AREA Consortium

February 2017 Newsletter

advanced process lab
research • process support • analysis

Dear Members,

The bulk of our consortium research projects address specific and often narrowly defined challenges posed to us by our members. Project work scope is defined by our research staff in consultation with perhaps one to three interested member companies and a scan of the relevant scientific literature. At other times though, a more pervasive problem with broader impact across the industry shows up on our work list. The solid state void formation in the Cu_3Sn solder interfacial intermetallic observed with some electroplated copper deposits comes to mind –a perplexing technical problem with potentially severe product reliability consequences. Reliability risks like these further tend not to be widely reported in the literature because companies are hesitant to admit their product is afflicted when they cannot also declare they've fixed the problem. Such challenges are ideally tackled in a consortium research environment where like-minded technologists can share experimental observations outside of the customer view.

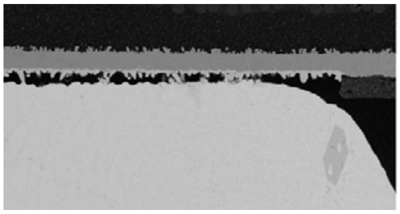
Several of our members are now wrestling with an apparently ubiquitous BGA soldering problem associated with VIPPO board structures and described in the first article below. Immediately following the technical program of our upcoming March meeting we will be hosting a work session to define a consortium based research effort to tackle this problem. We've invited a host of companies from around the industry to share their experiences with this particular defect. This experimental planning workshop will start at 1:00pm, March 23rd. Please plan to attend, particularly if you have experienced this defect in your product. We'd like to collect as many reference observations as possible to guide the experimental design for our research efforts.

Sincerely,

Jim Wilcox
Consortium Manager

REL9A. Mixed VIPPO Array Induced BGA Soldering Defects

The AREA Consortium is embarking on an investigation of an apparently pervasive BGA solder joint reliability issue arising from the use of mixed arrays of BGA pads, that is, PCB designs in which some BGA pads have underlying Via In Pad-Plated Over (VIPPO) structures and others do not. This problem manifests itself as a separation between the BGA solder and the component pad intermetallic during a second reflow. In cross-section the pad intermetallic appears largely intact and the separation surface of the solder is smooth indicating that, at least locally, the solder was liquid during the separation. Suspicion is directed at the differential expansion between adjacent regions of the PCB containing VIPPO and non-VIPPO pads due to CTE mismatch. A number of other factors however (material, design and/or process) are expected to either mitigate or promote this phenomenon. A study of these effects will be a key focus of the project. For a deeper understanding of the solder separation mechanism, determination of when in the reflow cycle separation occurs is needed; we speculate that it happens at the onset of the second reflow when the first liquid appears rather than at the end of reflow when solidification takes place. This will need to be experimentally determined.

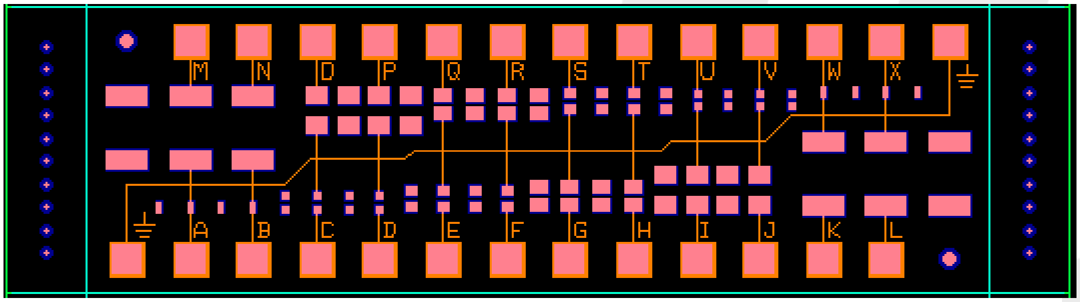


Cross-section of a BGA array (left) with solder separation defects (above) seen to occur at VIPPO locations.

Photo Credits: S.Perng, Proceedings of SMTA International, 2015

MAT8D. Conformal Coating for Mitigation of Sulfur Induced Resistor Corrosion

We have begun acquiring materials for the next phase of our ongoing conformal coating evaluations. As in earlier program phases, this years program will include evaluation of the ability of various coatings to mitigate sulfur induced corrosion on surface mount resistors which have not been expressly finished to resist a sulfur environment. The 2017 program will include Flowers of Sulfur testing of conformal coated boards at three different temperatures (60C, 80C, 100C) to identify the activation energy of the corrosion process and enable modeling of field behavior. A new resistor corrosion test coupon has been designed (below) which includes six different device formats (0201, 0402, 0603, 0804, 1206 and 2512). Test boards (with three coupons each) have been ordered and our resistor inventory replenished. A side study will explore the variability in corrosion behavior of resistors from various suppliers. Humiseal, Semblant and others have agreed to provide professionally applied conformal coatings to our resistor coupon assemblies before they are subjected to sulfur corrosion testing.

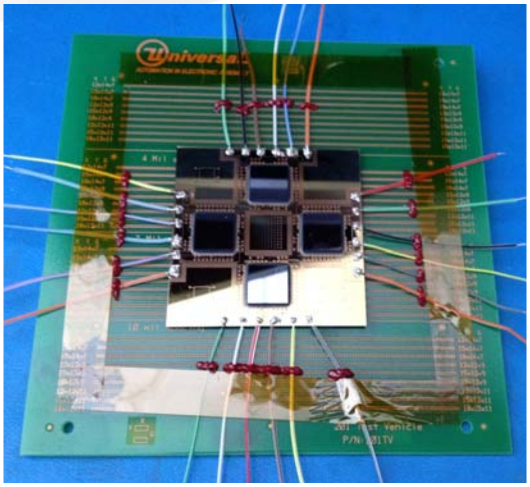


Resistor corrosion coupon designed to evaluate corrosion behavior of six different resistor formats.

REL12A. Fine Pitch Cu Pillar Interconnect for 2.5D Packaging

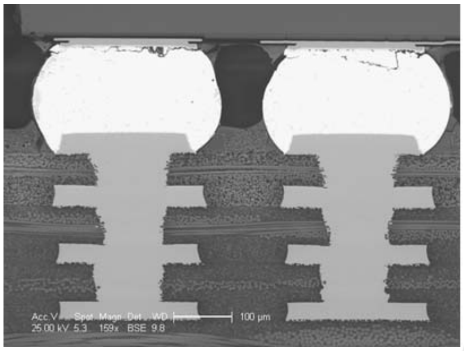
Our ongoing study of micro Cu pillar structures for 2.5D flip chip packaging interconnects has generated a wealth of microstructural observations on joints with varying diffusion barrier layers and solder compositions. Following closely behind these metallurgical results are thermal cycle reliability data for these same interconnect variants being collected as chamber space becomes available.

Underfilled flipchip-on-interposer assemblies now cycling include samples on silicon interposers as well as on high and low CTE glass interposers. Three different diameter solder capped copper pillars are on test: 100μm, 50μm, and 30μm diameter with correspondingly smaller pitches. Of primary interest are fatigue life correlations with the solder joint microstructural observations made for different combinations of diffusion barrier layers on the pillar and interposer metallization. Previous ATC reliability data has been reported for the Cu/Ni barrier combination (on die and interposer, respectively). Next up will be Cu/Cu for 100μm pillars, Cu/Ni for 30μm pillars, and Ni/Ni, Ni/Cu, and Cu/Cu for 50μm pillars. All cells are at 1000 thermal cycles of -40 to 125C with only a single fail observed among all cells.

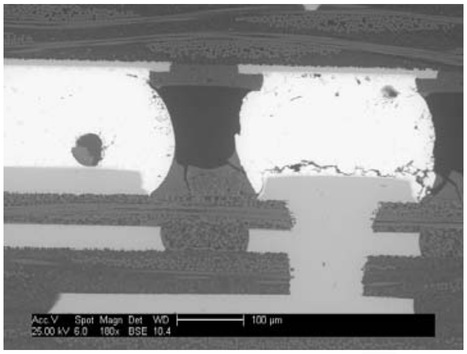


Emulating a 2.5D packaging structure, four 12 mm flip chip test die with copper pillar interconnections to a silicon interposer are wired for event detection in ATC testing.

REL17B. System in Package Interconnect Reliability – Alternate Pb-free Alloys



Failure of WLCSP (above) and CSP (below) corner solder joints with stacked vias. Both are SAC125Ni solder preforms attached with Senju M794 solder paste.



Designers are showing increasing interest in System in Package structures to increase functional density. Reliability of these SiP structures is therefore of obvious interest and several SiP reliability studies are now in the AREA research portfolio.

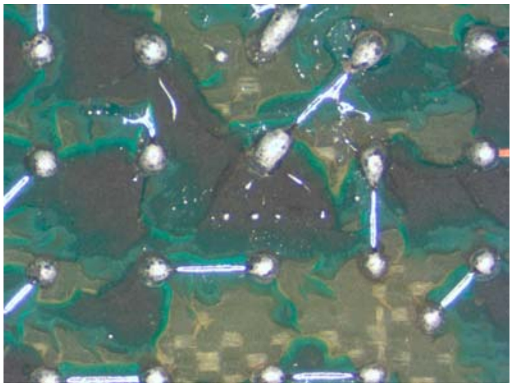
Reliability testing of WLCSP and CSP devices on a large laminate package was recently completed. This SiP test assembly used high temperature solder alloys as might be considered for an automotive SiP application. Paste alloys and ball alloys were mixed in various combinations. The reliability of the WLCSP was found to be dominated by the solder ball alloy with SAC405 assemblies surviving nearly twice as long as their SAC125Ni counterparts, irrespective of the solder paste. Conversely, the CSP interconnect demonstrated reliability with virtually no dependence on solder ball alloy. Instead lifetime correlated with the solder paste selection. With this CSP, M794 paste produced the most reliable assemblies, SAC305 paste the least.

Both device types failed due to bulk solder fatigue typical for WLCSP and CSP packages. The failure location was most often isolated to a corner joint which, unlike the other corner positions, contained a stacked via structure in the SiP substrate used for electrical routing from the CSP/WLCSP to the motherboard.

MAT1B. Reworkable Component Underfills

Both 2016 underfill studies are still in progress (ATC). In addition, cycling has started on another group of TB2015U boards populated with the same Sn/Pb components and underfilled with the same three underfills; the samples differing only in the solder mask material. The reliability results of this new group will be used in two ways. The first will look at any effect of the solder mask on the performance of underfilled assemblies. The second will examine the effect of solder alloy by comparing the new group of TB2015U with the earlier SAC305 TB2014U population having very similar laminate construction and materials and the same solder mask.

Cycling of TB2016U continues with several more failures. The main thrust of study here was the reworkability of the three underfills including any latent damage due to component removal as measured by laminate pad strength. Differences were observed in the ease of rework among the underfills and also between cycled and non-cycled assemblies. In all cases component removal caused extensive solder mask damage. Various removal temperatures and heating times were tried but the damage could not be avoided. This was different from what had been observed with the reworkable underfills used on TB2015U.



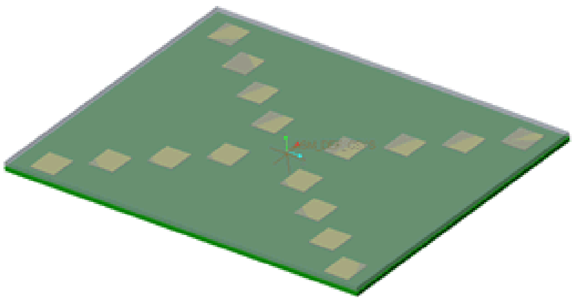
Typical solder mask damage observed after removal of underfilled component

MAT4C. TIM2 Reliability with Ganged Heatsinks

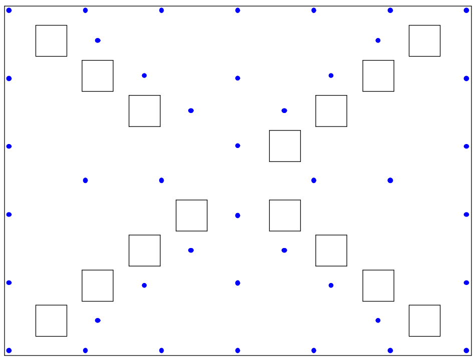
On large, complex printed circuit board assemblies (PCBAs), thermal interface materials (TIMs) are often applied between multiple, independent components and larger heat sinks that span several such components. Mismatch between the thermal coefficient expansion of the PCBA and the common heat sink (typically aluminum) produces global cyclic shear strains in the TIM layers on every thermal excursion. Cyclic accumulation of these shear strains can cause degradation in the TIM thermal performance during operational thermal cycles. The cyclic strains from such common, or ganged, heat sinks can be significantly larger than those encountered with individually applied component heat sinks.

In the case of electrically non-conductive TIMs, electrical capacitance has been found to provide an effective monitor of thermal mechanical stability. The TIM provides a dielectric layer between parallel plates that consists of first, a discrete component surface and second, a large common heat sink. Mathematically, the inverse of capacitance and thermal resistance has the same geometric dependence on the bond line thickness and bonded area of the TIM layer. Thermal resistance measurements on a TIM require the design and build of thermal test vehicles which are costly and time consuming. In contrast, simple and readily available parts can be assembled to represent a realistic application mechanical design which can be monitored using the capacitive analog. These simple parts include a blank PCB laminate board, stock aluminum plate and component heat spreaders. Assembly consists of bonding component heat spreaders with a structural adhesive onto the blank laminate on a footprint that represents an actual assembly or a range of shear strains. Wires are attached to the heat spreader for capacitance measurements. Thermal interface material of interest is applied to the component heat spreaders. Next, the common aluminum plate heat sink that is approximately the same size as the PCB is mated and joined with a fastening scheme representative of the application such as a pattern of bolts. Automated data acquisition is used to measure the capacitance of every TIM bond during thermal cycle testing. Changes in capacitance are indicative of TIM movement, delamination, voiding or, in general, degradation of the thermal transport path due to thermal cycle.

Parts have been procured for the TIM reliability test apparatus shown schematically in the figures below. The left schematic is a layout of 40.5 mm component heat spreaders along the diagonals of a blank 440 mm x 590 mm x 6.4 mm PCB laminate. The right schematic shows a bolt pattern used to mechanically join the aluminum heat sink plate to the PCB. Construction of the apparatus is nearing completion with thermal cycle TIM testing to begin later this month. Four different TIM2 materials will be evaluated in the first trial: Chomerics Gel 30, Jones 21-340E, Timtronics, and Laird 508.



Simulated laminate circuit board with local heat spreaders attached to emulate thermally intensive component locations to be cooled with a common aluminum heat sink.



Schematic of common aluminum heat sink with TIM2 contact sites and bolt locations (blue dots) indicated.