Reliability of BGA Solder Joints after Re-Balling Process

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Abstract
Due to the obsolescence of SnPb BGA components, electronics manufacturers that use SnPb solder paste either have to use lead-free BGAs and adjust the reflow process or re-ball these components with SnPb balls. The reliability of Lead-Free and Lead-Containing solder joints for BGA's has been investigated after re-balling using optimal microscopy. The goal was to compare the quality of the connections for both options. For the lead-free BGA, voids produced by the release of volatile species in flux during soldering were present. Large voids have been observed at the interface component/solder. Using components that were re-balled did not show the amount of voiding observed for the lead-free BGA. Kirkendall voiding has been observed for the lead-free component at the component/solder interface. It has been therefore concluded that the use of the reballed components is to be preferred to adjusting the reflow profile and using lead-free components.

Introduction
The use of lead containing solders for low temperature soldering in electronics has been commonplace for many decades. Due to the toxicity of lead the use of lead in electronic manufacturing has been regulated in Europe by RoHS.[i, ii] Eutectic SnPb solders have primarily been replaced by Sn, Ag and Cu (SAC) based solders at or close to eutectic composition, mainly because of its wetting ability and low melting point.[iii]

The reliability of these SAC solder connections has not been proven to such an extent to satisfy the requirements in place for critical application, such as aviation, aerospace, military and medical industries. These industries therefore are still exempt from the RoHS regulations and continue to use SnPb solders for the production of electronics. The use of SAC solders for the consumer electronics on one hand and SnPb solders for exempted industries on the other brings on its own issues.

One issue is the obsolescence of components compatible with a SnPb soldering process, due to the bulk of the electronic producing industry requiring lead-free compatible components. This causes component manufacturers to quit the production of SnPb compatible products because of economical reasons. In particular Ball Grid Arrays (BGA) can be affected as this could lead to the forced mixing of SAC and SnPb as the balls of the BGA are lead-free while the solder paste used is a SnPb variant. It has been shown[iv] that this leads to products that are not able to withstand the necessary life cycling test as stresses arise from different thermal expansion coefficients of the SAC balls and SnPb solder. This leads to cracking of the connection. The stresses might be avoided by either of two processes. First process is to re-ball BGA's with SnPb balls if the only version of a BGA component is lead free. Second process was to ensure complete mixture of the SAC BGA and SnPb solder by adjusting peak temperature and dwelling time. Both processes have their advantages and drawbacks.

The re-balling process leads to additional process steps, which could have a detrimental effect on reliability. It requires two additional heat processes and could lead to the extra growth of the brittle intermetallic layer between component and solder ball. Next to that because the original finish layer applied for better wettability such Au or Ag was dissolved in the old ball and therefore removed during de-balling. It will no longer protect the surface to oxidation and can decrease wetting properties for the new ball. The third issue comes from the application of flux used for re-balling, which could give rise to more and larger voids. The fourth aspect lies in the extra costs occurring due to the extra process steps. The main advantage is that if re-balling is done properly and the quality of the BGA is maintained, the remainder of the soldering process would stay the same and the quality of the connection could be assumed to be as good with original SnPb BGA components.

Adjusting peak temperature and dwelling time to ensure complete mixture of the SAC BGA and SnPb solder paste during reflowing leads to a solder connection which has different mechanical behavior compared to a eutectic SnPb solder connection. The different reflow profile could also lead to more oxidation and cause the problems commonly associated with oxidation during soldering. The adjusted profile could also lead to a thicker intermetallic layer. The main advantage is the relative ease and low cost of this process. It only involves a minimal adjustment of the reflow process.

The goal of the research reported in this work was to investigate the quality of re-balled BGA components compared to the connections produced with an adjusted reflow process. This was done by means of metallographic research.

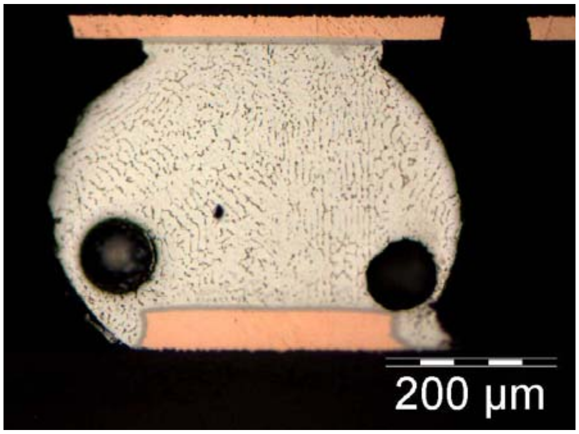
Experimental

Two similar BGA components have been investigated. The first sample consisted of a BGA with a SAC solder ball and was connected to a PCB using SnPb solder paste. The second sample consisted of a SAC BGA which was re-balled with SnPb balls and was connected to a similar PCB using SnPb solder paste. The original SAC solder balls were removed using flux and a desoldering device. The new SnPb balls were attached by a reflow process in air using a reballing mask and BGA holder.

The reflow process used to connect the first sample was adjusted to ensure complete mixture of the SAC BGA and SnPb solder paste. Both samples have been subjected to metallographic analyses by means of optical microscopy. The samples were cut along the line shown in Figure 1 using a low speed diamond saw and embedded in Technovit 5000. The embedded components were coarsely grinded with sandpaper and fine polished with a diamond suspension (0.25 μm particles). After polishing the microstructure has been investigated by optical microscopy. The microstructural analysis has been done with an Olympus BX-41 light microscope. For both samples eight solder connections have been investigated. For each connection the thickness of both intermetallic layers at boundaries was measured at two different points.

Figure 1 The BGA component with the red dotted line indicating the cross section area.

Results and Discussion



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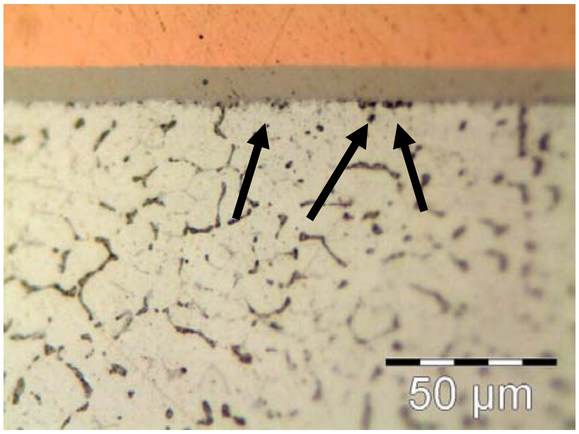

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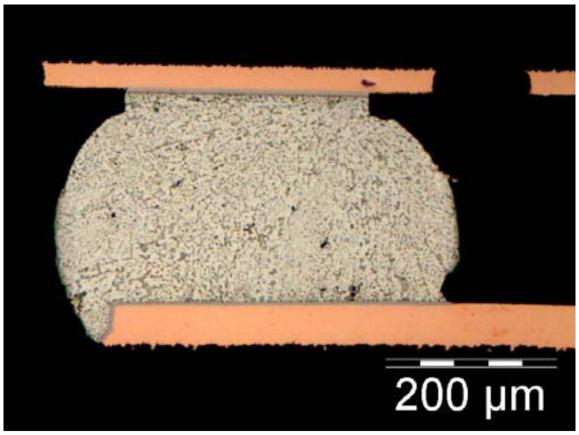
Figure 2 a) Cross section of a BGA component with SAC ball and SnPb solder paste; b) the enlargment of the component at the component solder interface. As indicated by the arrows Kirkendall voids can be found along the interface.

As can be seen in Figure 2, the solder connection was a thoroughly mixed solder connection with no visible distinction between the original SnPb solder and SAC BGA. The microstructure consists of Sn particles with the Pb phases dispersed along the grain boundaries of the Sn particles. This is a consequence of the relatively Sn rich lead-free SAC mixing with eutectic SnPb. Due to the too high Sn concentration during cooling down at first Sn particles will solidify and grow until eutectic temperature is reached. The liquid phase will then solidify in two phases to form a eutectic matrix between the already present Sn particles. Kirdendall voiding has been observed at the solder component interface, which is caused by different diffusion rates of Sn and Ni. For six out of eight investigated solder balls large voids were observed. This could be due to the adjusted refow profile in combination with the use of the SAC BGA, both of which are associated with voiding. The thickness of the intermetallic layer is between 0.8 and 1.5 micrometer for the component/solder interface and between 1.1 and 2.7 micrometer for PCB/solder interface.



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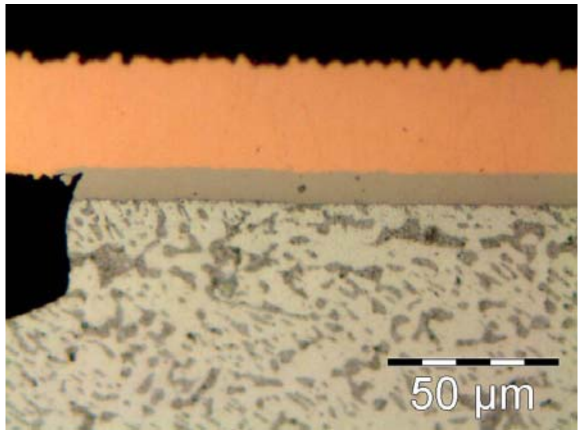

b)

Figure 3 Cross section of a BGA component with SnPb ball and SnPb solder paste; b) the enlargment of the component at the component solder interface.

As can be seen in Figure 3 the solder connection is a thoroughly mixed solder connection. The microsturcture is typical for a eutectic SnPb solder connection. No large voids have been observed for either of the investigated solder connection. The thickness of the intermetallic layer is between 0.6 and 1.1 micrometer for the component/solder interface and between 1.3 and 3.6 micrometer for PCB/solder interface.

The difference between samples concerning the thickness of the intermetallic layer at each sides is very slight an is within acceptable degrees. The difference in voiding behaviour could be explained as a combination of factors. First of all SAC solders have more and larger voids in general. The higher process temperatures could lead to more oxidation, which could cause more voiding. The connections of the re-balled component are of a better quality than the connections of the SAC BGA, as these do not show the large voids and Kirkendall voiding observed for the mixed connection.

Conclusions

The reliability of a SAC ball/SnPb solder BGA connection has been investigated and compared with the reliability of a re-balled SnPb ball/SnPb solder BGA connection.

- Large voids are observed for the mixed connection
- Kirkendall voids are present at the component/solder interface of the mixed connection
- A thoroughly mixed connection was achieved for the mixed connection (i.e. there was no visible distinction between a SAC region and SnPb region of the solder connection)
- The thickness of intermetallic layer between solder and component is comparable for both samples
- The thickness of intermetallic layer between solder and PCB is comparable for both samples
- The re-balled sample was of good quality

It can therefore be concluded that re-balling lead-free BGAs with SnPb balls, if done properly, should yield better quality connections than soldering lead-free BGAs with SnPb solder paste.

References

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