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Effect of Flux onto Intermetallic Compound Formation and Growth

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Abstract. In this study, the effect of different composition of no-clean flux onto intermetallic compound (IMC) formation and growth was investigated. The solder joint between Sn-3Ag-0.5Cu solder alloy and printed circuit board (PCB) was made through reflow soldering. They were further aged at 125oC and 150oC for up to 1000 hours. Results showed that fluxes significantly affect the IMC thickness and growth. In addition, during aging, the scallop and columnar morphology of IMC changed to a more planar type for both type of flux during isothermal aging. It was observed that the growth behavior of IMC was closely related to initial soldering condition.

1 Introduction

Nowadays, there are huge demand in multifunction of electronics products. To produce such products, it requires a larger number of input and output data which can be obtained through a good solder joint connection [1-3]. Nevertheless, the solder joint need to be controlled due to the existence of IMC, whereby excessive growth or unexpected morphological change of IMC may be detrimental to the solder joint performance which finally leads to failure [4, 5].

In general, reflow soldering process requires certain parameters to produce solder joint which includes flux. It is used to clean and activate the subtrate surface by forming a continuous film over the surface that inhibits access oxygen to the substrate. Thus, it can be wetted by the molten solder. In addition, flux also used to provide heat transfer and wetting enhancement among the solder material during solder making process. However, the solid solder or flux and molten solder/flux interfacial tensions differ with respect to flux type, composition and also temperature. This condition will also affect the type of IMC formed after reflow soldering since it encounters reaction between the solder and substrate [6, 7]. Most of the researchers were investigating on the wetting properties of solder alloy with respect to flux type or materials, but none of them were looking at the effect of flux type towards IMC formation and growth after reflow soldering and isothermal aging. The researchers were unaware of the importance of the IMC type produced by different type of flux. Different type of IMC leads to different solder joint strength.

Therefore, in this study the interfacial reaction between Sn-3.0Ag-0.5Cu solder alloy paste with different flux composition, and copper substrate were thoroughly investigated during soldering and isothermal aging with a focus on the IMC formation and growth.

2 Experimental Set Up

The substrate used was FR4 (epoxy glass) material sandwiched between two electroplated copper layers. The substrate has the dimensions: width x length x thickness of 25 x 40 x 1 mm. Firstly copper substrates were polished and grind in order to remove oxide layer that formed onto it. Then, Sn-3.0Ag-0.5Cu in a paste condition was reflowed on copper substrate for 25 minutes at the temperature of 250^{o}C. This was followed by cooling at room temperature. Since the composition of the flux remains confidential and disclosed by Electronic Packaging Research Society-Universiti Kebangsaan Malaysia (EPRS-UKM), thus it was labelled as Flux A and Flux B for this study. However, it is well known that both flux were epoxy based. The samples were then aged at 125^{o}C and 150^{o}C for up to 1000 hours. Cross sections from the samples were then prepared using standard metallographic steps and examined using optical microscopy as well as Scanning Electron Microscopy (SEM). The average thickness of the intermetallics formed is identified using Energy Dispersive Xray (EDX) and measured using imageJ software across the intermetallic layer on cross sections of the solder joints.

3 Results and Discussion

The results of the present work indicated that the interfacial characteristics of composite solder joints are affected significantly by the initial soldering condition since Flux A and Flux B produces different wetting

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characteristics onto copper substrate. This can be seen through Figure 1 whereby solder alloy with Flux B produced much larger grain and denser Cu_6Sn_5 IMC phase as compared to solder alloy with Flux A. The detail explanation of the wetting characteristics was explained in elsewhere [6, 7]. Nevertheless, this phenomena can be summarized as follow; whenever the flux was exposed to reflow temperature, some of Flux B begins to thermally decomposed due to its different composition, and thus activating the diffusion reaction between solder alloy and copper substrate. This will finally leads to producing IMC with larger and denser grain.

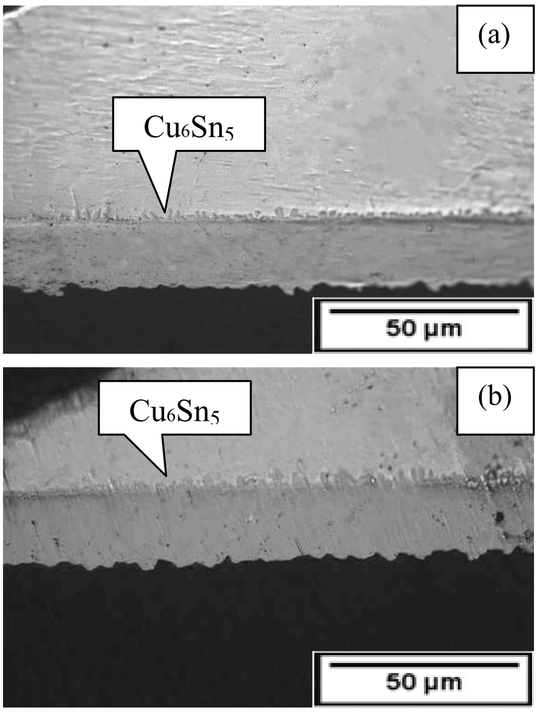
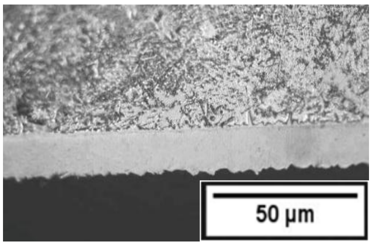
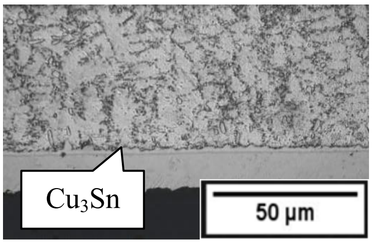
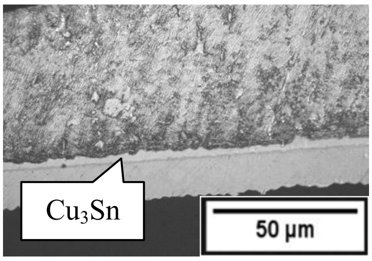
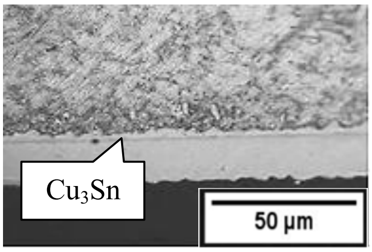


Figure 1. Interfacial reaction between Sn-3.0Ag-0.5Cu solder alloy and copper substrate after reflow soldering using; (a Flux A, and (b) Flux B.

In fact, after aging, the second layer of IMC produced by Flux B is also thicker as compared to Flux A for both aging temperature (Table 1). This explained faster interfacial reaction or diffusion rate for Flux B. However, no Cu_3Sn was detected for Flux A after 250 hours aging duration. It has happened because the temperature used is low enough to slow down the solid state diffusion. Thus, it took longer time to form Cu_3Sn. In addition, the IMC layer for both fluxes became thicker, compact and denser as aging duration increases.

Table 1. Cross sectional microstructure of the Sn-3.0Ag-0.5Cu using dissimilar flux for different aging temperature at 250 hours duration.

Flux	Aging temperature	Cross Section Image
A	125˚C	
B	125˚C	
A	150˚C	
B	150˚C	

Nevertheless, as the isothermal aging process started taking place, the IMC thickness for Flux B slightly lower than Flux A for both temperatures (Figure 2). It is believed that Flux A is suitable to be used for lower temperature of aging, whereas Flux B much more stable for both temperatures. It is suspected that its different composition or ingredient helps it maintain at that temperature. Besides, it can also be seen that for isothermal aging temperature of 150^{o}C, the total IMC for flux B became slightly lower than those IMC produced in Flux A at the duration of 500 and 1000 hours. This is happened because lack of Sn from the solder alloy that could diffuse towards the copper substrate due the existence of Cu_6Sn_5 between them. Therefore, the diffusion rate became slower. However, it was still increasing in thickness as the aging duration increased.

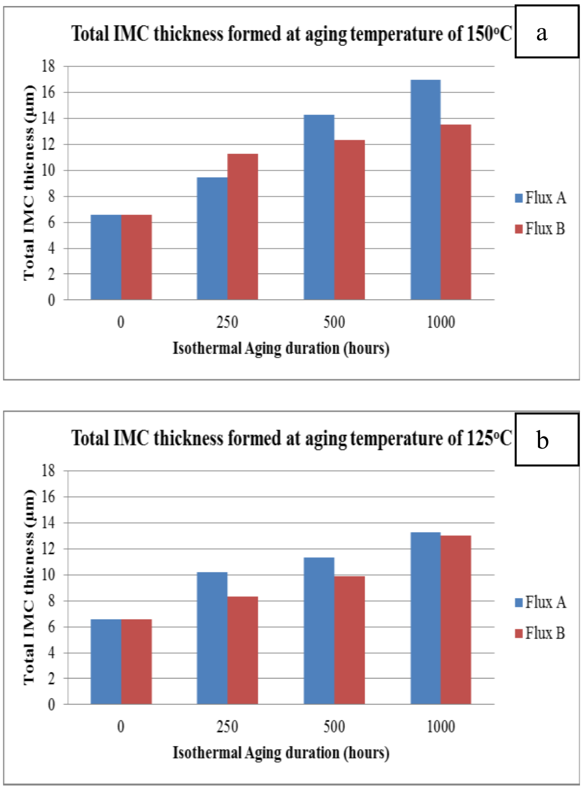


Figure 2. Total IMC thickness after isothermal aging at different temperatures; (a) 150°C, and (b) 125°C.

4 Conclusions

This paper presented the results of interfacial reaction between Sn-3.0Ag-0.5Cu solder alloy paste with different flux composition, and copper substrate with a focus on the IMC formation and growth. The results of this study show that different composition of flux significantly affect the IMC thickness and growth. The evidence from this study suggests that Flux B is the best candidate that could be used for reflow soldering and aging at high and low temperature because it is more stable. However, it is recommended that further research be taken to establish its optimum solder joint strength.

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