cox	Agilent
Alex Chan	Alcatel-Lucent
Richard J Coyle	Alcatel-Lucent
Marc Benowitz	Alcatel-Lucent
Joe Smetana	Alcatel-Lucent
Chen Xu	Alcatel-Lucent
Sherwin Kahn	Alcatel-Lucent
Polina Snugovsky	Celestica
Thilo Sack	Celestica
Linda Scala	Celestica
Donghyun Kim	Cisco
Ashok Domadia	Cisco
Tae-Kyu Lee	Cisco
Robert Healey	Cookson
R. Lewis	Cookson
Ranjit S Pandher	Cookson
Mike Varnau	Delphi
Richard Parker	Delphi
Mark Currie	Henkel
Michael Roesch	HP
Greg Henshall	HP
Cao Xi	Huawei Technologies
Dr. Sunny Liu	Huawei Technologies
Zhang Yuan	Huawei Technologies
Jim Arnold	iNEMI
R. Bernston	Indium
Eric Bastow	Indium
Tom Pearson	Indium
Fay Hua	Intel
Stephen Tisdale	Intel
Fay Hua	Intel
Vasu S. Vasudevan	Intel
Peter Biocca	Kester
Paul Wang	Microsoft
Michael Yuen	Microsoft
Tony Primavera	Microsystems Engineering
Masato Nakamura	Nihon Superior
Keith Sweatman	Nihon Superior
Bill Barthel	Plexus
Robert Kinyanjui	Sanmina-SCI
Derek Daily	Senju-Comtek
Diane Sahakian	STATS/ChipPAC
Heidi Reynolds	Sun
Karl Sauter	Sun
Edgar Zuniga	TI
Tushar A. Shete	Tyco Electronics

- Project team members are expected to participate in the identification and recommendations to update relevant standards, particularly in establishing recommended alloy test methods.
- Project team members are expected to support the accelerated thermal cycle (ATC) testing. This may be through test board assembly, thermal cycle testing, data analysis, failure analysis, or financial support from their company for experimental materials.

Project Plan

Schedule with Milestones

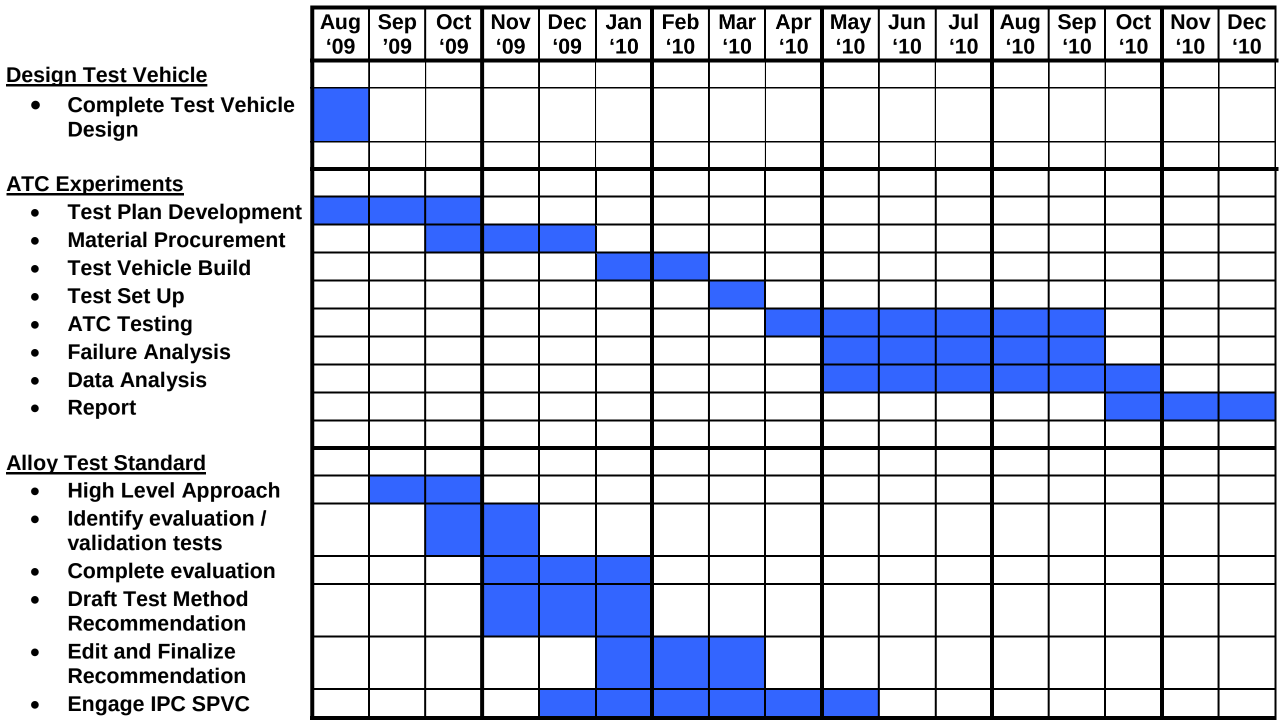
Key Milestones

Dates assume project start 01 August 2009

- **Design Test Vehicle**
  - Complete: Initial Test Vehicle design has been completed by Alcatel-Lucent

    (Participating companies can propose the reconfiguration of the Test Vehicle design; however resources for any redesign will have to be provided by the companies interested in modifying the current design.)
- **ATC Experiments**
  - 01 August 2009: Complete test plan (60 days)
  - 15 November 2009: Materials purchased and received (90 days)
  - 15 January 2010: Test vehicle builds (60 days)
  - 15 February 2010: Test set-up (wiring, thermal profiling, etc.) (30 days)
  - 15 August 2010: ATC testing complete (2000 – 6000 cycles expected; 4-6 months)
  - 15 August 2010: Failure analysis complete (failure analysis begins when failures start and continues as failures occur)
  - 15 August 2010: Data analysis complete (data analysis begins when failures start and continues as data on failures is collected)
  - 01 November 2010: Report complete
  - Spring and Fall 2010: Present findings at industry conference(s) (APEX & SMTAI)
- **Alloy Test Method**
  - 15 September 2009: High level approach established
  - 01 October 2009: Identify evaluation / validation tests
  - 15 November 2009: Complete evaluation of test method
  - 15 January 2010: Draft of test method recommendation completed
  - 15 February 2010: Final test method recommendation document sent to SPVC
  - April 2010: Engagement with SPVC completed (APEX 2010)

Phase 2 – Characterization and Recommendations



Detailed Information

- **Thermal Fatigue Testing**
  - Human Resources
    - Project participation will vary based on the role of each company.
    - Those doing the testing will require both engineering and technician involvement consistent with standard ATC testing. This is estimated to be a total of 3 person-weeks of effort per quarter for each company performing tests.
    - Those doing failure analysis will require both engineering and technician involvement consistent with standard industry practices. This is estimated to be a total of 2 person-weeks of effort per quarter for each company performing FA.
    - Those not directly involved with testing are expected to support planning, data analysis, interpretation of results, and reporting. Only engineering support will be required. This is estimated to be 1 person-week per quarter.
  - Materials and Processes
    - Amkor test packages per test plan. Packages similar to those used in current iNEMI “Early Failures” project.
    - Alcatel-Lucent designed test boards per test plan.
    - 14 to 16 different solder ball alloys per test plan.
    - Standard SMT processes and material for Pb-free and Sn-Pb assemblies.
    - Standard thermal cycle test and data acquisition equipment. Both data loggers and event detectors will be used due to testing at multiple labs.
    - Standard failure analysis equipment and procedures.

- Equipment
  - Single zone test chambers (8).
  - Data acquisition systems (8) – either data logger or event detector.
  - Wiring per standard test practices.
  - Standard metallographic and die stain equipment for FA.
- Testing Procedures
  - Test procedures provided in detailed test plan. Eight different thermal cycle profiles will be used to provide data for acceleration model development for alloys tested.
  - Testing for various profiles will take different lengths of time. We anticipate testing to take between 4 months and 9 months.

- **Drive industry standard for alloy testing requirements**
  - Resources
    - Only human resources required. No test materials or equipment required. Estimate 1.0 week of effort per participant per quarter over the course of the task.
    - No additional funding required
  - Materials and Processes
    - Not Applicable
  - Testing Procedures
    - Not Applicable
- **Drive industry standard specifying when part number changes are needed for specific BGA ball alloys**
  - Leverage existing iNEMI & EMS forum position papers.
  - Mostly an exercise in engaging the proper standards body (most likely JEDEC).
  - Develop criteria for when a part number (P/N) change is needed (e.g., melting temperature, Ag content, …).
  - Resources
    - Expected to be low effort.
    - Only human resources required. No test materials or equipment required. Estimate 0.5-1.5 weeks of effort per participant over the course of the task.
    - No additional funding expected for this task.
  - Materials and Processes
    - Not Applicable
  - Testing Procedures
    - Not Applicable
- **Push to update IPC/JEDEC J-STD-006 on requirements for solder alloys**
  - iNEMI support could be very helpful in pushing the IPC/JEDEC committee to make progress in updating this document.
  - Main issues include alloy tolerances and definition of "impurities" for micro-alloyed materials.
  - Goal is to open lines of communication between the project team and the J-STD-006 committee to our concerns and the need for an update of the standard.

- Resources
  - Expected to be low effort.
  - HP may be in a position to lead this (TBD).
  - Only human resources required. No test materials or equipment required. Estimate 0.5-1.0 weeks of effort per participant over the course of the task.
  - No additional funding expected for Phase 1 tasks.
- Materials and Processes
  - Not Applicable
- Testing Procedures
  - Not Applicable

Project Monitoring Plans

- **Ensure open lines of communication among participants**
  - Weekly conference calls
  - Meeting minutes provided through e-mail
  - Follow-up with individuals on an as-needed basis
  - Workshops and face-to-face meetings as appropriate
- **Technical reviews (2 per year) and progress reports at regularly scheduled iNEMI meetings**

Project Reports and Publications

- **Provide summary of work for iNEMI members (the team will decide on level of detail to be provided)**
  - Resources
    - iNEMI members will be provided with the ATC data and analysis report submitted for publication, and thus will receive this information well before the general public.
    - iNEMI members will be provided with the alloy test standard recommendation to the SPVC, and thus will receive this information well before the general public.
    - No additional funding is expected for providing iNEMI members with a summary of the work performed in this project. No equipment will be required. Project participants are expected to help in the writing and review of the summary. No additional effort beyond that described above is anticipated.

Outcome of the Project

- **Successful completion of thermal cycle experiment will manifest as publication and presentation of the data and interpretation of results. Deliverables of this portion of the project include the following.**
  - Test results in the form of Weibull curves for the various alloys under the 8 different thermal cycling conditions.
  - Results of the failure analysis for each alloy under each test condition. Validation of thermal fatigue failure mode.
  - Rank order of alloy performance as a function of thermal cycle condition and test package type (2).

- Interpretation of results
  - Impact of Ag concentration
  - Impact of micro-alloying elements
  - Impact of package type on rank order
  - Implications for acceleration models
- **Successful completion of the alloy test requirements portion of this project will manifest as publication and presentation of recommendations for alloy test standard(s). Deliverables of this portion of the project include the following.**
  - Formal recommendation of alloy test standard(s) to the IPC Solder Products Value Council.
  - Final report to iNEMI members.
  - Publication of recommendations in appropriate conference proceedings and/or archival journal.

General and Administrative Guidelines

General and Administrative Guidelines for this project and all other iNEMI Projects are documented at http://thor.inemi.org/webdownload/join/gen_guidelines.pdf.