COMPARISON BETWEEN SnPb 63/37 AND SAC305 SOLDERS: STRUCTURE AND INTERMETALLICS MORPHOLOGIES AFTER THERMAL STRESS ON PCB – ENIG FINISHING

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ABSTRACT

The reliability of electronics equipment depends largely on the constitutive components, but also on their assembly and the behavior of solder joints on thermal, mechanical and thermomechanical stresses.

It is then necessary to well understand the structure of the solder joints (composition, phases, intermetallic compounds,...), their physical and mechanical characteristics and their evolution in thermal ageing. These parameters will determine their behavior, and therefore the lifetime of the equipment.

The introduction of lead free solders has changed the traditional way of preparing and inspecting solder (modification of polishing instructions, chemical etching, polarized light ...). Thus, different behaviors compared to leaded solders have been observed, particularly on intermetallics compounds (IMCs) layers, which are the main contributors to the solder reliability.

This paper aims to determine which parameters have an influence on the intermetallics formation and growth, by comparing SnPb 63/37 to SAC 305 alloy, on ENIG finishing.

Studies of both solder alloys have reported that isothermal ageing temperature is the main parameter that significantly increased the size of intermettalics.

It also showed that SAC IMCs formation is more sensitive to process parameter than SnPb, and especially on the soldering time.

The association of revealed cross-sectioned views, and revealed aerial views (top view) allowed having a threedimensional representation of their morphology.

Thus, the correlation between thicknesses/shapes and process parameters/ageing was possible.

This revealed a difference of the morphology in isothermal ageing conditions. Although the structures seem similar at T0, during ageing, SnPb IMCs lose their shape, and their surface become smoother compared to SAC IMCs, which kept their needle structure.

This difference in ageing may explain the higher solder reliability at PCB/Solder interface on SAC305 compared to Sn/Pb 63/37. Actually, the presence of a finer structure in SAC, with larger specific surface could lead to a better adherence IMC/solder, and then limited the risk of cracking.

1 INTRODUCTION

During parts soldering, the formation of intermetallic compounds (IMC) at solder/PCB interface ensures a good metallurgical and electrical bond.

But it is known that the size of intermettallics has an influence on the solder joints strength, and could results –if not controlled– in the mechanical failure of the joints.

An excessive IMC size or a lack of them in solder could indicate a solder process issue, and would alter the mechanical performance of the solder joint. That is why IMC layers measurements is a good indication of the solder joint quality.

This paper will show you the influence of the soldering process time/temperature parameters, and thermal ageing on the intermetallics structure, with a different approach of intermetallics inspection. Indeed, the association of revealed cross-sectioned views, and revealed aerial views (top view) allows us to have a three-dimensional representation of their morphology. The lead free solder chosen is the more commonly used in electronics: SAC305 (Sn 96.5 %, Ag 3 % Cu 0.5%),

and will be compared to a leaded solder: SnPb 63/37 (Sn 63%; Pb 37%). The intermetallics morphologies were studied on a PCB substrate, with ENIG finishing.

2 EXPERIMENTAL PROCEDURE

2.1 Study description

The purpose is to study the formation, the evolution and the visual appearance of SnPb 63/37 intermetallics compared to SAC305, on ENIG substrate, in function of process and ageing parameters.

In order to assess and quantify which parameter(s) influence the size of intermetallics, the study was conducted as a design of experiment (DOE) using Taguchi method.

Input parameters, with their levels, are presented in Table 1. They were chosen in function of the most common usage in the industry:

- Bath temperature: 253°C and 255°C for SnPb bath ; 245°C and 265°C for the SAC305 bath
- Time on the solder bath: 5 seconds and 10 seconds
- 125°C isothermal ageing time : 0 hours ; 500 hours and 1000 hours

All other parameters that may affect intermetallics size were fixed (Same solder flux, operator, soldering equipment, samples geometry, inspection method, ...).

A total of 24 experiments have been performed (12 per solder type).

Solder type	SnPb 63/37			SAC 305		
Levels	#1	#2	#3	#1	#2	#3
Bath temperature (°C)	235	255	/	245	265	/
Time on the solder bath (s)	5	10	/	5	10	/
125°C Isothermal ageing time (h)	0	500	1000	0	500	1000

Table 1 : Input parameters and levels

Output value corresponds to the thickness of the intermetallics, measured in section.

Several inspection methods were used in order to have a complete view of the intermetallics morphologies:

- Cross sectioned views: useful for measuring the thickness of the IMC and observing the 2D profile of the structures. This observation mode corresponds to what is commonly practiced on IMC, but this method is limited to a section plan.
- Revealed cross sectioned views: This will confirm if the chemical etching did not reduce the intermetallics thicknesses by comparing the thickness obtained, with not revealed views. These views will also add a field depth, to assess the homogeneity of the structures formed
- Aerial and revealed views. These views will show the structures, their distribution, and their homogeneity with a larger field than those considered in sectioned view.

2.2 Samples description

Each experiment was performed on a four solder lands PCB (5mm²/pad), sampled from a larger bare PCB, with ENIG finishing (Au: $0.1\mu m$; Ni:4 μm), see Figure 1

The solder was performed by floating method on the solder bath with controlled time and temperature. By this soldering method, it was intended to simulate a wave soldering.

Intermetallics intended to be formed at the interface solder/PCB substrate are given by the equilibrium diagram: Ni3Sn, Ni3Sn2, and Ni3Sn4, see Figure 2

Note: Intermetallics with gold would not form. Because of the low quantity of the gold on ENIG finishing, this elements tends to dissolve inside the solder.

In order to perform the cross section, each sample was embedded in resin. Then the cross sections were performed, using smooth silicon carbide paper, and liquid diamond as finishing, see Figure 3

Revelation was performed by etching the sample in an acid solution, with controlled time

Optical and SEM inspections were then carried out in order to observe the intermetallics and determine the IMC thicknesses.

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Figure 1: Bare PCB and experiment sample



Figure 2: Ni-Sn Equilibrium diagram



Figure 3: Optical microscopic view of a cross sectioned sample

3 RESULTS AND DISCUSSIONS

3.1 Parameters effects

The results of the intermetallics measurements are summarized in the Figure 4.

Each graph showed the effects of each parameter: solder temperature, soldering time and ageing time, for both alloys.

On each sample the IMC measurements were performed in 5 different locations.

For this reason, each point on the graphs represents an average of 30 measurements for the temperature and time graphs, and an average of 10 measurements on the isothermal ageing graph.

The measurement accuracy is determined at +/- 100nm.



Figure 4: Effect of the parameters selected on the intermetallics size for each solder bath.

On SnPb 63/37 bath, the ageing time is the main factor that influences the IMC growth: about 500nm at 0h, 1100nm at 500h and 1300 nm at 1000h.

The absence of significant slope on time and temperature parameters showed that there is no influence of these two parameters on the intermetallics thickness.

On SAC305 bath, the isothermal ageing is also an important contributor to IMC growth, but we also note that the time spent on the bath has a great influence on IMCs size.

For both baths the results showed an increase in the thickness of the intermetallic compounds with the ageing time.

The isothermal ageing at 125° C promotes the diffusion, and then the growth of IMC

We also note that the temperature of the solder bath did not show any effects on the IMC size.

Process parameters chosen, time and temperature on the bath, have a very lower impact than the isothermal ageing

Note: Interaction between parameters was assessed but not reported in this paper because no interaction was identified.

3.2 Inspection after isothermal ageing

The results of the IMCs shapes inspections during 125°C isothermal ageing are presented in Figure 5.

For both baths, cross sectioned views confirmed that the longer the sample is aged, the higher the intermetallics thicknesses are.

Even if at T0, both structures are small and rough, during the ageing, the morphologies of intermetallics has changed and exhibited different behaviour in function of the leaded or non leaded bath:

On the leaded bath, the aerial views showed that the IMCs lose their shape during the ageing, and then during their growth. The isothermal ageing has made the surface smoother and flatter. The intermetallics have filled all the spaces, leaving no gap between them. This finding is confirmed by the other views.

On the lead free bath, T0 structures, which have some similarities with the leaded one, have a completely different behavior during ageing. Actually, during the ageing, and then during their growth, the intermetallics morphologies of SAC solder remained as needles.

Furthermore, revealed cross sectioned views showed that the measured thickness with the "classic" method (not revealed view) was not completely representative of the real morphologies of the IMCs. Some structures which have not a perpendicular growth are not taken into account by the measurements, because the cross section views are representative of only one plane, and not to the entire surface, see Figure 6.



Figure 5: Inspection of the intermetallics formed



Figure 6: SAC305 intermetallics size measurement

4 CONCLUSION

This study has presented the comparison of intermetallics thicknesses and morphologies for leaded and no leaded solder, and for several defined parameters.

It has been observed that the isothermal ageing is the main factor, which influences the IMCs growth, whatever the solder bath.

Moreover, IMCs growth from SnPb bath is not sensitive to process parameters. Actually, neither the solder time, nor the soldering temperature, influenced the growth. Whereas, IMC growth was influenced by the time spent on the solder bath SAC305.

In addition to intermetallic sizes, their morphologies have been compared and showed different shapes between leaded and not leaded bath.

Although the structures seem similar at T0, both solders exhibited a completely different behavior with the isothermal ageing. SnPb IMCs lose their shape, and their surface become smoother compared to SAC IMCs, which kept their needle structure.

This difference in ageing may explain the higher solder reliability at PCB/Solder interface on SAC305 compared to Sn/Pb 63/37. Actually, the presence of a finer structure in SAC, with larger specific surface could lead to a better adherence IMC/solder, and then limited the risk of cracking.

This study also addresses the question of IMC size measurement in section. Aerial views showed that in leaded solder a good correlation can be made between what is observed and the measured size. Whereas, on lead free solder, some large IMC, which grew not perpendicularly to the section plane, are not taken into account by the size measurement.

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