

Investigation on solder joint strength of nickel tin-plated and CRS tabs with PCB

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ABSTRACT Failure analysis on easily peels off Nickel and CRS steel tabs from PCB was carried out. Nickel Tin plated tabs, CRS steel tabs and tube were joined to the PCB using reflow/ convection soldering in an oven. The solder paste composition is Sn36/Pb35/Ag2. Peel test was conducted and it was found that many tabs could be easily peeled off with low force. Porosities which varies from 0.4 mm to < 0.01mm in diameter, developed during soldering process and solidification was noted. It was found, the number, size and position of these porosities inside the solder layer on both parts of the tabs affect the peel strength. Scanning Electron Microscopy study and EDX analysis were carried out. It was found that the low peel strength values were due to the combination of generation and development of porosities during soldering process which act as stress concentrators and the evolution (growth) of eutectic Sn/Pb and SnNi/Cu brittle grainy phase. Large eutectic microstructure with brittle Sn-Ni-Cu grainy phase enhances the failure with low peeling forces. Sample showing no feature of Sn/Ni/Cu grain gave high peeling strength value. Solder reflow, an important process, can result in strength enhancement (if it was controlled for example in a furnace).

(Failure analysis, SEM, EDX, Soldering, Peel strength)

INTRODUCTION

Soldering is primarily use to provide a convenient joint to ensure electrical contact or seal against leakages. The soldering process is where all the electrical connections between components leads and their corresponding PCB land areas are made. It is therefore very important that a consistently high quality of solder joint is made. The soldering process involves the application of molten solder and a flux material onto the board areas where the connections are to be made [1]. Tin plating on the components will provide a good solderability for electronic components. The best tin thickness is 0.05 mm. Tin is also non-toxic and has good corrosion resistance.

Tin Lead Plating (90% Sn, 10% Pb) is a coating of components. It is used for bearing function and plating is normally carried out at the room temperature up to 35°C. The plating aids soldering after the storage process and prevents the component surfaces from tarnishing and degradation. It is also good to replace tin plating

to prevent whisker generation. It can also increase the tensile strength of solder joints [2].

Undercoat is a layer between the plating and the base metal which is applied to prevent the atoms from the base metal from diffusing into the plating surface. This diffusion process will decrease the solderability of the components. Normally, Cu and Ni are principally used as undercoats. Copper undercoat has a good affinity and ductility. However, nickel on the other hand is a hard metal with low ductility.

In Electroless Nickel and Immersion Gold (EN/iG) PCB, electroless nickel metallization occurs after copper trace/feature definition (i.e. copper plate, image and etch operations). It can be applied before or after the soldermask application. It provides a conformal coating on all exposed copper surface. The finishes comprise approximately 5 microns of nickel with a very thin topcoat of gold. Soldering straight onto gold can cause brittle joint. Since the gold is so thin, the joint will require the nickel layer. This nickel layer will act as a barrier layer between the copper and the gold,

thus preventing any unwanted (unsolderable) intermetallic formation. Immersion Gold occurs after the electroless nickel process. It will provides a conformal coating on all exposed nickel surfaces. The combined nickel/gold metallization process provides an excellent corrosion resistance, solderability, pad coplanarity and shelf life. It is thus a good choice for fine-pitch and finer SMT and BGA technologies [3].

In organic solderability preservatives (OSP@Entek), the coatings are generally applied via immersion, spray or the flood mode. The coatings will be binded to copper and this will prevent humidity and high temperatures from degrading the solderability of the copper pad. OSP coatings can eliminate thermal shock whilst the Cu-Sn intermetallic layer will result in stronger joints. The application of an organic surface finish is easy to apply and cost effective. OSP may work well in some assembly processes that do not require extended shelf life prior to its assembly and is also not exposed to multiple fusing cycles. It is generally agreed that OSP coatings require special handling to retain its solderability over a period of time. For the assembler, OSP provide several benefits during its assembly process. One of the primary advantages is the access to flat PCB soldering pads. There is no rounded solder bumps on these pads. This will result in more accurate

solder paste deposition and component placement. A flat pad gives the assembler more control in depositing the solder paste and will also result in more complete transfer of the solder paste. However, Hot Air Solder Leveling (HASL) plating which consist of tin lead alloy will result in thickness within the range of 400 um.

The aim of this investigation is to apply failure analysis to these tabs/PCB joint and find out the root cause of failure at low peeling forces (low strength).

BACKGROUND INFORMATION/ TECHNICAL INFORMATION

Nickel 200 Tin-plated tabs and 1008CRS steel tabs, Figure 1, were joined to the PCB using re-flow/ convection at Sn36/Pb35/Ag2 whilst active together with the mild flux soldering paste into an oven. Figure 2 shows the soldering temperature profile during the re-flow. Peel test was carried out after soldering. It was observed that some of the sample test had low peel strength, peeling force ~ 0.9 kg (9 N). The total area of contacted tab ~ 8 mm². This gives lower peeling strength of 1.125 Nmm⁻². However, some 1008CRS tabs showed high value, ~ 8.45 Kg(84N) ~ 10.5 Nmm⁻² and are better than Ni200 tab.

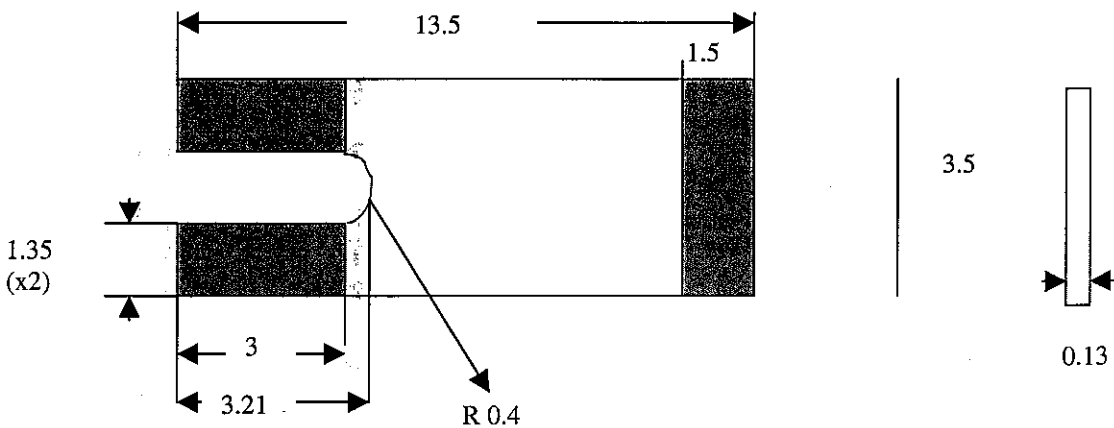


Figure 1. The specification of U tab Ni 200 Sn plated. The dimensions are in mm and the shaded areas are Sn plating.

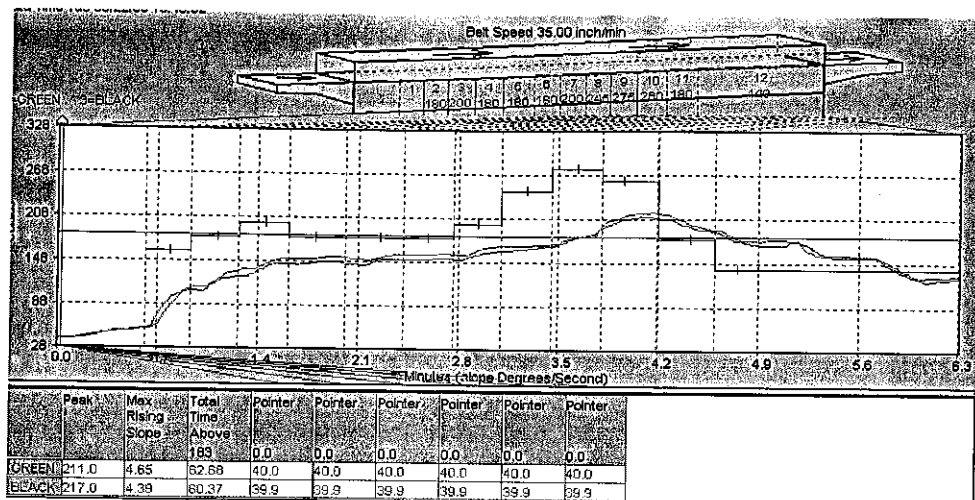


Figure 2. Soldering temperature profiles during the reflow

MATERIALS, BACKGROUND AND TECHNICAL INFORMATION

Twelve peel tested samples, ranging from low to high peeling strength, were analysed. Investigation revealed that the samples with longer exposure during reflows had detrimental effects, with active paste showing better peeling strength. There is no significant difference between one reflow and two times reflow. The PCB (OPS@Entek) and Tiger PCB (HASL)

showed no significant differences in peeling strength.

Initially, it was proposed that a full analysis comprising of failure investigation and non-destructive evaluation assessment should be carried out. Upon discussion, it was agreed that metallurgy investigation, SEM and EDX analyses for 12 different peel tested samples were to be carried out. Table 1 shows the details of the samples.

Table 1: Samples details.

| Sample | Bad No. | Tab No. | Peel force, N (Strength Nmm ⁻²) | Remarks: Total porosity and size range. (Furnace type) |
|----------------|---------|--------------|---|--|
| 1 (RO3) Ni200 | 61 | 122 Japan | 9 (1.125) | 31 (<0.075mm - 0.25mm)(Vitronics 6) 1 reflow |
| 2 (RO3) Ni200 | 281 | 562 Japan | 30.7 (3.84) | 18 (<0.05mm- 0.5mm)(BTU8) 1 reflow |
| 3 (RO2) Ni200 | 153 | 306 Japan | 16.5 (2.06) | 25 (<0.025mm-0.2mm)(BTU8) 1 reflow |
| 4 (RO3) Ni200 | 154 | 108 USA | 42.7 (5.34) | Failure through PCB. (Vitronics6) 1 reflow |
| 5 (RO2) Ni200 | 288 | 576 Japan | 47.1 (5.89) | Failure through PCB. (BTU8) |
| 5 (RO3) Ni200 | 158 | 315 USA | 45.7 (5.7) | Failure through PCB. (BTU8) 1 reflow |
| 7 and 8 | | | | No testing |
| 9 (1008CRS) | 76 | 378 USA | 72.1 (9.0) | 19 (<0.025mm-0.15mm) (BUT8) 1 reflow |
| 10 (RO6) Ni200 | 163 | 813 Japan | 73.8 (9.23) | 25 (<0.05mm-0.75mm) (BTU8) 2 reflow |
| 11 (RO6) Ni200 | 51 | 252 Japan | 6.3 (0.79) | 27 (<0.05mm-0.375mm)(Vitronics 6) 2 reflow |
| 12 (1008CRS) | 6 | 26 Japan | 11.7(1.46) | 37(<0.05mm-0.25mm) Vitronics 6) 1 reflow |

RESULTS AND DISCUSSION

The failure investigation comprised the following laboratory tests/examinations. Through visual examination and photographic documentation, SEM and EDX analysis as well as the metallurgical study were done and their respective assessments were subsequently carried out.

A failure assessment was also conducted based on the laboratory test/ examination results. Optical visual examination revealed that low strength trend will occur as the number of porosity increases, Figure 3. Wide range of porosity size was also noted. However, even with appreciated number of porosity, samples 9(1008CRS tab) and 10(RO6 Ni200), still have high peel strength. The location of porosities was randomly distributed with different sizes, (Figure 4). These porosities were probably generated due to the air entrapment during soldering and solidification process. In some cases the sample failed at low strength through copper/ PCB due to some defects in PCB, (samples 4, 5 and 6), during reflow and over heating causing detrimental effect in the polymer of the PCB. However, cold mounted cross section on one of these samples showed defects were produced during solder solidification as well, Figure 5. The location of porosities was randomly distributed with different sizes, Figure 4.

On the peel-out tab samples 1, 5 and 9 for Ni200 tabs and samples 10 and 12 for 1008CRS tabs were selected for metallurgical study and alloy elements analysis (using EDX). This selection is based on the observation that samples Ni200 tab (9) and 1008CRS tab (10) contain appreciable porosity which still show high peeling strength.

The structure of peeled sample 1 (tab Ni200) was observed under higher magnification in the vicinity of porosity/ fracture surface. It was noted that two type of microstructures were found. First, the porosity region showed eutectic Sn/Pb structure and second, fractured surface showed grain type microstructure, Figure 6. EDX analysis was also depicted in the figure.

It is believed that the structure in Figure 6c is responsible for the low strength because it showed typical brittle fracture. The growth of this brittle phase may happened either during

solidification process or from the temperature profile of melting of the solder paste which is not enough to combine the solder paste with Sn which is already available on the tab.

As a comparison, samples 9 (tab 1008CRS) and 10 (tab Ni200), which showed high strength was observed under high magnification. Figure 7 shows no brittle feature near the porosity fracture interface as shown in Sample 9, Figure 7a. Longitudinal grain structure at the porosity / fracture face of sample 10 was also noted and this become less pronounced in porosity, 7d.

EDX analysis of sample 9 and 10 revealed the same elemental analysis as shown in Figure 6. The difference is that the brittle feature Sn/Ni/Cu was less pronounced. It is noted that sample 9 and 10 failed in ductile manner with considerable plastic deformation.

In general the failure of tab/PCB under peeling forces can be explained as follow:

- 1- The porosities act as stress concentrator and become more effective when concentrated in the vicinity of the opening mouth of Tab /PCB. Sample 12 Figure 4d.
- 2- The cause worsens with peeling strength when Sn/Ni/Cu brittle grainy feature developed during reflow and solidification process because these features enhance a brittle failure with low stress level, (Table 1) samples 1, 12 and Figure 6 and Figure 8.
- 3- When proper reflow and solidification process were done, this will result in less porosity. Correspondingly, the elimination of the Sn/Ni/Cu brittle feature is also achieved resulting in high strength , (Table 1) samples 9 and 10 and Figure 7c.
- 4- When over heating occurred, the PCB may get damaged. The failure at the Copper connection / PCB interface may also take place at low force as in sample 4, (Table1). However even if the solder contained defect, (Figure 5). these defects can still act as a stress connector, Figure 9.

CONCLUSION

Based on the laboratory tests and/or examination results, it was observed that tabs which failed under low peeling force showed brittle failure due to the generation of porosity that acts as a stress concentrator combined with the evolution and growth of brittle Sn/Ni/Cu phase. However, the tabs, which failed under high peeling force,

contained porosity that have no growth of the brittle Sn/Ni/Cu feature.

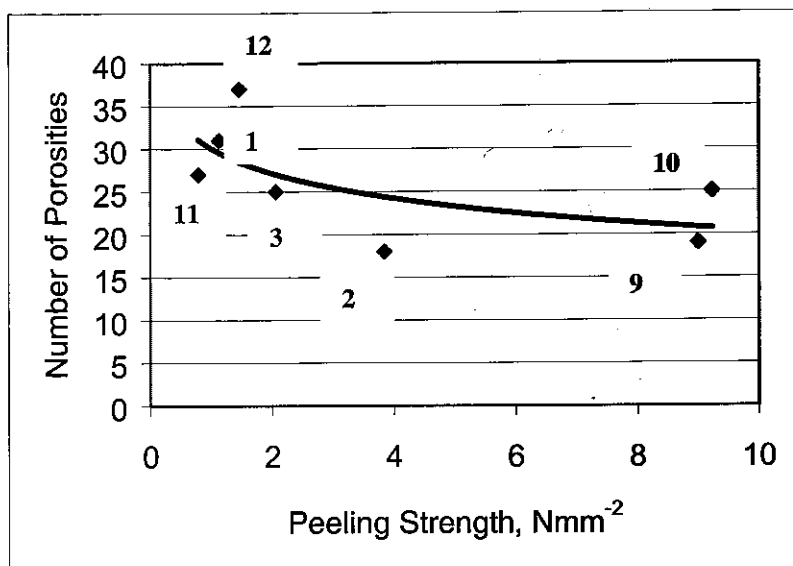


Figure 3. Influence of porosity on the peeling strength of tabs /PCB connection. The numbers in bold is the sample's number indicated in Table 1.

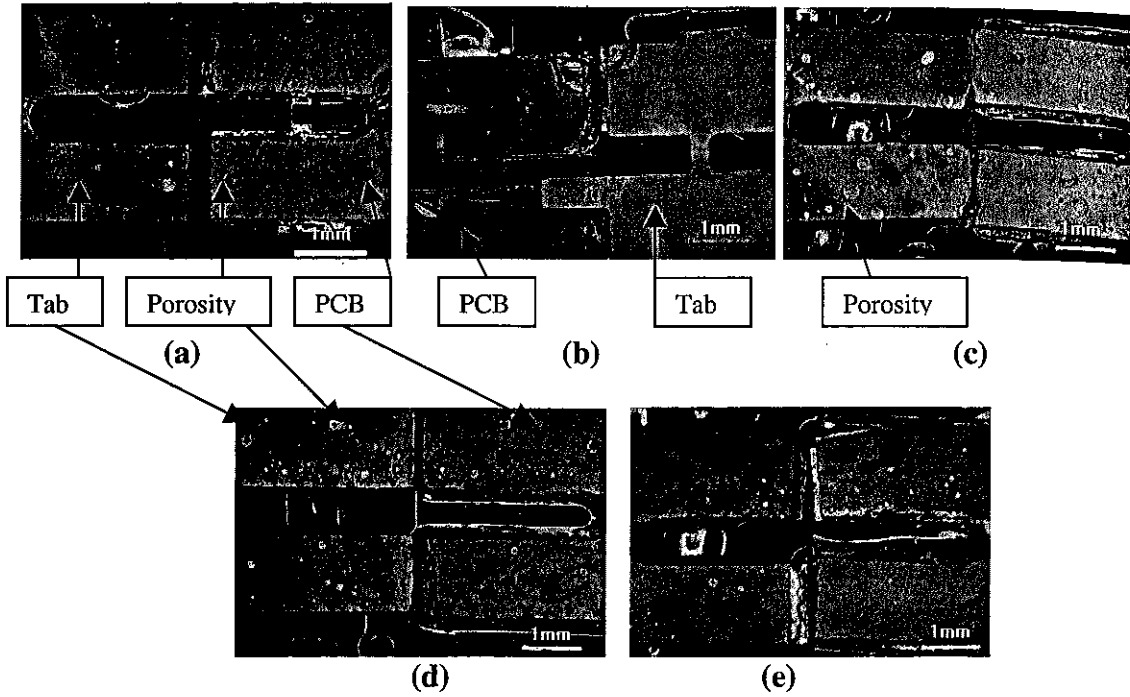


Figure 4. The porosities generated between tab and copper on the PCB at Sn36/Pb35/Ag2 for the samples tested. (a) Sample 1, (b) sample 4, (c) Sample 10, (d) sample 12 and (e) sample 9.

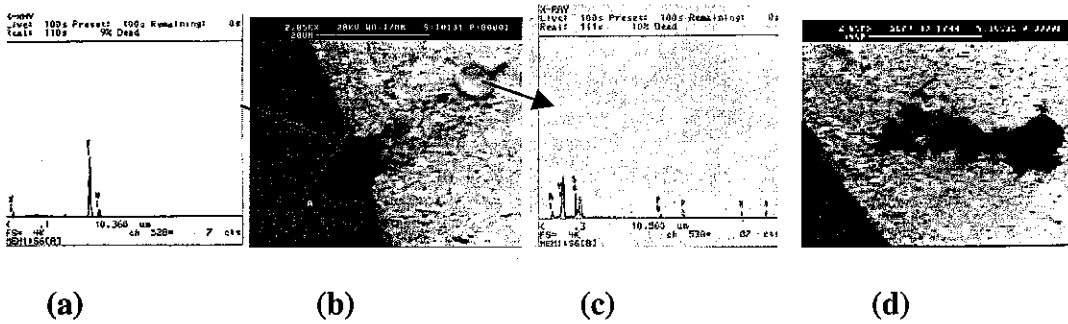


Figure 5. Sample 4 failed at Cu/PCB interface, (b and d) showing a porosity and defect at Sn36/Pb35/Ag2 solder. (a and c) EDX analysis of the tab Ni200 and a defect (contained Al, Mo with Sn) is also depicted.

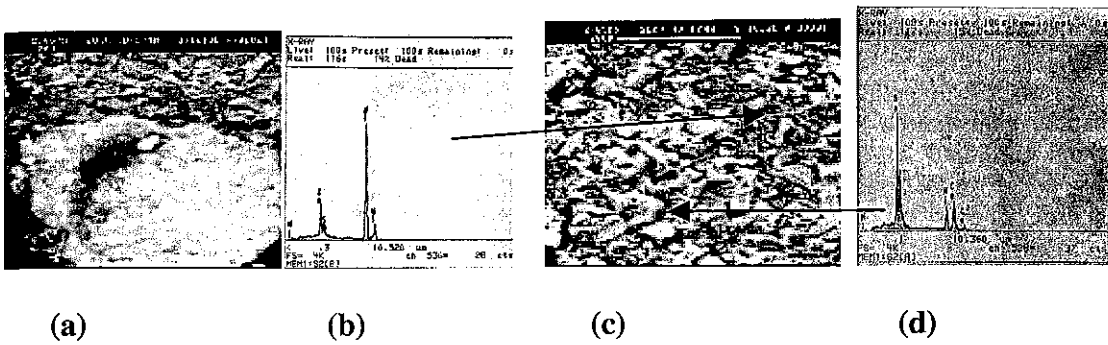


Figure 6. Sample 1, Tab Ni200. (a) Fracture surface near the porosity, the porosity showed eutectic Sn/Pb structure. (b) Ni/ Sn
 lating structure, EDX analysis,(c) fracture surface away from the porosity and (d) EDX analysis of grain type microstructure which
 contained Ni, Sn and Cu.

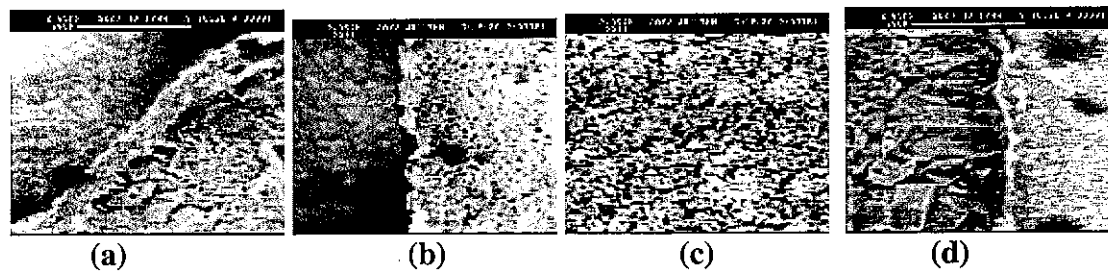


Figure 7. Scanning micrographs showing the topography of the fracture surface of sample 9 (tab 1008CRS) a, b and c and sample
 10 (tab Ni200) d.

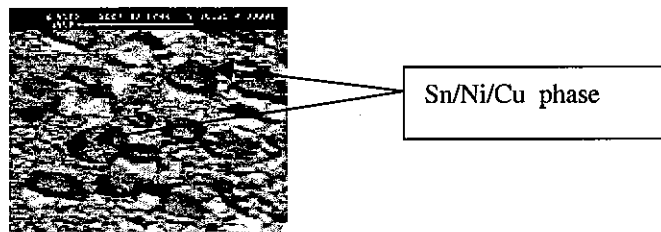


Figure 8. Typical brittle fracture of sample 12 indicating the cleavage of Sn rich grains not properly melted and combined
 with solder.



Figure 9. Side view of sample 5 failed at Copper/PCB interface. Opening crack through the solder is shown

SOLUTIONS AND RECOMMENDATION

From the above results two features have been identified to be the root cause of low peeling strength of Sn36/Pb35/Ag2 solder connections; namely the porosity and the growth of brittle Sn/Ni/Cu structure.

- 1- Porosity: to reduce the generation of gas entrapment and to produce porosity in the solder it is be adviseable to use active solder and to blend it thoroughly. Additionally, if possible to degass by vacuum before applying it on PCB. Correspondingly by implementing the same procedure as in sample 9 in BTU 8 furnace; will eliminate the Sn/Ni/Cu brittle features
- 2- The generation and growth of Sn/Ni/Cu brittle structures could be reduced through enhancing the melting as well as the combination of solder and sn/substrate. Nonetheless, for further improvement, the ideal temperature could be reached by testing the temperature at every 5 seconds interval up to a maximum of 58 seconds (with care throughout the process in ensuring that the PCB is not damaged. Eliminate Sn/Ni/Cu brittle feature by implementing the same procedure as in sample 9 in BTU 8 furnace.

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