

A Study of Lead-Free BGA Backward Compatibility Through Solderability Testing at Component Level

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Abstract

A study was conducted to assess the backward compatibility of two different lead-free BGA components using Jedec Solderability testing method (JESD22-B102D). The test was conducted at component level. The two components tested were 29x29mm Thermally Enhanced PBGA (TePBGA-II) and 35x35mm Tape BGA (TBGA) with SAC387 and Sn3.5Ag solder balls. Four units from each of the two component types were used to prepare the profiling pallet. These pallets were used to obtain a Low Solderability Profile and a High Solderability Profile to encompass the low and high end of the reflow profile according to Jedec SnPb Solderability Test Conditions. The sample size used in the final solderability testing study was 15 units for each component and solder ball alloy type. Prior to solderability reflow, all the 15 units per cell were subjected to 8hrs of steamaging and followed by 1hr baking at 100 degree C. This is followed by solderability testing which includes SnPb paste printing onto ceramic plates using stencil with the component's arrays. Next, components were placed on the solder paste array using Fine Placer machine. And the components were reflowed in the Low and High SnPb Solderability Profile which were obtained earlier for each of the two component types. Finally, components will be detached from ceramic plate by force. Inspection will be done on the solder balls on the component as well as on the ceramic plate. The passing criteria are based on Jedec Solderability standard which includes no satellite balls or paste remaining on the ceramic plate after reflow. The solderability testing result showed that all the two BGA component types passed without any solderability failure with both the Low and High SnPb Solderability Profiles. This result showed that backward compatibility is NOT an issue for lead-free BGA components with SAC387 and Sn3.5Ag solder balls from solderability point of view.

Key words: IC packaging, lead-free, SMT assembly, backward compatibility, solderability

1. Introduction

In the recent years, lead-free solder material have been increasingly applied to the green semiconductor products for RoHS compliance. One of the main lead-free transition issues at SMT assembly is backward compatibility. This refers to SnPb soldering with lead-free components. Such issue is especially real for most of the storage array systems, network infrastructure equipment for switching, transmission, signaling as well as network

management for telecommunication products. This is because these products are exempted from lead-free by the RoHS directive, hence there is no urgency for these products to be converted from SnPb soldering to lead-free soldering. However, since the electronics industry is transitioning to lead-free, some of the necessary SnPb components may have been converted into lead-free, and therefore the backward compatibility issue arises.

Backward compatibility is one of the intriguing topics under discussion in the industry. The industry

is moving towards the elimination of Pb, using lead-free alloys for the BGA balls. However, Sn-Pb soldering still exists during the transition period and beyond, as several product categories may take advantage of the exemptions. The compatibility of lead-free ball with Sn-Pb soldering process is very much questionable. This is primarily due to the fact that different melting point between lead-free alloy and Sn-Pb solder, where the SAC alloy melting temperature is 217°C will not always completely melt during reflow with the Sn-Pb solder. One of the concerns is poor interfacial bonding and increased voids are some of the other issues which have been observed leading to poor solder interconnect reliability, which, in combination with the process issues, render the lead-free area array packages 'incompatible' with the Sn-Pb soldering process.[1]

Based on these considerations, a study was conducted to assess the backward compatibility of two different lead-free BGA components using Jedec Solderability testing method. Solderability is a measure of how easily a component generates a good solder joint with the board after SMT assembly reflows. Solderability is a property of the component under the soldering conditions. A solderability test may therefore assist the component maker in identifying the root cause of the failure of the solder joint before the component reaches the end customer.

The test was conducted at component level. The two components tested were 29x29mm Thermally Enhanced PBGA (TePBGA-II) and 35x35mm Tape BGA (TBGA) with SAC387 and Sn3.5Ag solder balls. Four units from each of the two component types were used to prepare the profiling pallet. These pallets were used to obtain a Low Solderability Profile and a High Solderability Profile to encompass the low and high end of the reflow profile according to Jedec SnPb Solderability Test Conditions. The sample size used in the final solderability testing study was 15 units for each component and solder ball alloy type. Prior to solderability reflow, all the 15 units per cell were subjected to 8hrs of steamaging and followed by 1hr baking at 100 degree C. This is followed by solderability testing which includes SnPb paste printing onto ceramic plates using stencil with the component's arrays. Next, components were placed on the solder paste array using Fine Placer machine. And the components were reflowed in the Low and High SnPb Solderability Profile which were obtained earlier for each of the two component types. Finally, components will be detached from ceramic plate by force. Inspection will be done on the solder balls on the component as well as on the ceramic plate. The passing criteria are based on Jedec Solderability standard which includes no satellite balls or paste

remaining on the ceramic plate after reflow. The solderability testing result showed that all the two BGA component types passed without any solderability failure with both the Low and High SnPb Solderability Profiles. This result showed that backward compatibility is NOT an issue for lead-free BGA components with SAC387 and Sn3.5Ag solder balls from solderability point of view.

2. Study Design

This study comprises 4 parts:

1. Preparation of profiling pallets.
2. Preparation of four types of reflow profile according to Jedec Solderability Test Conditions.
3. Preparation of samples with steamaging condition
4. Performing solderability test.

3. Subjects and Methods

3.1. Subjects

In this study, 2 test vehicles were selected, with one for each package type, namely Thermally Enhanced PBGA (TePBGA-II) which has a heat spreader exposed on the package top surface, and Tape BGA (TBGA) which has a copper interposer. The package size was chosen to represent the worst case of each package type. Test vehicle details are shown on Table 1 & 2.

Table 1. TePBGA-II test vehicle

Package Type	TePBGA-II
Ball Count	620
Package Size	29x29mm
Ball Pitch	1.00mm
Ball Size	0.60mm
Solder Mask Opening Diameter	0.50mm
Solder Ball Alloy	SAC387 and Sn3.5Ag

Table 2. TBGA test vehicle

Package Type	TBGA
Ball Count	672
Package Size	35x35mm

Ball Pitch	1.00mm
Ball Size	0.66mm
Solder Mask Opening Diameter	0.45mm
Solder Ball Alloy	SAC387 and Sn3.5Ag

3.2 Methods

3.2.1 Preparation of profiling pallets

Four units from each of the two component types were used to prepare the profiling pallet. The units were placed on the center of ceramic plate with thermal couple (TC) wire secured between the unit and the ceramic plate, where the TC wire was cured with epoxy. Figure 1 displays the profiling pallet and TC wire arrangement used in the study.

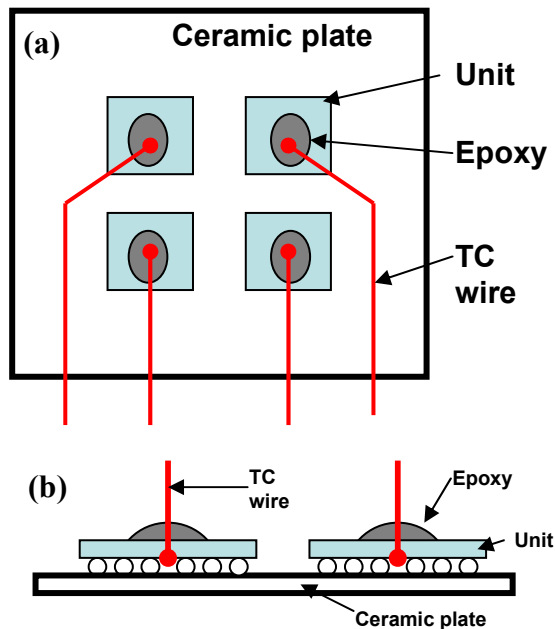


Figure 1. (a) Top view of profiling pallet; (b) Side view of profiling pallet.

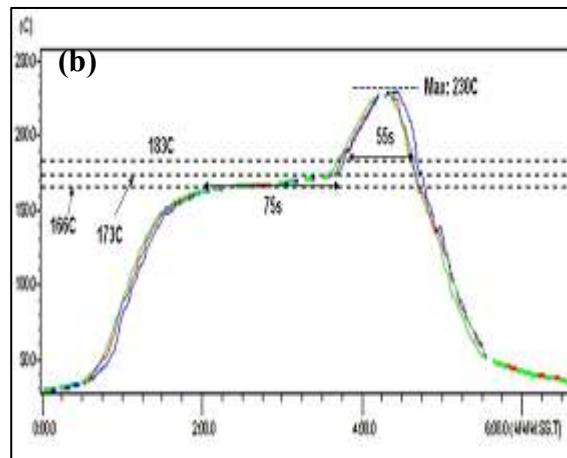
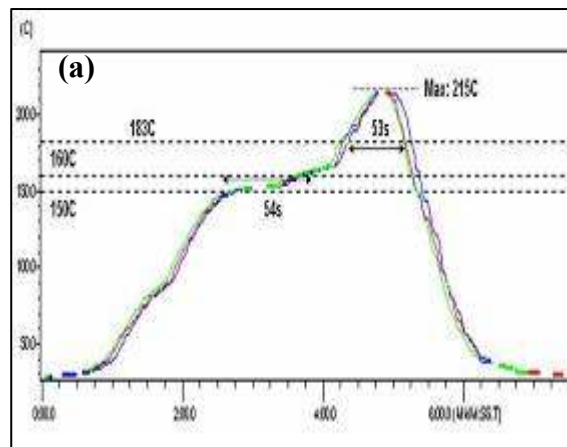
3.2.2. Preparation of solderability test reflow profile

These pallets were used to obtain a Low SnPb Solderability Profile and a High SnPb Solderability Profile to encompass the low and high end of the reflow profile according to Jedec SnPb Solderability Test Conditions. Reflow Oven used for Solderability Test is a 5-zone convection oven with Compressed Dry Air. Two types of solderability reflow profile were prepared based on the

requirement in Table 3. Figure 2 & 3 display the Low SnPb Solderability Profile and a High SnPb Solderability Profile for 29x29mm TePBGA-II and 35x35mm TBGA.

Table 3. Low SnPb Solderability Profile and High SnPb Solderability Profile Requirement

Solderability Test Requirement	
A) SnPb Paste: Low Profile	
Peak Reflow Temperature :	215°C
Reflow Time (TAL):	50 sec
Pre-Heat(Activation) Temperature:	160°C
Rre-Heat(Activation) Time :	50 sec
B) SnPb Paste: High Profile	
Peak Reflow Temperature :	230°C
Reflow Time (TAL):	50 sec
Pre-Heat(Activation) Temperature:	170°C
Rre-Heat(Activation) Time :	70 sec



**Figure 2. 29x29mm TePBGA-II
(a) Low SnPb Solderability Profile
(b) High SnPb Solderability Profile.**

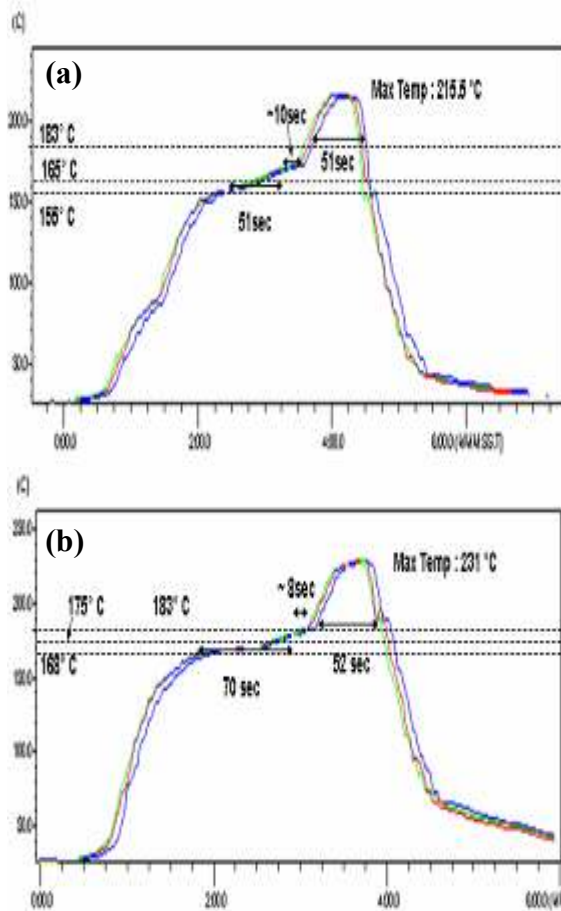


Figure 3: 35x35mm TBGA
(a) Low SnPb Solderability Profile
(b) High SnPb Solderability Profile.

3.2.3. Preparation of solderability test samples

The sample size used in the final solderability testing was 15 units for each component type and solder ball alloy type. Prior to solderability testing, all the 15 units per cell were subjected to 8hrs of steamaging and followed by 1hr baking at 100 degree C per Jedec Solderability standard. Steam aging will partially oxidize the solderball to simulate actual component application under adverse environmental condition. Solderability after steam aging is a stringent way to test the solder ball wettability on PCB. Figure 4 displays the steamaging equipment.

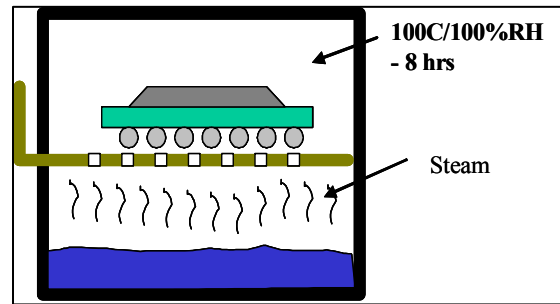


Figure 4. Steamaging equipment.

3.2.4. Solderability test

After samples preparation through steamaging process, solderability test is performed which involved the following 4 steps:

1. SnPb paste printing onto the ceramic plates using stencil with the component's array. Each stencil has the array of each component, and each printing will give 4 printed arrays, hence each ceramic plate will contain 4 components.
2. Placement of the components on the solder paste array using Fine Placer machine.
3. Reflowing the components through the 5-zone convection oven with the Low and High SnPb Solderability Profile which were obtained earlier for each of the two component types.
4. After reflow, components will be detached from ceramic plate by force. Inspection will be done on the solder balls on the component as well as on the ceramic plate. The passing criteria are based on Jedec Solderability standard which includes no satellite balls or paste remaining on the ceramic plate after reflow.

Figure 5 and 6 illustrate the steps of solderability test procedures. Upon inspection, the reject criteria applied per Jedec standard are satellite ball (Figure 7) and solder remains on ceramic plate (Figure 8) which both indicated poor solder wettability.



Figure 5. Solder paste printing procedures

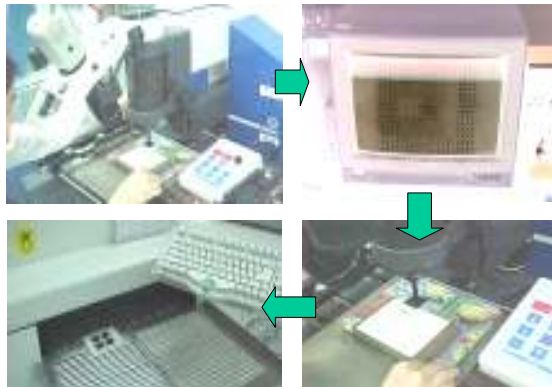


Figure 6. Component placement procedures



Figure 7. Solderability test failure mode: satellite ball

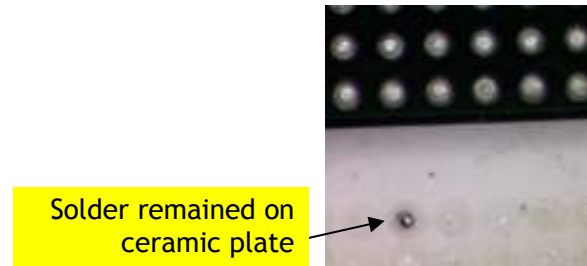


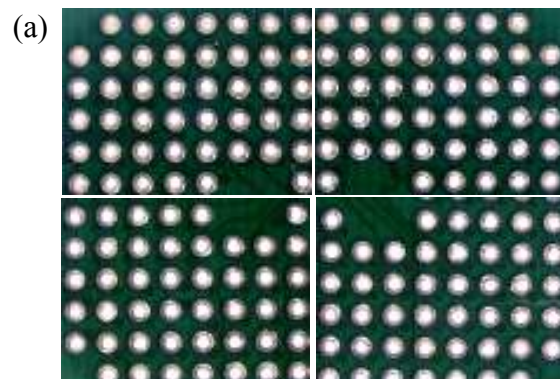
Figure 8. Solderability test failure mode: solder remained on ceramic plate

4. Results and Discussion

All package types with Sn3.5Ag and SAC387 solder sphere passed the Solderability test. Table 4 and figure 9 to 12 display the solderability result for 29x29mm TePBGA-II and 35x35mm TBGA samples after steamaging. No satellite ball or solder remained on ceramic plate.

Table 4. Low SnPb Solderability Profile and High SnPb Solderability Profile test result for each lot and solder sphere type.

Solderability Test Result			
Package	Condition	Solder ball Type	
		Sn3.5Ag	SAC387
29x29 TePBGA-II	SnPb-Low Profile	0/15	0/15
	SnPb-High Profile	0/15	0/15
35x35 TBGA	SnPb-Low Profile	0/15	0/15
	SnPb-High Profile	0/15	0/15



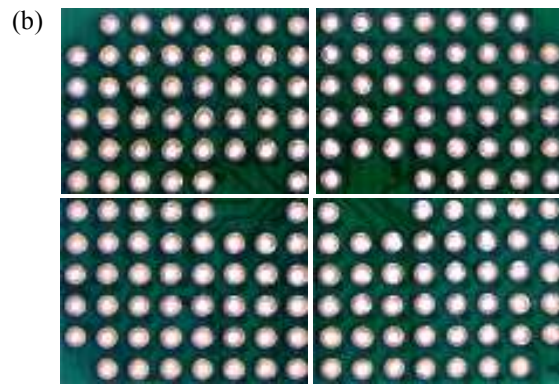


Figure 9. 29x29mm TePBGA-II with SAC387
(a) Low SnPb Solderability profile result
(b) High SnPb Solderability profile result.

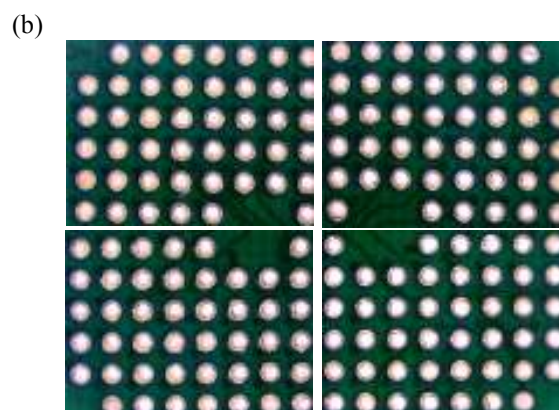
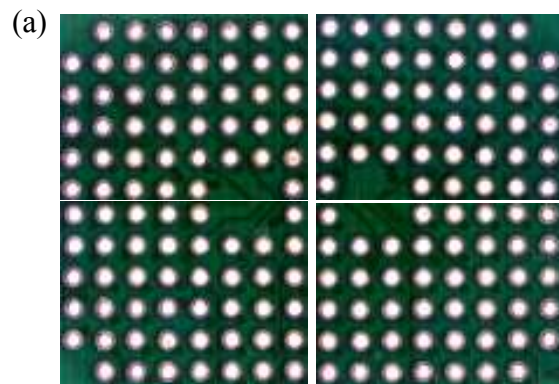
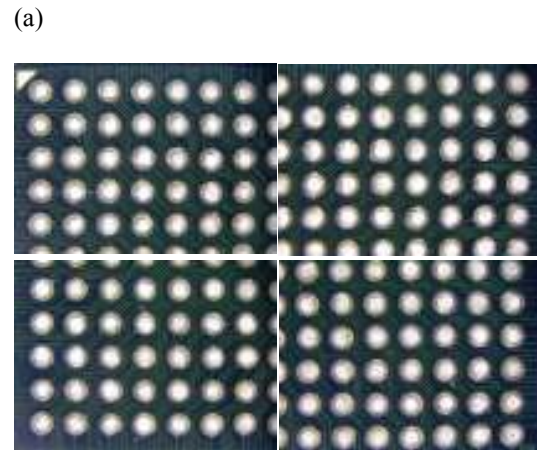


Figure 10. 29x29mm TePBGA-II with Sn3.5Ag
(a) Low SnPb Solderability profile result
(b) High SnPb Solderability profile result.

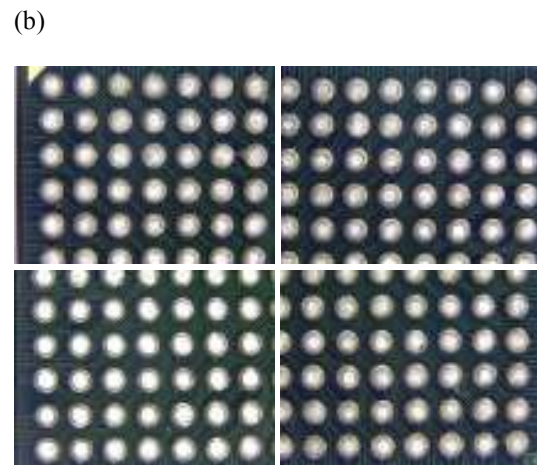
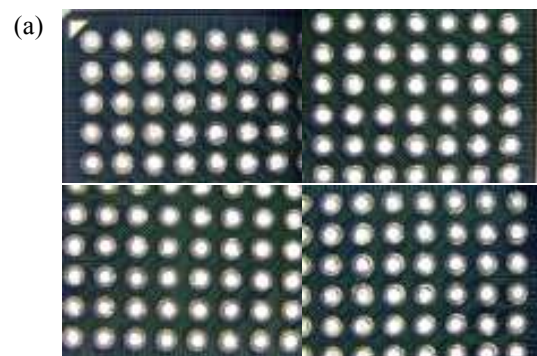


Figure 11. 35x35mm TBGA with SAC387
(a) Low SnPb Solderability profile result
(b) High SnPb Solderability profile result.



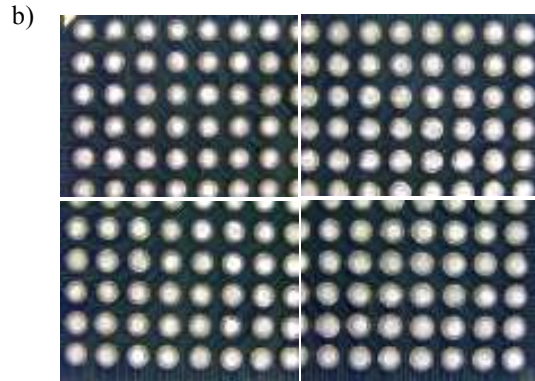


Figure 12. 35x35mm TBGA with Sn3.5Ag
(a) Low SnPb Solderability profile result
(b) High SnPb Solderability profile result.

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Conclusions

From the result of this study, it can be concluded that all the two BGA component types passed Jedec Solderability Test without any solderability failure even with both the Low and High SnPb Solderability Profiles. This result showed that backward compatibility is NOT an issue for lead-free BGA components with SAC387 and Sn3.5Ag solder balls from solderability point of view.

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