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- Medical Electronics

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Copper Wire Bonding Reliability Project

**Goal:** Understand key issues and concerns regarding reliability of fine-pitch Cu wire bonding for semiconductors.

**Strategy**
- 2-phased project. The first phase will focus on collecting information from the industry regarding the key processing and reliability issues pertaining to Cu wire bonding. The second phase of the project will perform necessary experimental work in the areas defined by Phase 1.

**Issues**
- Copper bond wires are increasingly being used for a wide variety of components.
- Reliability needs to be collectively assessed by the industry in a quantitative manner.
- Standard reliability test methods and durations for Au wire device may not be sufficient for Cu.

**Tactics**

**Phase 1**
- 1. Industry Survey
- 2. Existing Data Review
- 3. DOE Plan for Phase 2

**Phase 2**
- 1. Finalize DOE
- 2. Procure Materials
- 3. Package Assembly
- 4. Reliability Tests
- 5. Failure Analysis
- 6. Summary

**Milestones and/or Deliverables**

<table>
<thead>
<tr>
<th>Plan</th>
<th>Actual</th>
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<tr>
<td>Initiative Launch Date</td>
<td>Mar-10</td>
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<tr>
<td>Project Inauguration - Two PS Signers</td>
<td>Sep-10</td>
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<tr>
<td>Conduct survey, analyze inputs</td>
<td>Nov-10</td>
</tr>
<tr>
<td>Plan DoE for phase 2</td>
<td>Dec-10</td>
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**Project Lead:** Peng Su, Cisco Systems, inc.  
**Project Co-Lead:** TBD

Cu Wire Bonding Reliability
Project Members

CISCO
IBM
Agilent Technologies
Celestica
Dow
Electronic Materials
Amkor Technology
ASE GROUP
INVENT
iST
Integrated Service Technology
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Survey Mechanism

• The industry survey is Phase 1 of the iNEMI Cu Wire Bonding Reliability Project.

• Survey Objectives
  – Understand the key processing and reliability issues pertaining to fine pitch Cu wire bonding
  – Collect information to help outline an experimental study of reliability of components using copper wire bonding

• Survey Process
  – May – Aug 2010: Develop survey by project formation team
  – Aug 23 – Sept 30, 2010: Collect inputs from industry
  – Oct 1 – Nov 26, 2010: Review & analyze survey data
  – Dec 3 – Dec 24, 2010: Verify significant issues with follow-up questions
  – Jan 2011 : Report survey results
• 58 individuals from over 40 companies completed the survey.
  – Suppliers (32)
    • Bonding wire manufacturers
    • Interposer suppliers
    • Equipment manufacturers
    • Package assemblers
    • IC IDM
    • Total revenue ~40B USD
  – OEM/EMS (20)
    • System providers
    • End product manufacturers
    • Total revenue ~400B USD
  – Others (6) came from consulting, academia, industry organizations

• Survey data is analyzed separately for suppliers and OEM/EMS.
Survey Results
**Technology Adoption Status by Device Type**

**Question:**
Please select the current application status of Cu wire bonding of your company for different device types.

**Survey Results:**

- **Suppliers**
  - Only semiconductor suppliers and assembly houses are counted. Material or equipment suppliers are not included.
  - Most suppliers are in the process of technical qualification or production.
  - Cu wires are used for all device types but memory devices appear to have less usage.

- **OEM/EMS**
  - Many OEM/EMS have no plan for Cu wire bonding product introduction at this time.
  - Some OEM/EMS are conducting feasibility studies.
  - Small percentage in production for memory, logic and power devices.

**Observation:**

- Suppliers are already in the process of implementing Cu bond wires.
- OEM/EMS are just beginning to study feasibility and a few are in the early stage of production introduction.
Question:
Please select the current application status of Cu wire bonding of your company for different device types.

Survey Results: OEM/EMS in different product segments

- Memory, Logic and Power devices are in volume production for some Consumer/Portable, Computer and High End Server products.
- Not in production for Netcom, Medical, Automotive products.
- No plan for Military and Aerospace.
Question:
What package types do you plan to adopt (or have already adopted) for Cu-wire technology?

Survey Result:
• All package types are in “planned” or “already adopted” phase for Cu wires in the industry, but may vary for each company.
• xBGA, QFN and xQFP packages have highest adoption rates.

Observation
• Slow adoption by OEMs in contrast to suppliers, most likely because of reliability concerns (refer to results later in this report).
• Less implementation for memory devices, per suppliers’ input.
**Major Concerns**

**Question:** What are the major concerns with Cu wire bonding?

- In-service reliability
- Process yield
- Throughput
- JEDEC reliability spec
- Unproven historical performance
- Manufacturing statistical process control
- Equipment and assembly process parameters

**Survey Results:**

- Reliability and historical performance are major concerns for the OEM community.
- Suppliers have concerns in these areas as well but to a lesser degree.
- Suppliers have additional concerns about throughput and yield.

*When “In-service Reliability” is selected, the major reason is lack of use history (80%), followed by “unknown or poor correlation of JEDEC testing with in-field performance” (20%).*
Question:
For your current production process, which reliability tests are the most difficult to pass?

Survey Result:
- Suppliers see biased HAST as the most difficult reliability test to pass.
- OEM/EMS perceive biased HAST and thermal cycling as equally difficult.

Observation:
- HAST and thermal cycling are commonly used for package qualification. OEMs often have difficulty passing these items in qualification and would be aware of such failures.

65% respondents made their selection based on actual test results, while the other 35% were based on what they expect would be difficult to pass.
**Question:**
What are the most common failure modes for copper wire bonding?

**Survey Result:**
- Inputs from OEM/EMS and Suppliers are similar.
- Ball lift, IC damage and 2nd bond defect are the major failure modes.
- OEM/EMS also cite wire break as a common failure mode.

**Observation:**
- The responses for the ‘ball lift’ failure mode most likely refers to ball lift defect on the bonding process, not interface cracking after acceleration tests.
**Question:**
Are current JEDEC standard acceleration tests sufficient for system application requirements?

**Survey Result:**
- Both supplier and OEM/EMS responses indicate great uncertainty of the suitability of current tests.
- There are concerns on test duration, temperature range, and if current JEDEC standard can properly detect corrosion.
- A higher percentage of Suppliers believes different or new tests are needed for Cu wire device qualification.

**Observation:**
- The word ‘sufficient’ in the question may have been interpreted differently by different companies. Some may have interpreted it as ‘sufficient to generate failures’, while others may have interpreted it as ‘sufficient to ensure product reliability’.
Question:
For Cu wire bonding, have you seen any issues for the following Failure Analysis (FA) techniques?

Survey Result:
• Suppliers indicated that Decap, IMC thickness measurement and X-ray inspection of debonding / wire shifting are issues.
• X-ray inspection for debonding / wire shifting is an issue for OEM/EMS.
• C-SAM analysis for delamination is not an issue for either suppliers and OEM/EMS.

Observation:
• This data indicates that suppliers and OEM/EMS have seen challenges for FA.
**Preferred Wire Type**

**Question:**
What's the preferred type of wire material?

**Survey Result:**
- More than 50% of Suppliers prefer pure Cu wire, followed by Pd coated Cu wire.
- Most OEM/EMS prefer Pd coated Cu wire.

**Observation:**
- Choice of Pd coated or pure copper is determined by reliability performance and cost considerations.
- Some commented that Pd-coated wires have better reliability test results than bare Cu wires, while others showed opposite results.
**Question:**
Have you adopted new specifications on mold compounds for Cu wire bonding?

**Survey Result:**
- Some component suppliers are adopting materials (e.g. molding compound) with lower halogen content and more neutral pH.
- Others do not have special requirement on materials such as mold compound. Some (40%) stated no performance advantage was observed for materials with nominally better properties.

**Observation:**
- Some OEMs do not have sufficient information on package BOMs and currently can not clearly specify material property requirements.
Smallest Bond Pad Pitch & Wire Diameter

**Question:**
In your CURRENT/FUTURE PRODUCTION, what is the smallest bond pad pitch and smallest wire diameter for copper wire bonding?

**Survey Result:**
- General trend is moving to smaller wire diameter and pitch.
- 0.6 mil wire diameter is being considered for pitch ranging from 20 to 45 μm.

**Observation:**
- Fine Cu wires / fine bond pitch are already being used for current products and future trend is going toward even finer wires.
- Some data might have been mis-entered.
  - E.g., Current: 65um pitch for 0.8mil wire, 40um pitch for 1.38mil wire
  - 1.0mil wire for 30um pitch would be challenging.
- Data may be scattered due to die pad design differences or specific use for big pad size.
**Question:**
For the same device in your application, have the bond pad and under-pad structures been re-designed for copper wire bonding?

**Survey Result:**
- While almost half of respondents replied no re-design was required for pad structure, some indicated the need for re-design.
- Some re-designed the structure to prevent bond pad damage.

**Observation:**
- Accuracy of response might have been limited by manufacturing experiences.
- Chip manufacturers might not disclose this information.
**Chip Pad Finish**

**Question:**
What is the preferred surface finish on the chip bond pad?

**Survey Result:**
- No specific preference is indicated from suppliers’ input.

**Observation:**
- OEM/EMS may not have the information to make comments.
**Question:**
For different interposer types, what is the preferred surface finish?

**Survey Result:**
- Wide range of surface finishes are suggested. There is no clear consensus from suppliers or OEM/EMS.
  - Flex / Rigid Substrate: Au finish is preferred
  - Ceramic Substrate: No clear preferred finish
  - Leadframe: Ag was preferred by suppliers, but OEMs have no clear preference.

**Observation:**
- Variability of OEM/EMS inputs may have been limited by small sample sizes.
- Suppliers’ input shows similar surface finishes as presently used for Au wire bonding.
**Question:**
Have you adopted new cleaning process for Cu wire bonding (e.g. plasma clean prior to bonding process)?

**Survey Result:**
- Majority of respondents (75%) use the same cleaning process for Cu wire bonding as the current Au wire bonding process.
- The other 25% use slightly modified cleaning process.
Expectation for iNEMI Project

- Top 3 issues respondents expect iNEMI project to address:
  - Reliability assessment of representative Cu wire bonding currently in production;
  - Requirements for reliability testing (either new tests or modification of current standard JEDEC tests);
  - Recommendations about wire materials, pad materials, and design rules for under-pad Si structures

- Several other issues were also identified as important.
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