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Qualification of Thin Form Factor PWBs for Handset Assembly

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Abstract:

The handheld wireless product market place demands products that are small, thin, low-cost and lightweight and improved user interfaces. In addition, the convergence of handheld wireless phones with palmtop computers and Internet appliances is accelerating the need for functional circuits designed with smallest, low-cost technologies.

The miniaturization of portable electronics and Mobile handsets is resulting in thin form factor cell phones, camera modules and Bluetooth packages. The consumer appeal for sleek phones is driving the need for thin PWB roadmaps for the handset. [1]

Qualification of thin PWBs (less than 0.8mm) require careful evaluation of PWB stackup for warpage, delamination and successful lead free reflow and rework. The paper presents the qualification testing of thin PWBs for warpage characteristics. X-sectional analysis, shear testing, thermal shock, temp. Humidity testing and drop test for long-term reliability.

Introduction

High volume SMT assembly production requires careful evaluation of suppliers for critical commodities like PWBs as SMT assembly yields heavily depend on good quality PWBs, solder paste print processes and oven reflow profiles. This has become more critical in lead free reflow due to higher peak reflow temp. And narrow process windows. Proper processing thru reflow, storage, handling controls in the in the production process are necessary for good yields and reliability.

This paper presents the efforts directed in evaluating PWB suppliers and working jointly with contract manufacturer for successful assembly.

PWB Evaluation

The PWBs were procured from different suppliers and evaluated for flatness, warpage and reflow.

Warpage

Warpage characterization is important in understanding PWB and interconnect reliability. The current designs for portable products use multiple packaging formats and advanced substrates that demand tight mechanical tolerances. A typical Cellphone assembly has over 400 –500 components in various formats and material sets and assemblers are faced with the challenge of balancing the soldering profiles and yields.

The IPC spec 6012 acceptance criteria for bow and twist is 0.75% max. Most suppliers follow this specification and check for warpage on finished product, however there are some exceptions.
Some suppliers use their internal spec to meet the Bow &Twist acceptance criteria. One such criterion is for board with diagonal length across opposite corners not exceeding 200mm, bow and twist is set as ±1.0mm. For diagonal board length exceeding 200mm, the tolerance falls within 0.5% of its diagonal board length. e.g. For a PWB diagonal length of 212.9mm the Bow and twist is ±1. 06mm.

Total PWB Thickness:

This is a critical requirement as PWB thickness in some cases becomes a part of the overall tolerance stackup of the end product and most plastics etc. are procured using the PWB nominal thickness as a baseline. Per IPC 6012, currently the tolerance is +/-10%, however as we migrate to thin form factor PWBs, this tolerance needs to be tightened to +/- 7-8%
The preferred tolerances are:
Board thickness>0.8mm,+-10% tolerance
0.4mm<board thickness<=0.8mm, +-0.075mm min.tolerance
Board thickness<=0.4mm, +-0.05mm min. tolerance

Coplanarity Measurements using Thermoire system:

PWB flatness and war page characterization is important as it can contribute to lower yields and reliability problems. Warpage of PWB can result in misregistration of components, solder paste bridging and opens,

Cracked solder joints and line down situations. The warpage characteristics of a laminate have great significance in the soldering of BGAs as thermo mechanical deformations during reflow can impact the robustness of the assembly .[2]

PWB Coplanarity measurements were done using a Thermoire system to understand the warpage characteristics during temperature changes from room temp. to 260C. Measurements were conducted at six different temperatures 26C, 180C, 210C, 260C and then cool down to 200C and 26C. 3D Surface plots were done to assess +ve or –ve warpage and understand the impact of thermally induced warpage during reflow. The coplanarity results are summarized in Table 1.

Table 1 – Coplanarity Measurements for Hi Tg Laminate PWB (Supplier A)

Sample 1	Temperature	Coplanarity (Microns)	Sample 1	Temperature	Coplanarity (Microns)
Side A			**Side B**		
	26C Initial	556		26C Initial	618
	180C-Heat	2033		180C-Heat	2160
	210C-Heat	1543		210C-Heat	1237
	260C- Max	1275		260C- Max	752
	200C-Cool	686		200C-Cool	532
	26C-Final	559		26C-Final	527

The coplanarity changes were the highest at 180C, but the material recovered to its original state upon cool down. The higher impact at 180C, instead of 260 C was a concern for localized heat application for rework processes. However, the coplanarity changes were consistent for Side A and Side B.

The PWBs from another supplier (B) were evaluated for coplanarity measurements using both
High Tg (170C) and Tg (150C) laminates. There was a concern with using mid Tg material

The coplanarity analysis was conducted on both High Tg and mid Tg laminate on another set of PWBs. Based on the analysis results there was not a significant difference between the Hi and mid Tg laminate for warpage.

Table 2 – Coplanarity Measurements for Hi Tg and Mid Tg Laminate PWB (Supplier B)

Sample 1	Temperature	Coplanarity (Microns)	Sample 2	Temperature	Coplanarity (Microns)
Hi Tg			**Mid Tg**		
	26C Initial	357		26C Initial	380
	180C-Heat	423		180C-Heat	471
	210C-Heat	485		210C-Heat	558
	260C- Max	738		260C- Max	724
	200C-Cool	647		200C-Cool	471
	26C-Final	563		26C-Final	383

The coplanarity analysis was conducted to understand the differences in behavior of the High and mid Tg material during the reflow process. The highest coplanarity change was seen at 260C unlike the PWBs from supplier (A) that showed the maximum change at 180C. Moreover, both High and Mid Tg substrate material showed similar behavior during the heat cycle and peak, but the high Tg remained less coplanar at cool down. This analysis was done to make the cost tradeoffs between High and Mid Tg material. In this case, mid Tg material was chosen for lead free reflow.

Additionally, 3D Plots were conducted to understand the type and location of the warpage. This is as critical as understanding the magnitude of the warpage. Figure 1 and Figure 2 show the displacement at room temperature and 260C.

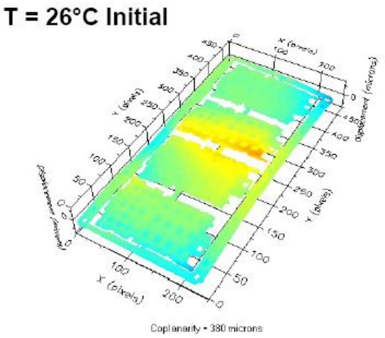

Figure 1 -Room Temp. Coplanarity

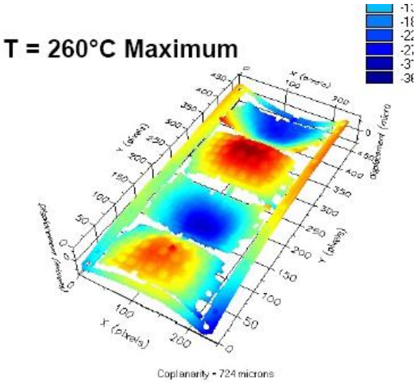

Figure 2. 260C – Coplanarity

Product Qualification

The board assembly process was a double-sided surface mount assembly soldering of ball grid array packages, connectors, chip resistors, capacitors, and diodes etc. The assembly was reflowed in convection air at a peak temperature of 243C. The solder paste used for assembly was Tin/Silver/Copper) – SAC 305 - No clean version. [3].

X-sections were performed on the BGA packages and other components to evaluate the quality of the solder joints and ensure compliance to IPC 610 – Rev D for leaded packages and IPC 7095 for BGA packages. Also microvia integrity was evaluated with X-sectional analysis. The initial proto build X-sections showed some cracking of the BGA corner pins post reflow. But after optimization of the reflow profile solder joints were acceptable and there was no degradation of microvias. [4, 5].

The qualification process was conducted using product build for a phone program and conducting X-sectional analysis, shear test and reliability testing per IPC 9701. Temp. Humidity test was conducted at 85C/85% Relative Humidity for 500 hours and Thermal Shock testing was conducted from –25C to +125 C - 20 min. dwell for 500 Cycles. Solder joints were inspected using IPC 610D [3] specification and BGA solder joints were evaluated using IPC 7095B.[4]. Figure 3 shows X-sections of the BGA package post reflow showing cracks at the board/solder ball interface.

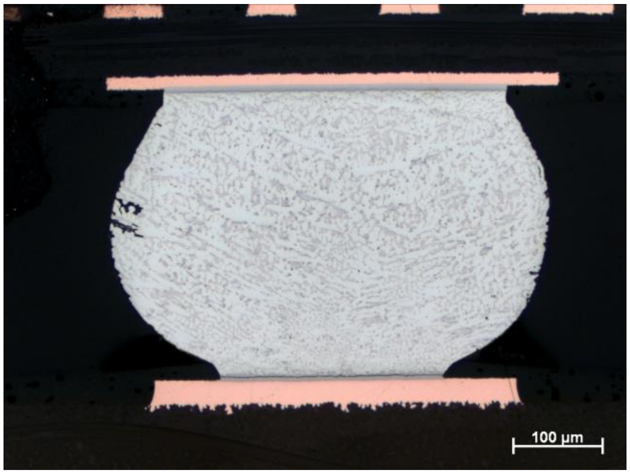

Figure 3 BGA Package Cracks at PWB /Ball interface

SEM/EDX Analysis was conducted to understand these cracks. Figure 4 shows the cracks seen in SEM.

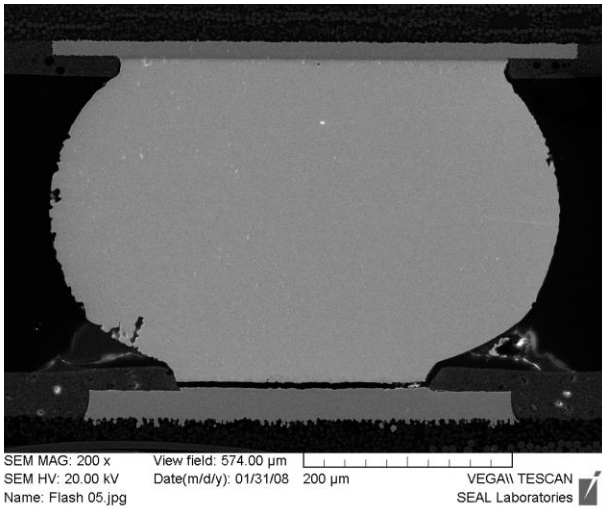

Figure 4 BGA crack in SEM Analysis

Several process items were optimized to address this issue, including pad diameter, paste volume and reflow profile. The cracking issue was resolved after these changes and the shear values improved from 17-18 lbs to 30- 35 lbs, which is typical of this BGA package.

Rework Process

Rework evaluation is essential prior to releasing high volume product for manufacturing as uncontrolled rework can cause damage to PWB and result in large scrap costs. SMT packages were reworked using hot air soldering tools and BGA packages were reworked with hot air tools using a controlled ramp/soak profile. The intent was to assess damage to BGA pads, Soldermask and microvia connections. Component rework was performed 2X on the SMT packages and 1X on the BGA packages. There was no bridging or damage to PWB pads, or microvias post rework. Figure 5 and 6 show the X-Rays of BGA packages post rework.

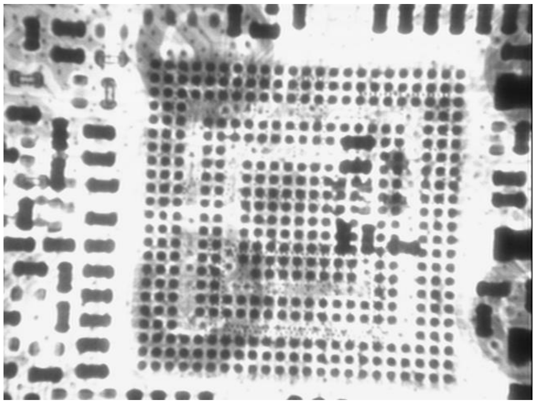

Figure 5 BGA X-Ray Post Rework

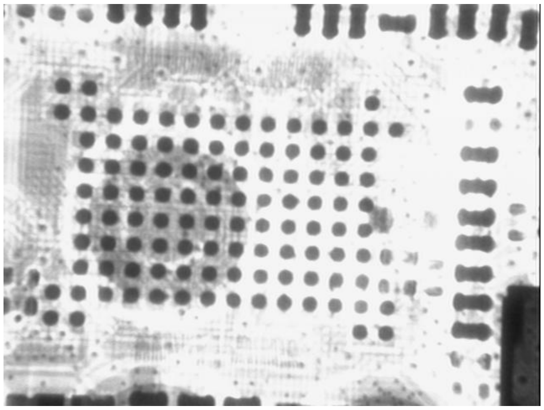

Figure 6 BGA X-Ray Post Rework

Reliability Testing

Assembly qualification requires thermal shock testing at –25C to +125C for 500 cycles and temperature and humidity testing at 85C /85% RH for 500 hours depending on product application and use conditions. This is defined in IPC9701 [5] for qualification of Surface Mount Solder joints. Also, maximum package warpage of BGAs is governed by JEDEC spec JESD22B112. [6]. It is essential to have a good understanding of package and PWB warpage to address failures resulting after Thermal shock testing.

The thermal Shock test showed some issues with BGA cracks in the early proto builds, but after optimization of the reflow process this cracking was minimized. Some ceramic packages showed cracking due to CTE mismatch between package and PWB, but no cracking was seen in the plastic packages. Figure 7 and Figure 8 show the X-sections of BGAs post thermal shock. No cracks were observed in the microvias to capture pad interfaces as showing the images.
No failures or shorts or corrosion/migration was seen during Temperature and humidity test.

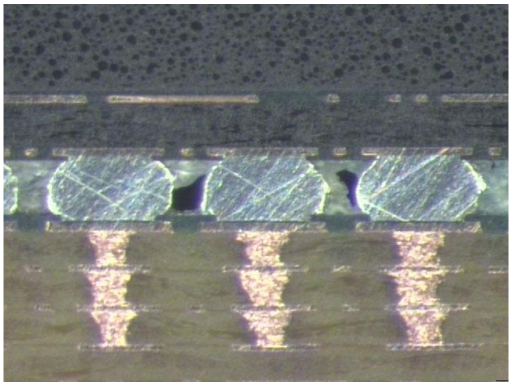

Figure 7- BGA – Post Thermal Shock.

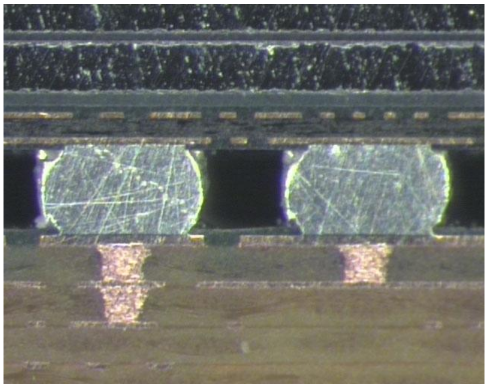

Figure 8- BGA/Microvia Post Thermal Shock.

Drop Test:

Drop testing is a common mechanical reliability test for portable products. Phones are dropped at different faces and angles from a certain height and inspected for internal and external damage to plastics, lenses, LCDs, solder joints , components etc.. Phone level drop test was conducted on these assemblies and post drop inspection was conducted. No solder joint cracks were seen in the plastic BGA packages. PWBs microvia connections were also intact post drop.

Conclusion:

Thin form factor PWBs can be successfully assembled and used in portable products. Proper understanding of the warpage characteristics of the PWBs and packages is essential for a reliable assembly. For success in assembly yields, correct thermo coupling of the PWB and critical packages for both sides A and B reflow is required. The concerns with damaged and misregistered components and cracked interconnects can be addressed by fully characterizing device and substrate warpage behavior prior to production and help reduce in-process defects related to adverse mechanical behaviors.

References

1. Microvias for low cost, high density interconnect .John H. Lau, S.W.Ricky Lee
2. Advanced Warpage Characterization – P. B. Hassell
3. IPC A-610D Acceptability of Electronic assemblies
4. IPC 7095 Design and assembly Process Implementation for BGAs
5. IPC 9701 Performance Test Methods and Qualification Requirements of Surface Mount Soldered Assemblies.
6. JESD22B112 - High Temperature Package Warpage Measurement Methodology