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Solderability of Sn-0.7Cu-0.05Ni-xZn Solder Ball on Sn-0.7Cu and Sn-0.7Cu-0.05Ni Solder Coating

M. I. I. Ramli^{1,*} and M. A. A. Mohd Salleh¹

¹Center of Excellence Geopolymer & Green Technology (CeGeoGTech), School of Materials Engineering, Universiti Malaysia Perlis (UniMAP), Taman Muhibbah, 02600 Jejawi, Perlis, Malaysia

E-mail: mohdizrulizwan@gmail.com

Abstract. In this study, the solderability of the Sn-0.7Cu-0.05Ni-xZn solder ball on solder coating were investigated by using Gen3 wetting balance test machine. By using wetting balance test in globule mode, the solderability of solder ball was determined by the maximum force and wetting time. The result of a good solderability is generally referred to short wetting time and high wetting force. It was found that by increasing amount of Zn in Sn-0.7Cu-0.05Ni solder ball, the maximum force was decrease and wetting time was increase. This result indicates that by increasing amount of Zn in Sn-0.7Cu-0.05Ni solder ball, it will decrease the solderability of solder ball to the solder coating.

1. Introduction

Surface mount technology (SMT) is an area of electronic assembly used to mount electronic components to the surface of printed circuit board (PCB). This surface mount technology is important with the growth of printed circuit board in electronic industry. This advantage of SMT is it has lower



cost and can be placed closer to the board. In surface mount devices, the surface finish has an important role. This surface finish has several functions, to protect surface impurities such as oil and dust, a barrier to prevent oxidation and to be solderable. There are several surface finishes that are currently used in PCB manufacture such as immersion tin (ImSn), immersion silver (ImAg), Electroless Nickel immersion Gold (ENIG) and Hot Air Solder Levelling (HASL). However, HASL surface finish has been a popular surface finish for PCB used for circuitry with large components used in heavy-duty applications in harsh environments. In HASL surface finish, the copper is coated with solder as a coating. The traditional Sn-Pb solder has been widely used in the solder coating. However, due to health issues and negative effects on the environment, the use of Sn-Pb solder alloy is banned in the electronic packaging industry [1-3]. The studies on new lead-free solder have been studied to replace the Sn-Pb solder alloys as solder coating [2, 4]. Among the lead-free solders, the Sn-0.7Cu and Sn-0.7Cu-0.05Ni solder is the most commonly used as a solder coating for hot air solder leveling (HASL).

Solderability of solder can be defined as the ability of the molten solder to spread over on a substrate during the reflow process. In the HASL process, a PCB is fluxed and dipped into a molten solder bath so that entire copper surfaces are wetted. The result of a good solderability is generally referred to as short wetting time and high wetting force. Recently, Zn addition has been found to be able to reduce the nucleation undercooling of β -Sn in Sn based Pb free solder alloy [5]. The formation of Cu-Zn intermetallics can be correlated with an enhancement of mechanical properties. However, the effect of Zn in Sn-0.7Cu-0.05Ni on solderability is rarely studied.

In this study, we investigate the IMC thickness of Sn-0.7Cu and Sn-0.7Cu-0.05Ni solder coating by aging method to mimic the storage condition of surface finish. The influence of Zn in Sn-0.7Cu-0.05Ni solder on solderability properties of Sn-0.7Cu and Sn-0.7Cu-0.05Ni solder coating were also investigated.

2. Experimental

In this study, the Sn-0.7Cu and Sn-0.7Cu-0.05Ni solder alloy was supplied by Nihon Superior Co., Japan as a base solder for dipping method. The dipping process was simulated by coating copper strips with solder by using wetting balance machine. The copper strips with a dimension of 10mm x 3mm x 0.3 mm were cleaned by acid to remove the surface oxides. The copper strips were then fluxed and mounted on the clip holder then immersed in the molten solder with withdrawal speeds of 30 mm/s and immersion time of 20 s using the dipping method. The coated samples were then aged at 180°C for 24 hours, 120 hours and 240 hours. The samples were

then cross sectioned and observed the IMC of solder coating. The interfacial IMC thickness were then measured by using J-Image software. The solderability testing were performed by using wetting balance machine in globule mode. In this mode, the sample were fixed at an angle in the grip and the solder ball raised until it touches the surface coated copper strip. The result of this testing is evaluated by wetting time and maximum force.

For solder ball fabrication, the base Sn-0.7Cu-0.05Ni were mixed with three different compositions of Zn (0.5, 1.0, and 1.5 wt.%) by using conventional casting process and have been namely Sn-0.7Cu-0.05Ni-0.5Zn, Sn-0.7Cu-0.05Ni-1.0Zn, and Sn-0.7Cu-0.05Ni-1.5Zn. The casting sample were takeout and poured onto the stainless-steel plate and rolled into 30 μ m foils thickness. The sheet solder was melted in a reflow oven and form a solder ball by the action of surface tension. Figure 1(a) show a schematic diagram of dipping process and Figure 1(b) explain the solderability test in globule mode. In this study, the effect of aging to the interfacial IMC has been investigated by cross sectioned and the solderability performance for the coated sample with influence of Zn in Sn-0.7Cu-0.05Ni solder alloys has been investigated.

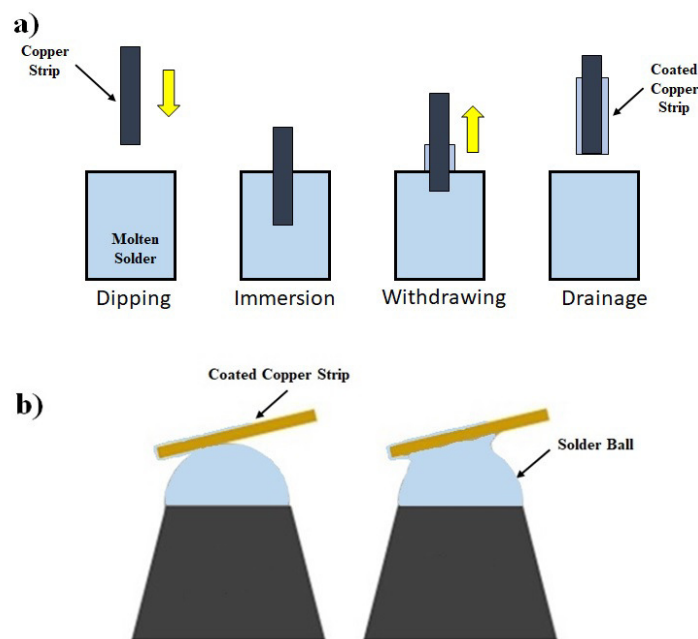


Figure 1.(a) show a schematic diagram of dipping process and (b) explain the solderability test in globule mode.

3. Results and Discussion

3.1. Wettability of Sn-0.7Cu and Sn-0.7Cu-0.05Ni solder coating

Figure 2 show the wettability of Sn-0.7Cu and Sn-0.7Cu-0.05Ni solder coating on copper strip. The wettability performance of copper strip was evaluated by wetting time and maximum force that carried out using dipping wettability balance test. This result show that the Sn-0.7Cu-0.05Ni solder coating show better wettability compared to Sn-0.7Cu solder coating. The highest maximum force and lowest wetting time show a better wettability for coating solder. The above result indicate that the addition of Ni may influence in the surface tension of the solder which eventually change the wetting time and maximum force. Wang et al. also [6] reported that the influence of Ni addition on Sn-0.7Cu have influenced the surface tension between solder and flux interface in the molten state.

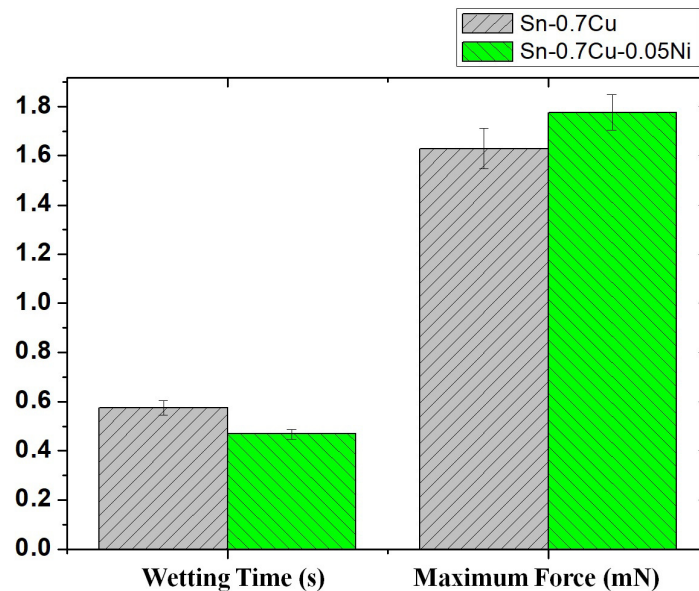


Figure 2. Relationship between wetting time and maximum force.

3.2. Effect of aging sample to the interfacial intermetallic of Sn-0.7Cu and Sn-0.7Cu-0.05Ni solder coating

After the aging process, the sample were cross sectioned to investigate the interfacial IMC of Sn-0.7Cu and Sn-0.7Cu-0.05Ni solder coating as shown in Figure 3. The interfacial IMC of Sn-0.7Cu is increase from 2.45 μm to 3.85 μm , 7.70 μm , and 8.78 μm after 24 hours, 120 hours and 240 hours. For

Sn-0.7Cu-0.05Ni with 3.54 μm , and increases to 5.02 μm , 10.9 μm and 11.94 μm at 24 hours, 120 hours and 240 hours. This indicated that the IMC thickness will increase with increasing of aging time. The IMC growth are occur by the dissolution of element in the substrate to the solder and interdiffusion kinetics.

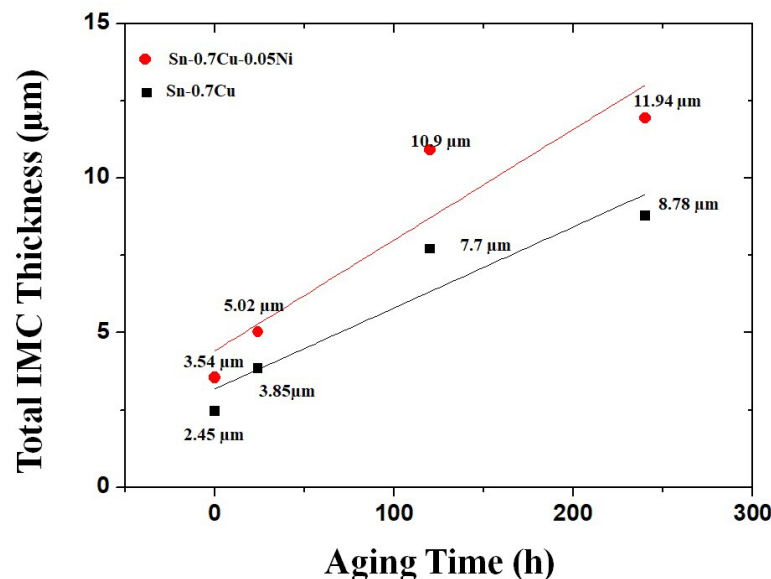


Figure 3. Total IMC thickness of Sn-0.7Cu and Sn-0.7Cu-0.05Ni solder coating as a function of aging time.

3.3. Effect of interfacial IMC to the solderability of Sn-0.7Cu and Sn-0.7Cu-0.05Ni solder coating

Solderability is crucial in soldering process and plays an essential role to determine a good bonding formed between solder materials and substrate. It is also an important issue in the reliability of electronic products. Figure 4 show the effect of Zn addition on Sn-0.7Cu-0.05Ni solder ball to the solderability of solder coating in term of wetting time and maximum force. After the aging process, the interfacial IMC are measured and has been found that with the increasing of aging time, the thickness of the IMC layer were increase. It clearly shown that the wetting time has been increased with increases of Zn addition on Sn-0.7Cu-0.05Ni solder ball. The maximum force of Sn-0.7Cu and Sn-0.7Cu-0.05Ni solder coating also decrease with increases of Zn element in Sn-0.7Cu-0.05Ni solder ball. It can be concluded

that when interfacial IMC increases by aging process, it also increase the wetting time and decrease the maximum force. The shorter wetting time and higher maximum force will indicates a good solderability.

With increasing the interfacial IMC, it were found that the solderability of solder coating will decrease. This finding related to the increases of interfacial IMC will decrease the free solder thickness. The increases of IMC also reduce the free solder thickness were suggested by Ramli et al.[7]. They reported that if interfacial IMC is increase, it will decrease the free solder thickness thus decrease the solderability of solder coating. Noh et al. [8] also reported that, by the increasing maximum force and shorter wetting time are resulted from a better wettability of solder alloy. In this study, with the addition of Zn into Sn-0.7Cu-0.05Ni solder ball, the solderability in term of wetting time and maximum become worse. This is due to the addition of Zn, which can directly prevent the wetting on Cu substrate because of the oxidation and high activity of Zn in Sn alloy. Kamal et al. [9] also suggest the formation of oxide residue during soldering which may lessen the wettability of Sn-Ag-Cu solder.

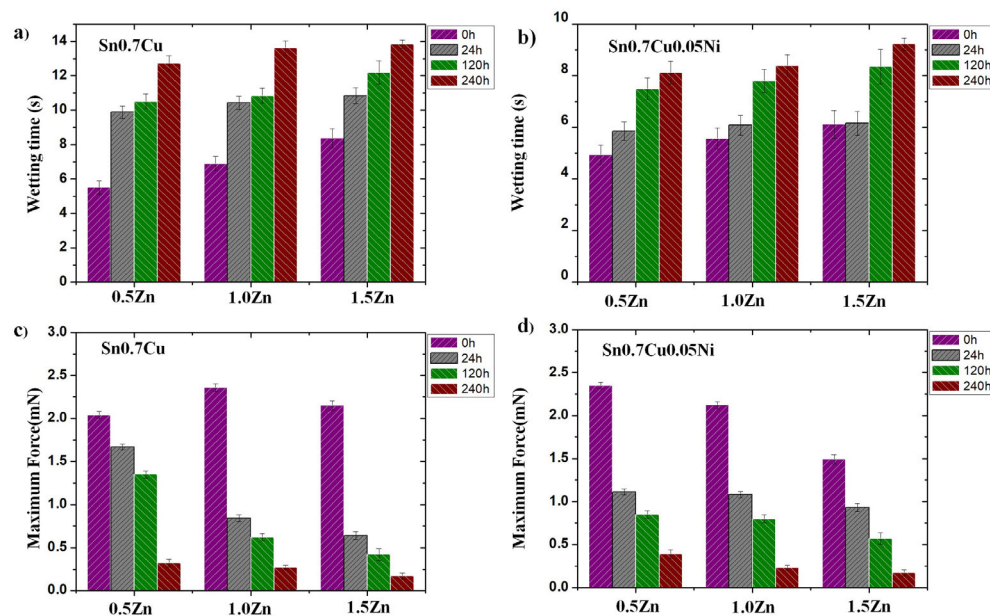


Figure 4. Effect of Sn-0.7Cu-0.05Ni-xZn solder ball on wetting time, a) Sn-0.7Cu coating, b) Sn-0.7Cu-0.05Ni coating and on maximum force, (c) Sn-0.7Cu coating and (d) Sn-0.7Cu-0.05Ni coating.

4. Conclusions

This study investigated the solderability of Sn-0.7Cu-0.05Ni-xZn solder ball to the Sn-0.7Cu and Sn-0.7Cu-0.05Ni solder coating that influenced by the aging process. The conclusion was summarized as follows:

- i. The Sn-0.7Cu-0.05Ni solder coating show better wettability compared to Sn-0.7Cu solder coating in dipping test.
- ii. The IMC thickness of Sn-0.7Cu-0.05Ni were higher than Sn-0.7Cu solder coating IMC thickness.
- iii. The addition of Zn into Sn-0.7Cu-0.05Ni solder ball reduced the solderability of solder coating for both solder coating.

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