Lead Free BGA Rework: A comparison of the effect on reliability of reworked BGAs that have been processed with solder paste printing or flux only attachment

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Abstract
The use of the Area Array Package and in particular, Ball Grid Array (BGA) technology in the electronics industry continues to increase due to the fact that this package type allows for a greater I/O count in a smaller area while maintaining a pitch that allows for ease of manufacture. The original assembly process, and to a large extent the rework process for BGA devices utilizing tin/lead solder materials, has proven to be fairly trouble-free. Environmental and legislative concerns are forcing many manufacturing facilities to transition to Lead Free materials and processes that don't have the same long history of use as tin/lead products.

It is now common knowledge that Lead Free solder will exhibit reduced wetting when compared to traditional tin/lead solders. As more and more assemblies are transitioned to Lead Free materials, it is important to understand what impact the variables of solder wetting will have on the reliability of these Lead Free assemblies. What effects will a "flux only" attachment of the BGA have on the wetting characteristics? What about paste print volume or the size and shape of the stencil apertures?

This paper will review the results of thermal cycling of BGA samples that were processed with Lead Free materials utilizing different solder paste print parameters, flux attachment only, and different BGA land pattern diameters. The goal will be to use the resulting correlations to develop guidelines for the best reliability of reworked BGA devices.

Background
There are currently two methods used for the rework (removal and replacement) of BGAs. One method uses solder paste the other uses liquid flux or paste flux.

There has been much controversy over whether BGA solder joint reliability is better when processed with solder paste versus paste flux. Some studies[1,2] indicate that the solder joint shape may have a greater impact on the solder joint reliability than the volume. There are still some claims[1] that greater solder volumes (given the correct solder joint geometries) result in greater solder joint strengths and greater reliability, however, the additional amount of solder volume provided by the solder paste at a typical paste print thickness is usually minimal compared to the volume of solder provided by the eutectic solder balls and has little effect on the joint characteristics.

Another question is whether the use of solder paste can improve the yield of the BGA rework process when compared to the use of flux only. Coplanarity can be critical during the rework process. Many things can affect the coplanarity. If the BGA has solder balls that are not coplanar it can result in a "open connection" (a ball that has not contacted and wetted the land while surrounding balls have made contact). Variations in surface finish height, warp of the board or area, and warp or bow of the device itself can create coplanarity problems. The use of solder paste may help to overcome variations in solder ball height. On newer technology PCBs, the utilization of drilled (usually laser) micro-vias in the center of the BGA land may require the use of solder paste to reduce voiding and to prevent loss of the solder ball volume as a result of filling the via.

Test vehicles
In an effort to reduce expenses and to simulate a very common BGA package, a Lead Free, daisy-chained, PBGA-256 was selected for the testing. The solder ball diameter for this device is 0.030", with a pitch of 1.27mm. The printed circuit board (PCB) used for the testing had a corresponding daisy-chained land pattern (see Figures 1 & 2) to allow for electrical testing once the BGA installation was complete. The boards were supplied in 8-up arrays to facilitate testing. 8 arrays (64 boards) were fabricated with 0.55mm diameter lands as an example of small lands. 8 arrays (64 boards) were fabricated with 0.84mm diameter lands as an example of large lands. The PCBs were fabricated from standard FR-4 laminate, 0.062" thick, with one ounce copper, and solder mask over bare copper (SMOBC) utilizing liquid photo-imagable (LPI) solder mask. The surface finish selected was immersion silver.

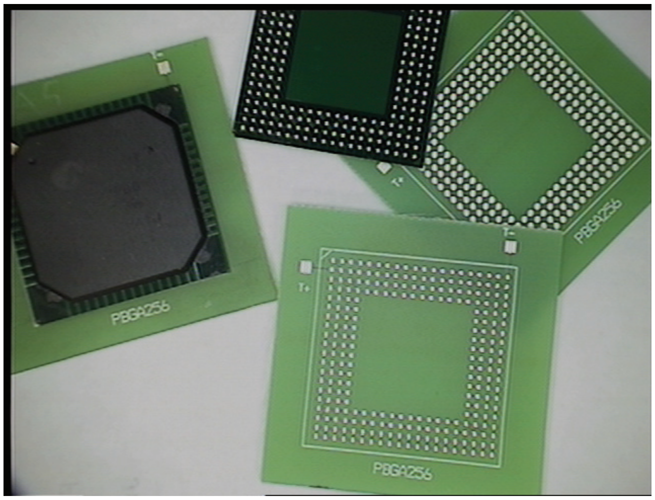

Figure 1 - Individual Boards and BGAs.

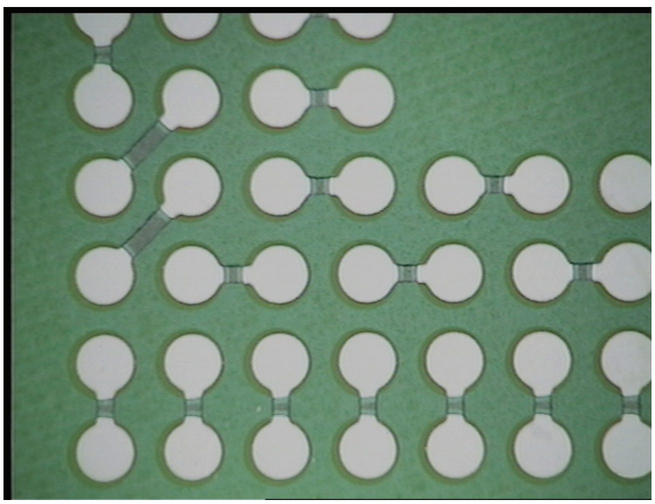

Figure 2 - Close up of Daisy-Chained Pattern on Boards.

Test Vehicle Preparation

Each individual board was labeled for identification (see figure 3). All the BGA land patterns on all the test vehicles had Lead Free (SAC-305) solder applied and then wicked off of the surface (see figure 4). This process would eliminate the variability's of selecting different surface finishes and also represent a BGA site that has already been paste printed or has had a BGA removed for replacement. It has the additional advantage of matching the solder paste (SAC-305) to the surface finish (SAC-305) to provide the best opportunity for wetting.

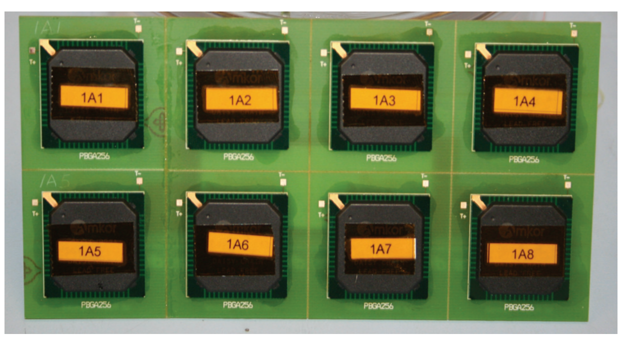

Figure 3 - Labeled Boards.

Lead free solder

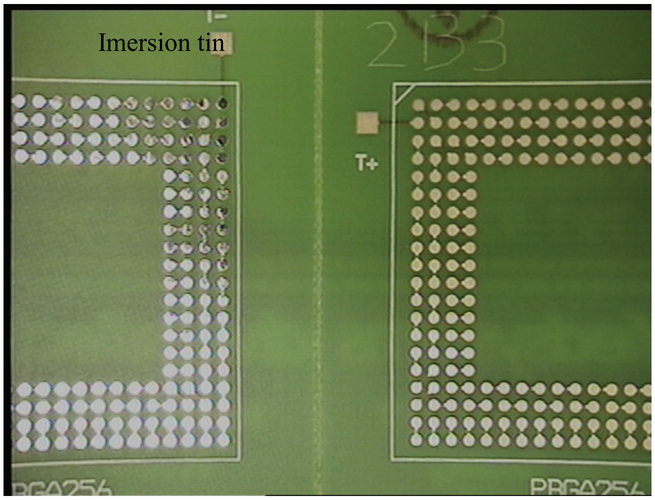

Figure 4 - Lead Free and immersion tin finishes.

Test Vehicle Production

Laser cut stainless steel stencils were used to print solder paste on two of the sets of boards (large and small lands). Two sets of boards (large and small lands) had a no-clean paste flux manually applied. The stencils were 0.008" thick and the apertures were cut 1-1 for the two different land diameters. The solder paste was a SAC-305 alloy no clean. After the solder paste was printed on the boards, the BGAs were placed using automated placement equipment. The entire array was then processed through a convection reflow oven with a peak temperature of 240°C. After reflow, the boards were X-Rayed, visually inspected, and electrically tested for continuity through the daisy-chained pattern.

During test vehicle production, it was noted that the first pass yield for paste printed BGAs was 100%, while the first pass yield for flux only BGA attach was 87.5%.

Testing

Testing was accomplished in a thermal chamber (see figure 5) with ambient humidity. The parameters were -25°C to 125°C with a 30 minute dwell at both extremes and 30 minute ramps.

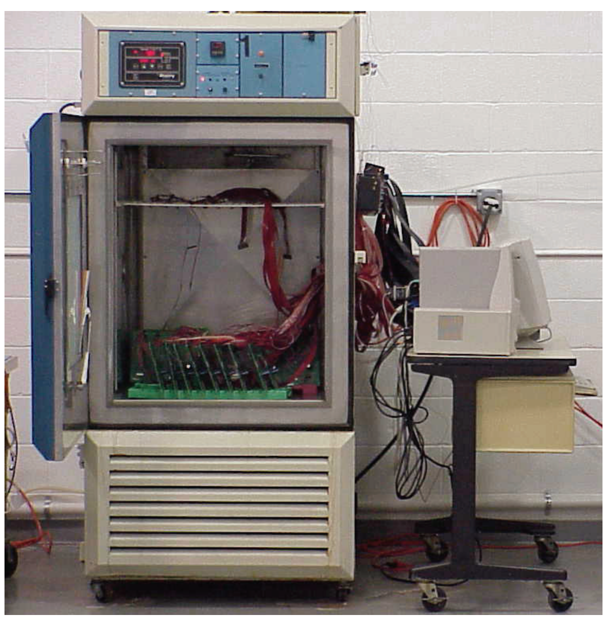

Figure 5 - Test Chamber.

Test results

The samples have completed 672 cycles. To this point there have been no failures out of any of the groups tested. Testing will continue to at least 1,000 cycles in an attempt to create failures.

Conclusion

With 672 cycles completed without any failures, it appears that variations in the dimensions of the BGA lands will have no detrimental effect for a variety of processing methods in normal environments. Paste flux and solder paste have both performed well with the exception of first pass yield.

Summary

While additional testing is ongoing, the preliminary results indicate that, with the exception of high reliability assemblies, variations in the diameter of BGA lands will have little to no effect on the long term reliability of the assemblies and the use of paste flux instead of solder paste performed equally well. First pass yield was improved when paste printing instead of flux only attachment.