TECHtips

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Electronics Manufacturing Insights from ACI Technologies, Inc.

Investigation of PCB Failure after SMT Manufacturing Process

An ACI Technologies customer inquired regarding printed circuit board (PCB) failures that were becoming increasingly prevalent after the SMT (surface mount technology) manufacturing process. The failures were detected by electrical testing, but were undetermined as to the location and specific devices causing the failures. The failures were suspected to be caused predominately in the BGA (ball grid array) devices located on specific sites on this 16 layer construction. Information that was provided on the nature of the failures (i.e., opens or shorts) included high resistance shorts that were occurring in those specified areas. The surface finish was a eutectic HASL (hot air solder leveling) and the solder paste used was a water soluble Sn/Pb (tin/lead).

The diagnostic approach that followed included an examination of both the quality of the manufacturing process and the materials used for assembly.

- SMT Process - determine any obvious manufacturing issues
- Reflow Profile - assess the profiling techniques to assure proper application of recommended parameters
- Bare Board Inspection - look for unusual surface anomalies
- XRF (X-Ray Fluorescence) Analysis - determine correct solder and pad metallurgy
- X-Ray Analysis - proper placement of components, opens or shorts
- Endoscopic Analysis - assess proper BGA collapse
- Wetting Balance - determine acceptable soldering surfaces

1. SMT Process

The first order of diagnostics involved a manufacturing audit that was conducted to assess the SMT process which revealed the following:

- The solder paste was properly stored and allowed to reach ambient conditions prior to usage. The solder mesh was appropriate for the type of assembly, and the dates of the paste were not expired.
- The stencils used for the application of the paste were properly proportioned with an aperture size appropriate to the BGA device pitch.
- The stencil printing operation revealed no flaws and the paste was applied in a smooth consistent manner with uniform height and width.
- The paste reflowed uniformly and covered leads as per IPC-A-610 class 3 specifications. No apparent skips or de-wetting was noticed on resistors, capacitors, or leaded chip devices.
- The reflow oven is a four zone construction and short oven length, but no issues around reflow quality was seen as a result. The recommendation was made to increase to a seven zone oven for an increase in flexibility in profiling for various designs.

2. Reflow Profile

The reflow profile was in the specified range for the solder paste of choice (ALPHA WS-809 water soluble paste). The placement of the thermocouples was in appropriate locations, and the temperature uniformity among each location reflected an even distribution of heat. The time above liquidus (TAL) varied by only six seconds between the highest and lowest time, while the peak temperature varied by 13 degrees among locations. There was no evidence of hot or cold spots.

The assembly TAL averaged 90 seconds; well within the allowable TAL ranges of 40-120 seconds recommended by the vendor. Since reflow was clearly achieved and there was no evidence of cold solder joints, a recommended step was to decrease the TAL from 90 to 60 seconds, which would improve wetting without a risk of incomplete solder reflow.

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However, the present reflow profile is consistent with the recommended parameters prescribed by the solder paste vendor.

3. Bare Board Inspection

A visual assessment of the bare boards showed evidence of:

- solder mask overlap into the pad areas
- exposed copper (Cu) under the HASL surface finish
- non-uniform HASL finish in certain cases (Figure 1)

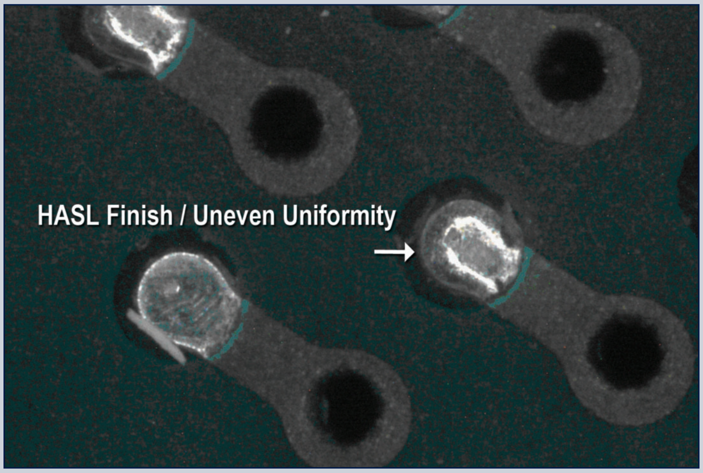

Figure 1: Non-uniform HASL finish.

4a. XRF Inspection

The BGA devices and the bare board were analyzed using x-ray fluorescence (XRF) to determine the alloy composition of the metal. This is a common method used when the composition of the component alloy or surface finish is in question. The results are shown in Tables 1 and 2.

Component	Area	Sn (%)	Pb (%)
1	1	68.01	31.99
1	2	68.51	31.49
1	3	66.13	33.87
2	1	68.25	31.75
2	2	67.47	32.53
2	3	68.32	31.68
3	1	69.65	30.35
3	2	69.76	30.24
3	3	72.11	27.89
4	1	65.82	34.18
4	2	65.99	34.01
4	3	64.27	35.73

Table 1: XRF Data - Components.

Bd Area	Sn (%)	Pb (%)	Cu (%)
1	7.77	15.02	92.75
2	39.70	35.46	24.84
3	0.0	0.0	100.0

Table 2: XRF Data - Surface of PCB Board.

4b. XRF Summary

Components indicate a eutectic or near eutectic Sn/Pb composition.

The analysis of the HASL board finish indicated a non-uniform thickness, and at certain locations, the finish was thin enough to allow the underlying copper to overwhelm the alloy analysis.

5. X-Ray Analysis

X-ray analysis was performed on a populated board at the various BGA locations that were suspected as problematic. No evidence of shorting opens or misalignment was prevalent.

6. Optical Endoscope

The populated assembly was analyzed through an endoscope to see any evidence of incomplete collapse or other observable phenomena such as de-wetting or head and pillow effect. No unusual occurrences such as excessive solder or flux residue were visible. However, the graininess of the solder balls may indicate the start of an oxidizing surface. This can be due to excessive time in liquidus state. The solder balls seem to be well collapsed and formed.

7. Wetting Balance Test

The wetting balance test showed significant issues with the wettability of the HASL board at various locations (Figure 2 on next page). Criteria from IPC J-STD-003 suggest time to buoyancy corrected zero, T_0 (where the wetting force goes positive), should be less than 1-2 seconds. In every sample tested, T_0 was greater than 5 seconds.

Conclusions and Recommendations

The HASL surface finish is non-uniform, with exposure of copper and very thin layers of HASL in some areas.

The wettability of the HASL board is well below the recommended wetting criteria as specified by the IPC specifications and can be a primary concern during assembly. Residual oxides on the surface of the HASL may prevent proper wetting, or form weak intermetallic interfaces when reflowed. The type and amount of oxide residue can be ascertained through SERA (Sequential Electrochemical Reduction Analysis).

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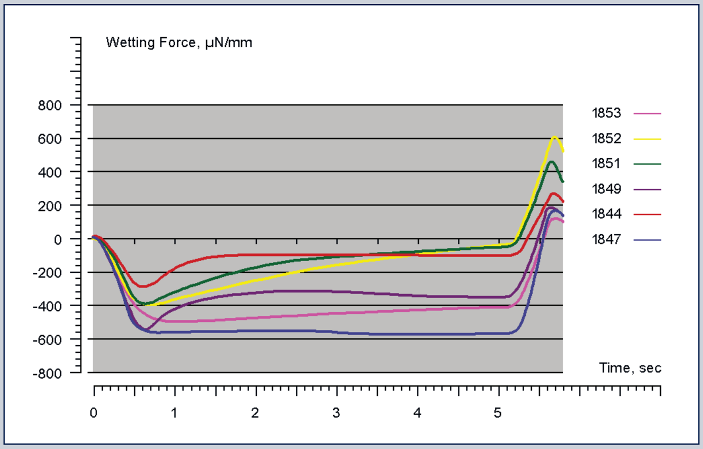

Figure 2: Wetting balance curves showing T_0 >5 seconds.

The x-ray images showed no evidence of poor alignments, opens or shorts.

Optical endoscope images showed no anomalies and good BGA ball collapse.

ENIG (Electroless Nickel Immersion Gold) should be considered as a board surface finish instead of HASL, if available. It is the most common finish for BGAs, and would eliminate the non-uniform surface finish.

Application of a more uniform HASL surface will assure complete coverage of the underlying pad and will alleviate the exposure of the underlying copper, while reducing the risk of oxidation.

The HASL bath should be analyzed to determine if contamination exists from excessive metals and other residuals from the soldering process.

Reducing the liquidus time by 30 seconds may help alleviate excessive formation of oxides on the solder.

A seven zone oven will allow more flexibility in shaping the reflow profile around a varied array of designs and constructions.

Lessons Learned

Thoroughness can be vindicating and enlightening.

The results of the analysis indicated that, though certain process and manufacturing improvements can be made to reduce both systematic and randomized failures, examination of the raw materials (for example, the PCB) can prevent a significant amount of manufacturing defects from occurring.

In this particular case (which is not atypical), a thorough investigation provided the engineer enough data to support the claim that the cause of electrical failure was due to non-compliancy in the surface finish which caused de-wets. Establishing documented proof of failure can exonerate the manufacturing process, and prevent excessive and unnecessary expenses.

There is a natural inclination to avoid impugning an established process that has, for the most part, produced a successful product. However, the temptation to maintain status quo should be avoided if the potential to reduce manufacturing failures exists. Most issues arise when an interaction between non-centered processes result in a multiplicative effect. In this case, the effect of poor distribution of the HASL surface, along with a marginalized reflow process, combined to produce failures which may not have occurred if either of the conditions for HASL or reflow were optimized.

For electronics manufacturing assistance, contact the Helpline by phone at 610.362.1320 or via email to helpline@aciusa.org.

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