BGA Reballing Reliability

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已有很多有关混合合金焊点的可靠性的文章发表，主要重点放在BGA装置上。乍看起_，这些BGA装置上的混合合金焊点看来有可以接受的焊点强度及可靠性，但工序要求对回流工艺和温度曲线有更大的控制。因此，很多制造商以含铅锡球对无铅BGA进行锡球重整，并未更改工序即加工组件。本文回答有关经重整锡球的装置的可靠性问题，特别是装置焊盘铜溶解及额外热循环对芯片/封装的影响。

A study of multiple reball processes looks at copper dissolution and functionality.

There are many differences in the alignment and placement of balls for reattachment. Yet to ensure a good metallurgical and mechanical attachment, the common element for all reballing methods is the need to reflow solder balls while aligned on the BGA lands.

Most questions concerning BGA reballing process reliability focus on two specific areas: First, the physical or mechanical strength and reliability of the ball attach to the device. (Of course, it is desired that the physical characteristics of the replaced solder ball be the same or very similar to the original solder ball.) Second, the effect on additional heat cycles (necessary for the reballing process) on the device itself. It is generally understood that exposure to reflow temperatures can degrade many materials used in various steps of electronics manufacturing. While BGAs come in many different configurations, many are packaged in some type of plastic. These plastics can be affected by increased exposure to thermal heat cycles or excessive temperatures. Many vendors specifically warn against reballing, even informing users that using a reball process will void the device warranty. One other area of concern is the effect reballing – solder ball removal and device land preparation, in particular – will have on the device lands. Thanks to Pb-free soldering, users are now aware of the aggressive nature of high-tin-content solders on other metals. If dissolution of the copper device lands is occurring, what effect will that have on the overall reliability of the device and ball attach?

Testing Process

The testing process includes reballing PBGAs (plastic ball grid arrays) and subjecting them to various tests. The BGAs were received from the vendor with Pb-free solder balls and then reballed using Pb-free solder balls. Cross-sections were performed to evaluate the grain structure and intermetallics formation of the devices before and after reballing, as well as the potential effect of copper dissolution of the device lands. Functional tests were performed on the devices before and after processing to determine if any failures could be attributed to the rework process, and in particular, the additional thermal cycles.

Process step 1: ball removal. Two common methods are used for removing solder balls from BGA devices. One uses a handheld soldering iron, a “wicking” tip, and wicking braid. The other method uses a flowing solder pot to remove the solder balls.

The manual method usually starts with the application of a high viscosity flux (paste flux or “sticky” flux) to the solder balls or residual solder (if removed from a PCB) of the device. The technician can then quickly move the wicking tip across the device, permitting the bulk of the solder to be wicked onto the tip for removal (**Figure 1**).

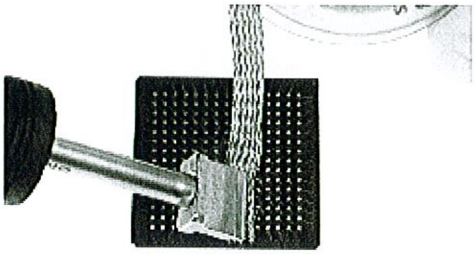

Figure 1. Manual solder removal.

After the bulk solder removal has been completed, the technician can then reapply paste flux and use wicking braid with the soldering iron to remove all remaining solder residue. The advantage of this method is that because it can be accomplished relatively quickly, there is little time for the heat to transfer to the die and cause thermal degradation. The disadvantage is that it is considered a contact desoldering method, and depending on the integrity of the device materials and technician's skill, may result in damage to the solder resist or lands on the device.

The dynamic or automated method uses a flowing solder pot to "melt" and flow away the solder balls (**Figure 2**). This is considered a noncontact desoldering method. Nothing, besides molten solder, touches the bottom of the device. This means there is virtually no chance of lifting a land on the device or damaging the solder mask. One disadvantage is solder remaining on the device lands will now be "crowned" as a result of the surface tension of the solder (**Figures 3** and **4**). This may affect the reballing process because of the additional variability of the height of solder on the lands. There are also questions about the effect the flowing solder bath may have on the device lands because of copper dissolution of the device lands.

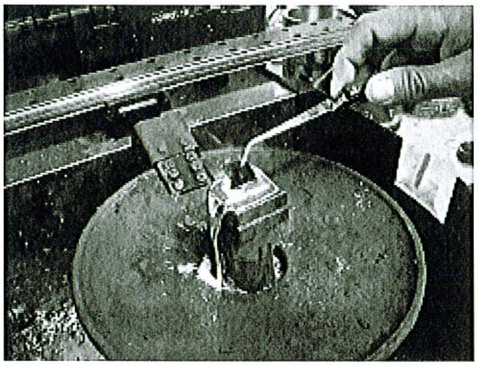

Figure 2. Flowing solder pot ball removal.

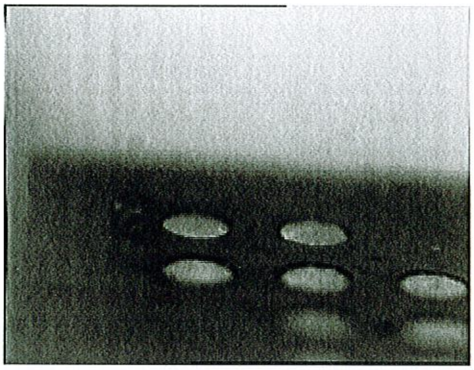

Figure 3. Land flatness with wicking.

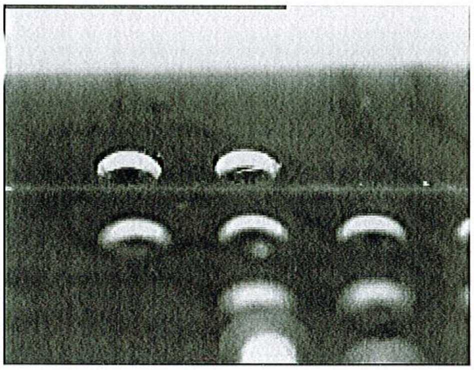

Figure 4. Land flatness with flowing solder pot.

Process step 2: reballing. BGAs reballing was performed using EZReball preforms. After all residual solder was removed from the device lands, a thin layer of water-soluble paste flux was applied. The preforms were aligned with the BGAs and placed on a piece of ceramic substrate. This is then processed through a reflow oven using an appropriate thermal profile for the solder ball alloy. After the BGA is removed from the oven and cooled, the polyimide portion of the preform is peeled from the device, leaving the solder balls soldered in place on the BGA. In most cases when using solder preforms, there are some inconsistencies in ball shape and location. This usually requires an application of flux to the BGA and an additional reflow cycle through the reflow oven. After this secondary reflow, the BGAs are then cleaned and inspected.

Process step 3: placement. The reballed BGAs are then placed and reflowed on the test platforms. These test platforms permit the BGA to undergo full functional test (**Figure 5**).

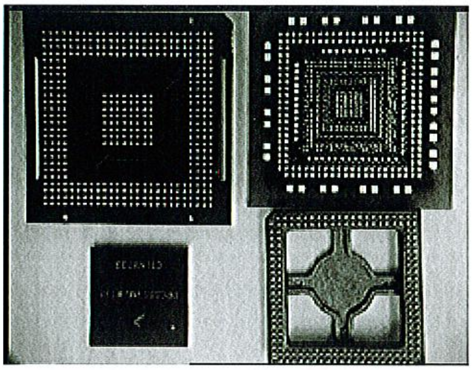

Figure 5. Individual pieces of test vehicle.

Process Steps – Thermal Summary

BGAs that were removed, reballed and replaced had been exposed to the following thermal excursions:

- Full reflow for initial placement.
- Full reflow for removal.
- Limited thermal exposure during solder removal.
- Full reflow for ball attach.
- Full reflow for ball irregularities.
- Full reflow for rework placement.

This reveals that, in most cases, a reballed device will have seen five complete thermal profiles. Four additional reflow cycles would be encountered for any subsequent reball attempts (**Figure 6**).

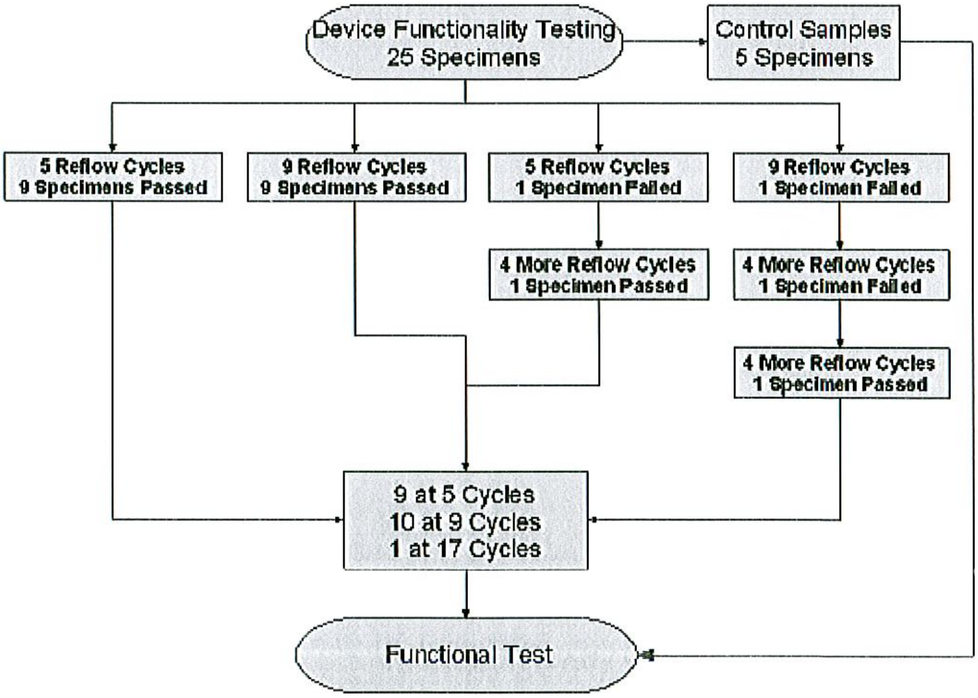

Figure 6. Reflow cycles and testing process flow.

Copper dissolution evaluation. Ten specimens were prepared for evaluation of copper dissolution during the ball removal process. One specimen was used as a control sample. This control sample was exactly as received from the vendor. Group A consisted of three specimens prepared with a flowing SnPb solder pot. Group B was three specimens prepared using a Pb-free flowing solder pot. For both Group A and Group B, one BGA was subjected to the solder bath once; one BGA was subjected to the solder bath twice, and one BGA was subjected to the solder bath three times. It was thought that any differences would be more pronounced after multiple cycles in the molten solder. Group C was three specimens prepared using a soldering iron with a blade tip and wicking braid.

For the ball removal evaluation, cross-section analysis was performed on the test specimens. The area of focus was the copper lands of the BGA. The control sample revealed a copper thickness of approximately 13 µm and a nickel thickness of 7 µm. Groups A, B and C revealed no significant changes in the metal thickness measurements, regardless of the number of solder bath exposures and wicking operations. It was hypothesized the nickel layer acted as an effective barrier against the aggressive nature of the Pb-free solder (**Figures 7** and **8**).

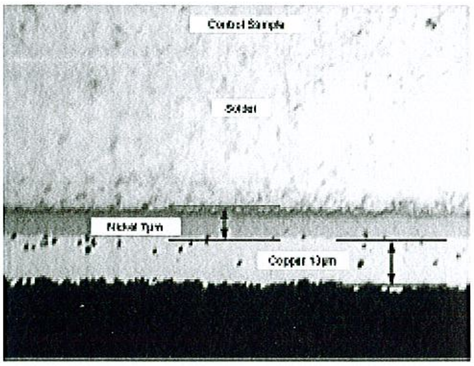

Figure 7. Cross-section of control sample.

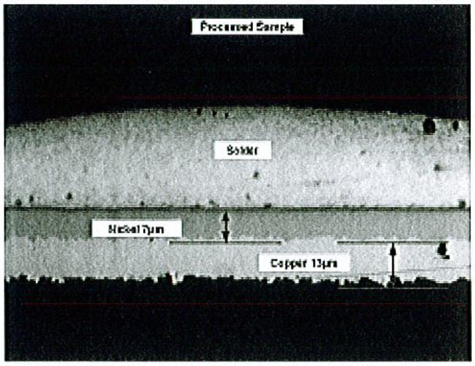

Figure 8. Cross-section of sample processed through flowing solder pot.

Ball removal thermal effects. In addition to the cross-section review of copper dissolution, a thermocouple was embedded in the die area of the BGA to observe the internal temperatures during wicking or exposure to the solder baths. As expected, a manual operation using wicking braid and a soldering iron provided reduced thermal exposure to the device when compared to a flowing solder bath. Using an iron and tip, the tip is quickly moved across the surface of the device limiting the time and contact area. Of course, a solder bath has a much greater capacity for heating and in higher temperatures for longer durations (**Figures 9** and **10**).

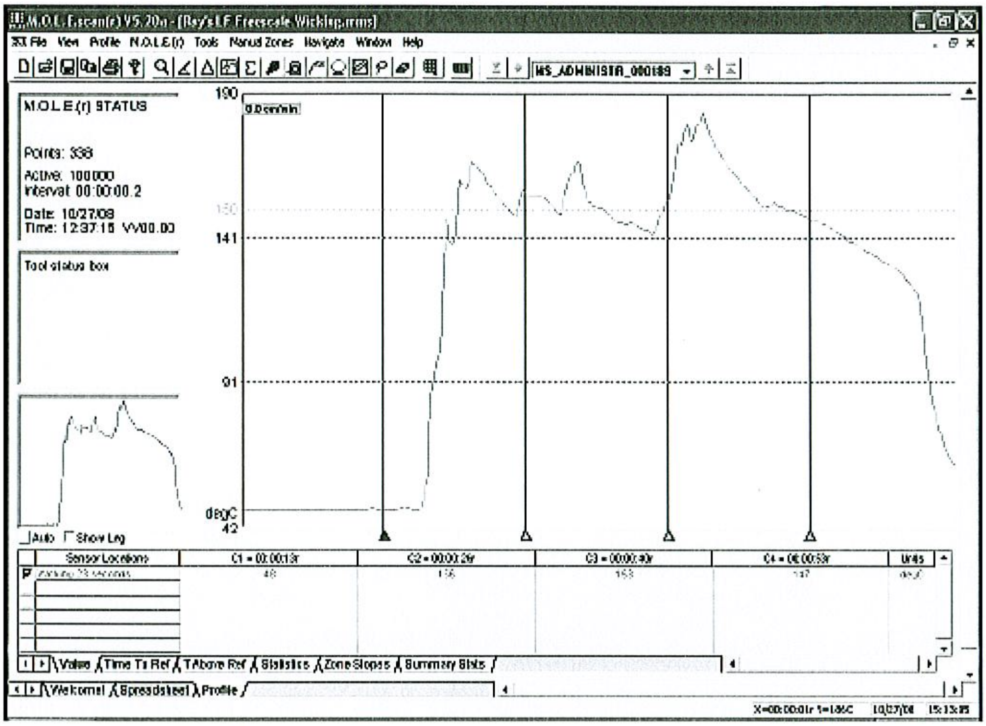

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Figure 9. Thermal profile of ball removal with flowing solder pot.

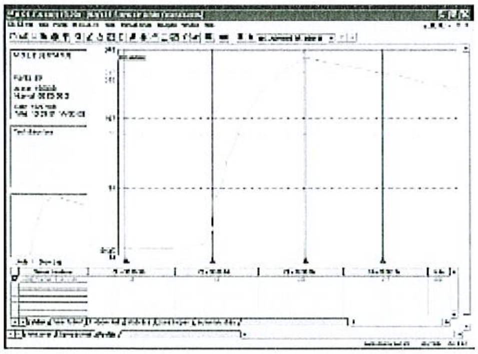

Figure 10. Thermal profile of manual ball removal with wicking braid.

Device functionality. After the process steps were completed, the test specimens were sent to the vendor for full functional testing. Five control samples were not reballed; 10 samples were reballed once (five heat cycles), and 10 samples were reballed twice (nine heat cycles). Electrical testing included base loopback, top loopback, memory, flash, script and SRAM. The 10 single reball samples had one failure, and the double reball samples had one failure. The failed samples were removed, reballed and replaced, and then passed all tests. One of these samples was subjected to 17 thermal cycles and still passed.

Conclusions

During the solder ball removal process, the manual method using wicking braid resulted in the BGA

being subjected to fewer thermal stresses than would be encountered with a flowing solder bath method.
It was expected there would be significant copper dissolution when using a Pb-free flowing solder bath to remove the solder balls. However, the robust nickel layer on these particular devices appeared a very effective barrier, preventing solder from leaching the copper from the device lands.

All devices passed all electrical tests after numerous thermal cycles.

While the results of this testing shine a positive light on the reballing process, it must be remembered this was a test of one particular device from one particular vendor. Should these results drive requests of BGA suppliers for waivers to the three-reflow cycle limitation on its warranties? Doubtful. It should, however, provide the confidence to proceed with reballing plans expecting the physical attributes of the device to be unaffected.

Acknowledgments

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