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The effect of PCB surface roughness on the reliability of the SAC405 lead free solder

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ABSTRACT – The focus of this research is to investigate the surface roughness on the reliability of lead free SAC405 solder material. Surface roughness influences reliability where high reliability improves the bonds of the solder and the substrate. In this study, aluminium and copper substrate is used with 4 different types of surface roughness. Hardness testing is performed using nanoindenter on each of the substrate where the hardness is in increment with the surface roughness. It is discovered that the increase in surface roughness causes increase in wettability and formation of intermetallic compound thus increases the reliability of the solder.

1. INTRODUCTION

Lead (Pb) based solders are the commonly used solders for the electronics industry. Pb based solders poses many negative impact on the machine and consumer [1]. This leads to a safer Tin (Sn) based material that reduces environmental impact as well as satisfies the metallurgy of solder economically [2,3].
Solder alloys subjected to a controlled condition leading to the formation of intermetallic compound (IMC) combined with surface roughness influences the reliability of the solder joints, although IMC is not dependent towards surface roughness. In soldering, surface roughness can affect the quality of wetting and spreading behaviour of filler and reduces the effective contact angle as was discovered in previous research [1, 4].

The objective of this study is to investigate the reliability of the SAC 405 solder joint on different surface roughness of the substrate. The strength of the solder joint is evaluated from its hardness to find the effect of surface roughness using nanoindentation.

2. METHODOLOGY

2.1 Material selection

SAC405 is chosen as the solder material with aluminium and copper plates with dimension of (20 mm × 10 mm) as substrates.

2.2 Sample preparation

The substrates are prepared with 4 different surface roughnesses through 3 different grits of abrasive paper and the substrate initial surface roughness. The surface roughness of the samples is then measured using a calibrated Mitutoyo SJ-301 Portable Surface Roughness Tester.

The SAC405 solder is then formed into balls and attached to the substrate labelled A1, A2, A3, A4, C1, C2, C3 and C4. The samples are then mounted through cold mounting (resin) in which the mounted sample will be grinded and polished for a cross-section cut and analysed through surface profiler.

Hardness of the sample is calculated from the load-displacement measurement of the nanoindentation test through Equation 1:

$$H = \frac{P}{A} \quad (1)$$

where P is the maximum loading and A is the value of h_c from the load-displacement measurement.

3. RESULTS AND DISCUSSION

The surface roughness of the substrate is determined from the value of arithmetic average roughness, Ra shown in Table 1-2.

Table 1 Average value of arithmetic average roughness, R_a for aluminium.

Sample	**Type of grits**	**Average R_a (µm)**
A1	-	0.21
A2	240	1.77
A3	800	0.74
A4	1500	0.49

Table 2 Average value of arithmetic average roughness, R_a for copper.

Sample	**Type of grits**	**Average R_a (µm)**
C1	-	0.13
C2	240	0.92
C3	800	0.3
C4	1500	0.17

The mechanical properties of copper are far superior than aluminium thus copper is more resilient towards deformation resulting in a lower surface roughness as compared to aluminium.

3.1 Nanoindentation test

A load-displacement measurement is obtained and for the aluminium samples at maximum loading of 10 mN are 1350.839 nm, 1404.721 nm, 1451.982 nm and 1500.649 nm for sample A2, A3, A4 and A1 respectively. For the copper samples, the displacement values are 1319.417 nm, 1481.304 nm, 1478.730 nm and 1553.384 nm for C2, C3, C4 and C1.

The initial value of displacement shows increments which indicates that the loading applied causes the sample to undergo elastic behaviour until it exceeds the maximum loading of. The unloading process will cause the sample to reach the elastic+plastic behaviour until the sample reaches plastic region where deformation occurs. This behaviour is the result of the formation of IMC between the contact of the attached solder ball and the substrate where at maximum loading the solder behave in the plastic region resulting in no cracking.

The samples shows an increase in hardness as the surface roughness increases with copper slightly superior than aluminium as observed in Figure 1. In previous research, the effect of the material substrate depends on the composition of the solder material and IMC growth condition used and thus varied intermetallic layers formed causing various results of enhancements and also diminishment [5, 6].

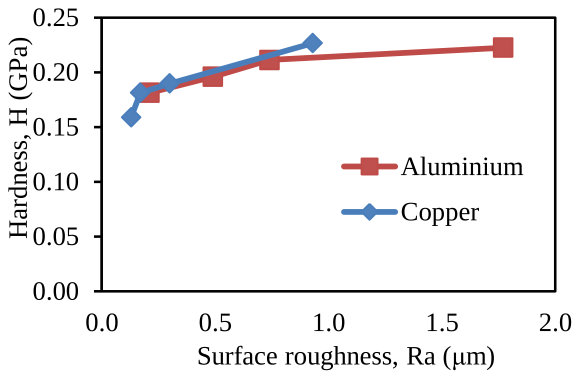

Figure 1 The relationship of surface roughness and hardness value of the sample.

From the results obtained, it is discovered that the value of hardness increases as the value of surface roughness increases. The surface roughness reduces the wettability of the solder causing the increase in the formation of intermetallic compound which in turn affects the hardness value of the attached solder ball. Substrate material is discovered to influence the hardness of the SAC405 by a small margin where copper is superior to aluminium. This is most likely due interaction of SAC405 with the substrate; interlayers of hard intermetallic Ag_3Sn and Cu_6Sn_5 forms for copper while on aluminium substrate the formation of soft particles of AlAg and AlCu were observed resulting in distinguishable hardness strength [7]. The IMC interface is prominently different between the substrate where copper had continuous interlayers while the solder alloy dissolves the substrate along the grain boundaries forming no interlayers for aluminium [8].

4. CONCLUSION

The investigative study leads to various results where it is found that as the surface roughness of the substrate increases, the hardness value of the attached solder ball increases. This suggested that the surface roughness of substrate influence the reliability of lead free SAC 405 solder material. It is also concluded that larger surface roughness of a material specifically aluminium and copper leads a higher reliability for the lead free SAC 405 solder material as well as a slight superiority in for copper substrate as compared to aluminium

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