Current Industry Adoption of Fine-Pitch Cu Wire Bonding and Investigation Focus at iNEMI

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ABSTRACT

Gold (Au) wire bonding is one of today's most common and well understood first level interconnects. However copper (Cu) wire bonding is increasingly being used for a wide variety of components, predominantly driven by the cost benefit of Cu. As the application moves from mostly consumer products to high-reliability electronic systems, the long term reliability of fine-pitch Cu wire bonding must be better understood. A collaborative project has been launched by iNEMI (International Electronics Manufacturing Initiative) member companies to assess the current adoption landscape of Cu wire bonding in the industry, and to understand the critical factors that impact component reliability. An industrial survey has already been conducted by the project. The results of the survey not only provide a clear overview of the general application status of Cu wire bonding, but also illustrate key technical concerns such as reliability performance, materials and process capability (or optimization), and qualification standards requirements.

INTRODUCTION

Cu bond wires are increasingly being used for a wide variety of components, from consumer applications to high-reliability electronic products. Recent published papers have shown that Cu wire bonding requires more rigorous bonding process control and stricter packaging material selection. Despite the positive impact of these improvements, reliability still needs to be collectively assessed by the industry in a quantitative manner. Furthermore, for component qualification purposes, standard reliability test methods and durations established for Au wire device may not be appropriate for Cu. Extended reliability evaluation may be needed to validate today's commonly used BOMs (bill of materials) for Cu wire bonded devices.

iNEMI launched a collaborative project on Cu Wire Bonding Reliability in 2010. At this stage, fifteen companies are participating in this project.

The project includes two phases. In the first phase, member companies outlined and conducted a survey on the industry-wide conversion status, as well as key reliability concerns for Cu wire bonding. Based on the findings from this survey and published literature, it was determined that reliability performance of Cu wire bonding needs to be further evaluated with experimental work, so that the effects of key factors such as packaging material selection on reliability performance can be better understood. The project team has designed an experimental matrix that includes realistic packaging material variations for both leadframe and substrate-based packages. During the 2nd phase a series of accelerated tests will be performed on components made with these material variations and lifetime data will be collected. Based on the accelerated tests and failure analysis data, the effects of packaging material properties will be better understood. The effectiveness of current accelerated test methods and durations will also be determined.

SURVEY METHODOLOGY

The project team conducted an initial survey in September 2010, and a follow-up survey in December 2010 to clarify some issues from the initial results. Representatives from more than 40 major companies responded to the survey. These companies covered a full spectrum of the industry, ranging from material and interposer suppliers, semiconductor manufacturers, assembly houses, to OEMs with total annual revenue of over 300B USD.

32 suppliers, 20 OEM/EMS, and also several industry organizations and research institutes responded, providing good coverage of end-product segments including consumer/portable, Netcom, computers and medical, automotive. The survey included 20 questions covering Cu wire adoption status, reliability, process, materials, failure analysis and technical concerns.

SURVEY RESULTS

This section summarizes the major observations from the survey.

1. Preferred Wire Type

The survey asked what the preferred type of wire material is.

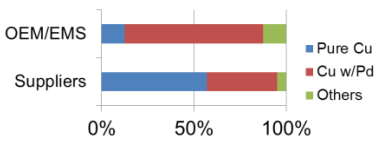

Fig.1 Preferred Wire Type

Response from suppliers and OEM/EMS were different. OEM/EMS preferred Palladium (Pd) coated Cu wire, while Suppliers preferred pure Cu wire. The choice of wire type was influenced by both reliability performance and cost considerations. Some commented that Cu wire with Pd shows better reliability test result than bare Cu wires, while others reported opposite results.

2. Cu Wire Adoption Status

The survey asked the current application status of Cu wire bonding for different device types.

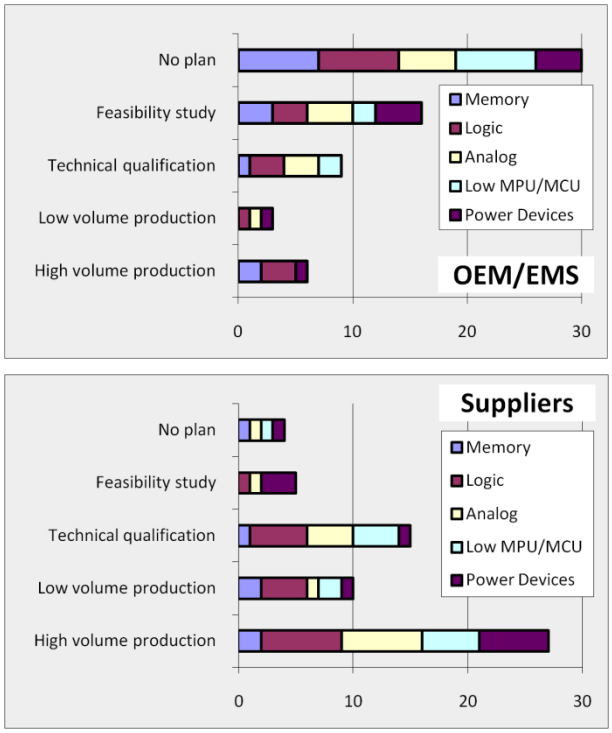

Fig. 2 Adoption Status by Device Technology

Many OEM/EMS have no adoption plan at this time, but some are conducting feasibility studies. A small percentage reported being in production for memory, logic and power devices.

The responses from semiconductor suppliers and assembly houses were counted in the graph, but material or equipment suppliers were not included. Most suppliers are in technical qualification or production stage. Cu wires are used for all device types.

Adoption status by market segment was also assessed for OEM/EMS.

Memory, Logic and Power devices are in volume production for some Consumer and Portable computers and also some High-end server products.

No production was reported for Netcom, Medical, and Automotive products and there were no plans reported for Military or Aerospace.

3. Cu Wire Implementation Status

The survey asked for what package types were there plans to adopt Cu wire bonding technologies.

Copper wire usage in all package types is in “planned” or “already adopted” phases, but varys from company to company. xBGA, xQFN and xQFP packages have higher adoption rates.

Results showed more cautious views of implementation by OEMs than suppliers, which seems most likely related to reliability concerns.

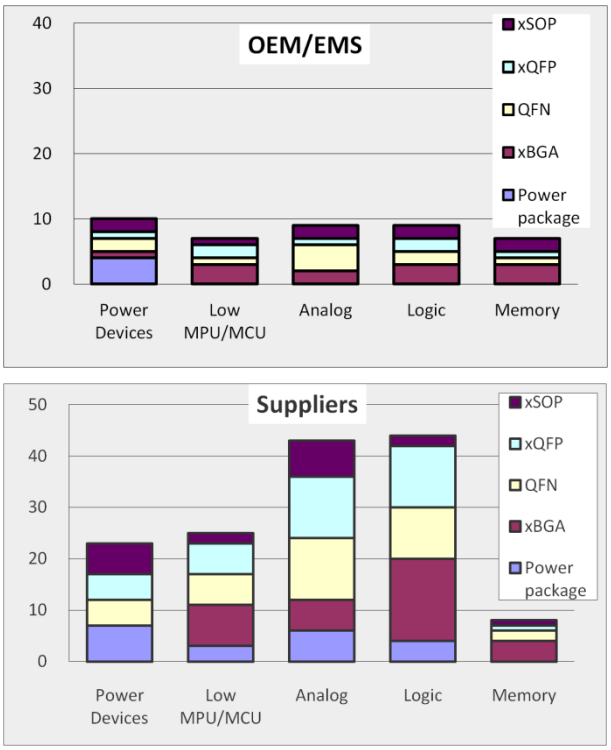

Fig. 3 Implementation Status by Package Type

4. Bond Pad Pitch & Wire Diameter

The survey asked what the smallest bond pad pitch and wire diameter were for current and future production.

Currently copper wire diameters from 1µm down to 0.7µm diameter of Cu wire are in use for pad pitchs of 40µm to 55µm. There is a trend towards use of more fine wire diameters and smaller pitches. 0.6µm wire diameter is being considered for pitches ranging from 20µm to 45µm.

5. Main Concerns:

The survey asked for information on the main concerns with Cu wire bonding.

In-service reliability and unproven historical performance were the major concerns expressed by the OEM/EMS community. Suppliers had concerns in these areas as

well, but to a lesser degree. Suppliers had additional concerns about the throughput and yield.

When “in-service reliability” was selected, the major reason was a lack of use history (80%), followed by “unknown or poor correlation of JEDEC testing with in-field performance” (20%).

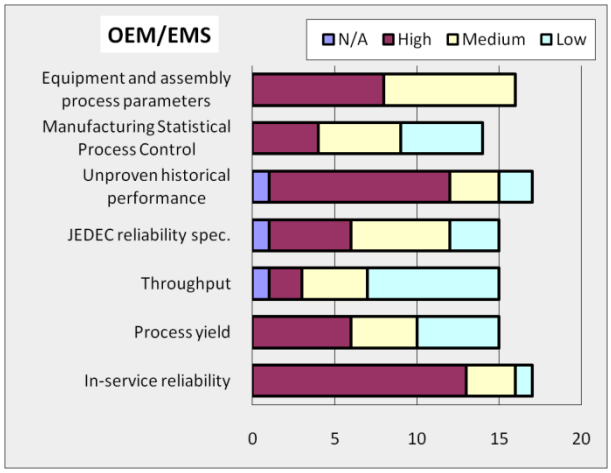

Fig. 4 Concerns with Cu Wire Bonding

6. Failure Analysis (FA) Techniques

The survey asked whether there are any issues for FA techniques.

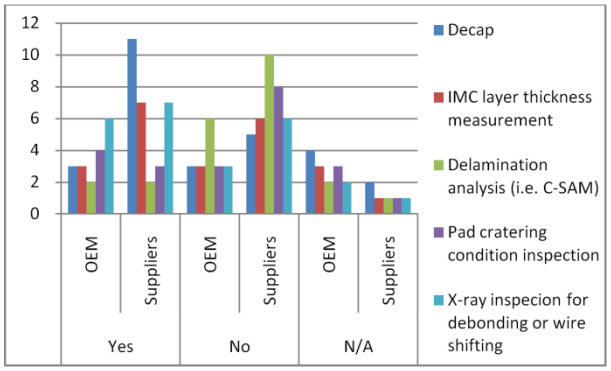

Fig.5 Concerns with Failure Analysis Techniques

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 was not reported to be an issue for either suppliers or OEM/EMS. This data indicates that suppliers and OEM/EMS have seen challenges for FA.

7. Failure Modes

Reported failure modes were similar from both OEM/EMS and Suppliers – with Ball lift, IC damage and 2nd bond defects being the major failure modes. OEM/EMS also cited wire break as a common failure mode.

The responses for the ‘ball lift’ failure mode most likely referred to ball lift defects during the bonding process, rather than interfacial cracking after accelerated testing.

8. Surface Finish

The survey asked about the preferences for both chip pad finish and interposer surface finish.

Chip Pad Finish: There was no specific preference indicated from suppliers, while OEM/EMS may not have the information required to make comments at this time.

Interposer Surface Finish: A wide range of surface finishes were suggested. There was no clear consensus amongst suppliers or OEM/EMS. For Flex / Rigid Substrate: Au finish is preferred. For Ceramic Substrate: No clear preferred finish. For Leadframe: Ag was preferred by suppliers, but OEMs had no clear preference. The variability of OEM/EMS inputs may have been limited by small sample sizes. Suppliers’ inputs showed similar surface finishes to those presently used for Au wire bonding.

9. Mold Compound

The survey asked whether new specifications for mold compounds were required for Cu wire bonding.

45% of component suppliers are adopting materials with lower halogen content and more neutral pH. Others reported not special requirements for materials such as mold compound. 32% of suppliers stated no performance advantage was observed for materials with nominally better properties.

Some OEMs may not have sufficient information on package BOMs to allow them to clearly specify material property requirements.

10. Reliability Test

The survey asked what reliability tests are most difficult to pass for the current production process.

The survey results showed that suppliers see biased HAST as the most difficult reliability test to pass, and that OEM/EMS perceive biased HAST and thermal cycling as equally difficult. 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% of respondents responded to this survey question based on actual test results, while the responses from the remaining 35% were based on what they expected would be difficult to pass.

The question also asked whether current JEDEC standard accelerated test methods were sufficient for system application requirements.

Responses showed that both suppliers and OEM/EMS have great uncertainty about the suitability of current tests. There are concerns on test duration, temperature range, and whether current JEDEC standard tests can properly detect corrosion. A majority of suppliers believe different or new tests are needed for Cu wire device qualification.

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'.

SURVEY SUMMARY

The purpose of this survey was to understand key issues and concerns regarding the adoption of Cu wire bonding.

- 58 individuals from over 40 global leading companies responded to this survey, covering a wide spectrum of the industry, ranging from material suppliers to OEMs with total annual revenue of over 300B USD.
- The results showed that 20% of the OEM/EMS surveyed use Cu wire for either high volume production (HVP) or low volume production (LVP), and 55% of suppliers are in either HVP or LVP phase.
- Main concerns for OEMs about factors that would slower the implementation progress were reliability and unproven historical performance Suppliers had similar concerns, but to a lesser degree.
- Establishing appropriate failure analysis techniques is challenging Decap, IMC thickness measurement and X-ray inspection are most difficult ones based on suppliers' input. OEM/EMS mentioned that X-ray inspection for debonding/ wire shifting is an issue.
- Biased HAST was rated as the most difficult reliability test to pass. Test duration, temperature range, and whether current JEDEC standard can properly detect corrosion were the major concerns.
- Overall, there was strong consensus that the reliability performance of Cu wire bonding needed to be further evaluated with experimental work.

NEXT STEP

iNEMI is now initiating the 2nd phase of the Cu wire bonding reliability project. Experiments have been designed to investigate the technical issues highlighted in the survey results. Phase 2 will:

- Assess reliability performance of components with Cu bond wires and compare to components with Au bond wires. 3 bonding wire types will be studied: pure Cu and Pd coated Cu, vs. an Au wire control.
- Identify key packaging material properties that impact reliability performance, and provide guidelines on packaging material selection. 2 mold compounds and 3 surface finishes will be evaluated on 2 package types (BGA and leadframe package).
- Evaluate results from several temperature-humidity level combinations and attempt to derive a lifetime model based on the results from these tests. 5 conditions for Biased-HAST, 1 condition for HTS, 1 condition for AATC, and MSL3 are planned.
- Perform failure analysis and identify test methods and material properties that impact lifetime during such tests.
- By using a test-to-failure methodology, assess the effectiveness of standard reliability test methods and durations so as to better address reliability risks for Cu wire bonded devices.

The project phase 2 is expected to be completed in approximately 1 year from the time of project launch.

AKNOWLEGEMENT

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