AREA Consortium

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Dear Members,

The full scope of our laboratory capabilities for evaluating the processing characteristics, material performance and reliability of thermal interface materials continues to attract industry attention. While the need for such high performance materials is ubiquitous across all sectors of the electronics industry, the ability for objective customer assessment of such materials is quite limited. Most users are solely dependent on vendor supplied measurements and published technical data sheets to make their material and process selections. We actively fill this need for our members.

Our thermal rod test has proven to be efficient, accurate, and quite versatile. With the ability to measure thermal resistance over a range of bondlines and applied loads, it has been used for thermal putties, greases, gels, phase change materials, thermal pads, graphite pads, and more. Moreover, measuring the long term stability of these thermal interfaces is a particularly unique capability in the APL. While we do this most conveniently with dielectric TIMs we are actively exploring approaches to assess electrically conductive materials as well.

I have included in this Newsletter issue two key examples from our TIM research portfolio: first, another data set from our on-going program to assess the environmental reliability of thermal interface materials for heatsink applications, and second, a member requested study to provide some guidance on the surface roughness of aluminum heat sinks.

Sincerely,

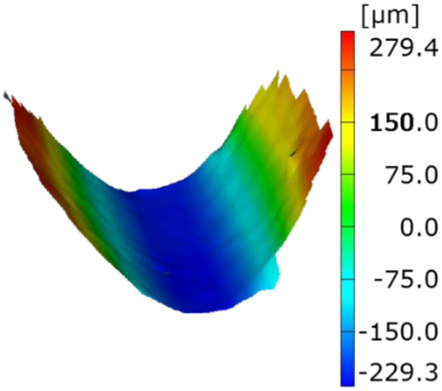
Jim Wilcox

Consortium Manager

APD2B. Thin Die Flipchip Assembly – Extraction from Tape

Picking of die from an adhesive wafer tape is critically dependent on the bending silicon die imposing a peeling stress around the perimeter to force a release from the tape adhesive. The response of ultra-thin Si die being ejected and picked from wafer tapes was explored. High speed digital image correlation (DIC) was used to monitor ejection of thin die (5x5mm and 20µm thick) from a UV cured dicing tape. Die were ejected by pushing from the back, through the tape, with four tungsten pins near the corners of the die. Images from an ejection event in which the die broke are shown below: left, an optical image as the die broke, and right, the measured warpage of that die just before breaking. The DIC measurements were used to calibrate a finite element model created to examine imposed stresses and strains for various thin die ejection parameters.

High-speed image capture of 'speckle enhanced' die breaking during a 4-pin ejection from the tape



DIC measured die bending just before fracture

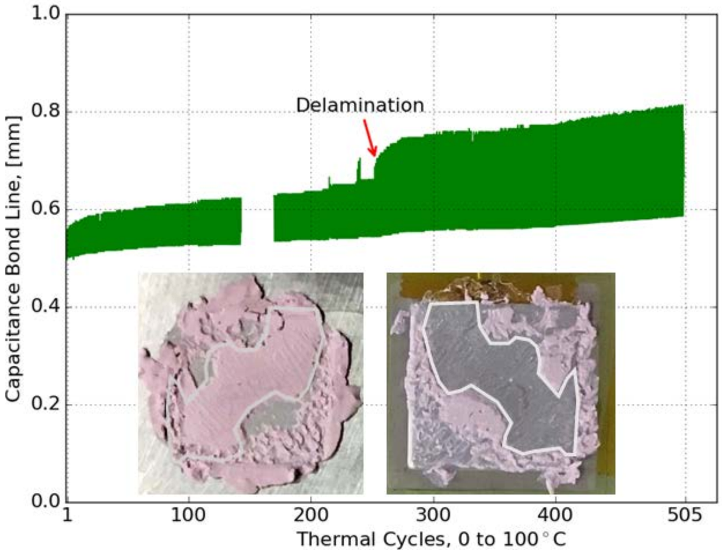
MAT 4C. TIM2 Thermal Cycle Reliability

A second batch of member suggested thermal interface materials (TIMs),

- Global Technology NSP36X1 non-silicone thermal putty
- Laird 607 silicone thermal putty
- Jones 21-361 silicone thermal putty
- Bergquist GP 6000 ULM silicone thermal pad,

has completed 500 cycles of environmental reliability testing in a 0 to 100°C thermal cycle.

Sixteen component level nickel plated copper heat spreaders (40.5 x 40.5 mm) were adhesively attached along the diagonals of a blank PCB laminate (440 x 590 x 6.4 mm). Each of the four TIMs was deposited on four of the component level heat spreaders along a half diagonal. A large aluminum plate heat spreader was mated to the array of component heat spreaders and fastened to the PCB with screws to produce a target bond line of 0.5 mm for all TIMs. As described elsewhere, electrical capacitance measured across the interface is used to monitor the thermal mechanical stability of the individual TIM samples when exposed to environmental thermal cycling.

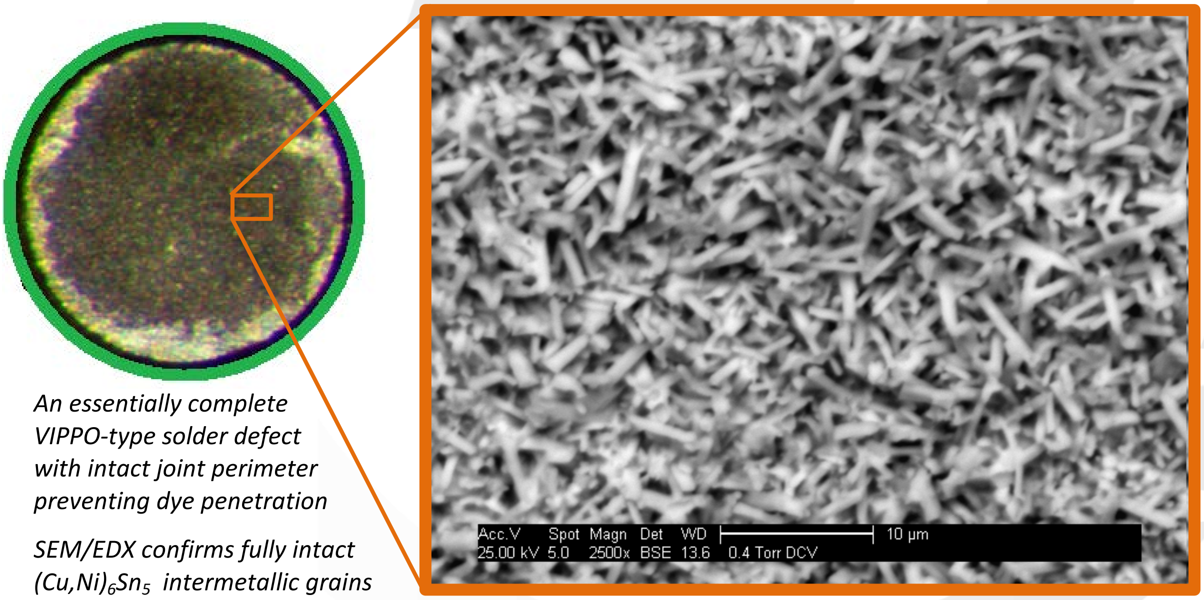


Jones 21-361 Silcone Thermal Putty

At left is the capacitance response by thermal cycle for Jones 21-361 expressed as an equivalent bond line thickness. Data shown correspond to the site located at the furthest distance from the center of the board where the cyclic shear strain is highest. The inset images show the mating surfaces of the Jones material after disassembly. An area of adhesive failure can be seen at the nickel plated copper heat spreader surface (outlined in white). It is hypothesized that delamination occurred in this area during the thermal cycle test as is noted in the plot with a red arrow (~260 cycles) where the measured capacitance decreased suddenly. As a figure of merit, the capacitance decrease is converted to an equivalent capacitance bond line increase. A similar sharp increase in capacitance bond line was observed for the other three locations closer to the center, but at a higher thermal cycle count. In previous testing, the decrease in capacitance always correlated with TIM movement such as pump out, voiding or cracking. This evidence of TIM movement is not apparent for Jones 21-361 TIM, which has higher thermal conductivity than the TIMs tested previously. High filler loadings are used to increase thermal conductivity. This result suggests that mechanical responses such as adhesion and viscosity can be adversely impacted for sufficiently high filler loadings resulting in the TIM becoming more like a dry cake of filler. The high temperature of the thermal cycle could also play a role in advancing cure or in polymer chain scission which, in either case, could adversely impact stiffness and adhesion. This result further emphasizes the importance of thorough material studies that include environmental aging and representative thermal mechanical stressing.

REL9A. Mixed VIPPO (Via-in Pad Plated Over) Array BGA Soldering Defects

Analysis of the distribution of VIPPO-induced defects in the primary test board assemblies continues, with emphasis on the effect of the immediate neighborhood of a VIPPO joint. Because instances were found where a partial IMC separation remained completely internal, with a ring of still-connected solder around the perimeter preventing the dye from coating the failure surface of the joint, all the parts in one twice-reflowed board were potted for cross-section and multiple rows of each part were sequentially polished and inspected. Although the main purpose of this phase of the project was an empirical study of factors affecting the VIPPO defect, more evidence has been collected to be used for a mechanistic understanding of the defect formation phemomenon.

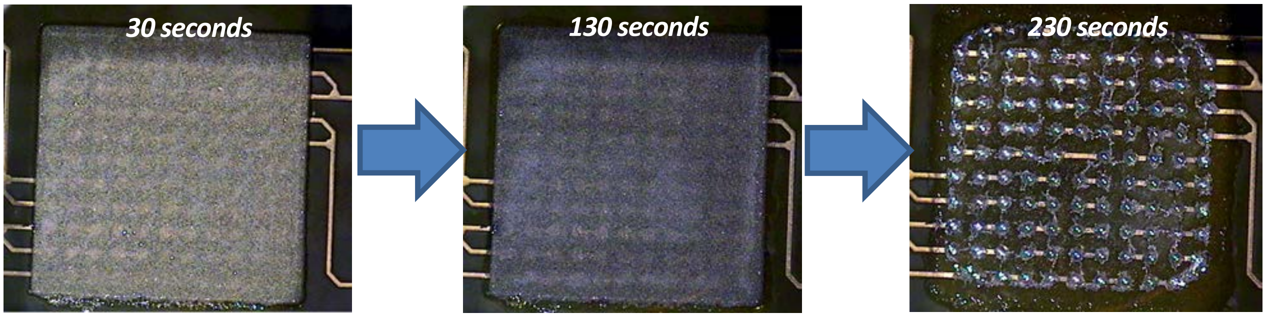


An essentially complete VIPPO-type solder defect with intact joint perimeter preventing dye penetration

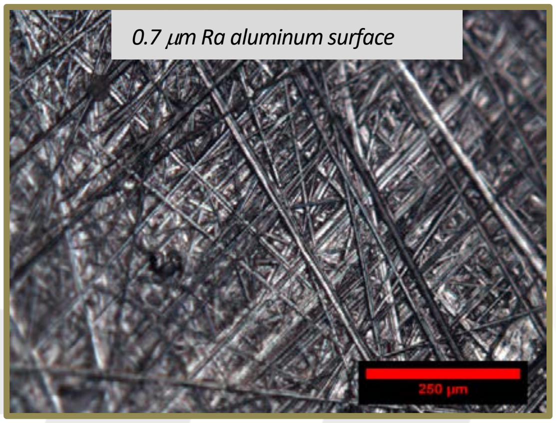
SEM/EDX confirms fully intact $(Cu,Ni)_6Sn_5$ intermetallic grains

MAT9B. Anisotropic Conductive Adhesive for Low Temperature Die Attach

Initial evaluations of Sekisui Self Assembly Anisotropic Conductive Paste (SAP) are underway. The SAP material is a printable polymer resin containing uniformly dispersed BiSn solder particles. It is blanket printed on the base substrate to cover the entire device footprint. Bumped devices are placed into the printed paste above the target pads. Solder joining is initiated by heating the system to 165°C. During a prescribed hold time at temperature, dispersed BiSn particles (now liquid) migrate to the nearest copper pad location, agglomerate, and flow together to form individual joints. The process is illustrated below (minus the placed device for visibility). Early results for SAP attachment of CSP devices with bump pitches ranging from 350µm to 500µm are promising. Additional work to optimize the volume of deposited paste to avoid bridging of excess BiSn particles is required.



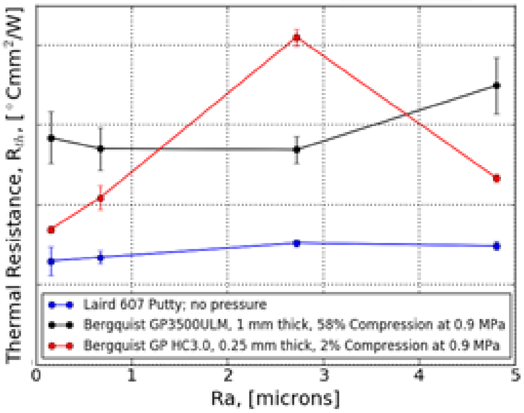
MAT4B. Characterization of Heatsink Thermal Interface Materials—Surface Roughness Effects



A first experiment was completed to understand how surface roughness on an aluminum heatsink affects the thermal resistance of various thermal interface materials. The tested TIMs are listed in the adjoining table; one is a putty material, two are thermal pads. The thermal resistance of each TIM was measured between aluminum surfaces prepared with four different values of surface roughness (Ra): 0.15, 0.7, 2.7 and 4.8 µm. All twelve TIM|roughness combinations were measured using the APL thermal rod tester (described in earlier Newsletter issues). One pair of Al thermal test rods was prepared for each desired roughness value. Each material|roughness combination was measured three times using the same fixed roughness Al rod pairs for all measurements. The thermal pad materials were loaded to 0.9 MPa for the measurements. The Laird putty material was applied with a 0.5 mm bond line; no pressure was applied during its measurement. After every measurement, the rod surfaces were cleaned and sonicated before reuse. The measured values for every TIM|Ra condition appear in the plot below.

TIM2	Type	Thickness	Load
Laird 607	putty	0.5 mm	0
Bergquist GP3500ULM	thermal pad	1.0 mm	0.9 MPa
Bergquist GP HC3.0	thermal pad	0.25 mm	0.9 MPa

Laird 607 thermal putty produces a constant thermal resistance for all surfaces. Bergquist GP3500ULM is constant except for the roughest surface at 4.8 microns. At 0.9 MPa pressure, this thermal pad is highly compressible at 58%. Bergquist GP HC3.0 however is a thin pad with only 2% compressibility and shows significant increase in thermal resistance as Ra increases. The very significant increase at Ra = 2.7µm appears anomalous but several measurements (>3) confirmed this to be a repeatable result. A preliminary observation is that compressibility and likely wettability appear to impact thermal resistance vs Ra. Decreased compressibility and wettability of a TIM results in increasing thermal resistance with increasing surface roughness: the TIM has difficulty filling and displacing the air in the valleys. The thermal putty, which inherently has better wettability than a thermal pad, maintains a constant thermal resistance over a wide range of roughness.



Average thermal resistance as a function of aluminum roughness average. (1σ error bars}

MEMBERS ONLY

Additions to the AREA report archive …

[Assessment of BiSn/SAC Mixed Assemblies: Microstructure and Strain Rate Sensitivity]
by Luke Wentlent

[Soldering of WLCSPs to Temperature Sensitive Flexible Substrates with Area Laser Selective Reflow]
by Peter McClure