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EFFECT OF TIN COATING THICKNESS ON TIN WHISKERS FORMATION AND GROWTH

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ABSTRACT

The effect of various thicknesses of tin coating towards tin whiskers formation and growth in 30°C/60%RH environmental condition had been studied. Electroless plating method was used to coat a layer of tin onto copper, Cu substrates. Three different thicknesses were obtained by controlling the plating times of immersion tin. 8 minutes, 12 minutes, and 20 minutes of plating times produced 1.2µm, 1.5µm, and 2.3µm thickness of tin coating respectively. After storage time up to twelve weeks under 30°C/60%RH environmental condition, it was found that the length of tin whiskers in thinnest tin coating (1.2µm) is 48.96µm, followed by 54.24µm in thicker tin coating (1.5µm), and the longest tin whiskers was recorded as 58.58µm in thickest tin coating (2.3µm). Based on the results, it was clearly shows that the thickness of tin coating affects the growth of whiskers as the thickest tin coating promotes longest whiskers compare to the thinnest tin coating.

1. INTRODUCTION

Pure tin was extensively used as tin surface finish to replace tin-lead alloy since lead had been banned in industry. Banning of using lead in industry was enforced due to concern towards human health and environment because of toxicity of lead which can affect human health for long term period. The properties of pure tin such as non-toxicity (Vicenzo, 2011), good conductivity (Dimitrovska, 2009), good wettability, and cheapness (Illés, 2010) are the good reasons why pure tin became the choice to replace tin-lead alloy in electronic industry.

However, there many cases had been reported regarding tin whiskers formation on tin surface finish. Tin whiskers can be described as monocrsytalline metal protruding from tin surface finish which grow spontaneously and cause short circuit when it touch each other (Horvath, 2013). Tin whiskers formed as early after 24 hours plating stored in room temperature as reported by Jo *et al.* in his research (Jo, 2013). The conductivity of tin whiskers may cause serious failure towards components. Tin whiskers cases was revealed since 1950s and became interested topic among researchers since a lot of studied regarding tin whiskers was published in literature (Puttlitz, 2007).

Even though the studied of tin whiskers was done by many researchers for more than six decades, the exact mechanism of tin whisker growth is still not completely understood. To date, researchers agreed that the main factor of tin whiskers growth is due to compressive stresses generates by intermetallics compounds (IMCs) types Cu_6Sn_5 which located between Cu substrate and tin layer (Baated, 2011, Dimitrovska, 2009, Miller, 2010). In order to relieve the stress in tin layer, whiskers form and grow spontaneously.

Plating thickness is one of the factor which can affect the growth of tin whisker (Miller, 2010). Most of researchers found that whiskers growth in the range of 1 – 2 µm of plating thickness (Baated, 2011, Susan, 2013). Miller *et al.* reported that 10 – 250 µm tin whiskers grew on 1 µm tin coating onto Cu substrate stored in room temperature within 11 days (Miller, 2010). Jo *et al.* mentioned the thicker coating would reduce the whisker density as it might reduce the compressive stress in tin layer (Jo, 2013). Therefore this study was carried out in order to provide better understanding regarding the effect

of tin coating thickness towards tin whiskers formation and growth.

2. EXPERIMENT

2.1 Experimental Apparatus

Materials used in this research is Cu substrate with dimension of 40 x 20 x 1 mm. Plating bath equipped with stainless steel heating coil was set up for plating process in order to maintain the temperature of plating. The chemical composition of plating solution was prepared according to Table 1 below. Then after all samples were plated, the samples were stored in humidity chamber (Memmert HCP 108) with temperature of 30°C/60% RH which comply the JEDEC standard No. 22-A121A for temperature/humidity testing of whiskers. In material characterization part, field emission scanning electron microscopy, FESEM (Supra-35VP, Carl Zeiss) equipped with energy dispersive x-ray, EDX was used to analyze the whiskers formation and composition respectively. Whiskers length was measured by using software (i-SOLUTION/LITE). Optical microscope (Nikon-MIDROPHOT-FXL) was used to measure the thickness of tin coating.

Table 1 Chemical composition for tin solution

Chemical	Composition
Stanneous chloride	20 g/L
Hydrochloric acid (37% ml)	37 ml/L
Sulfuric acid (50% ml)	50 ml/L
Sodium Hypophosphite (gm)	16 g/L
Thiourea	200 g/L
Phenolsufonic acid	5 ml/L
Temperature	75 °C

2.2 Technique

Tin surface finish was produced by using electroless plating method. Pre-treatment process on Cu substrate was performed prior to plate to remove oxide layer and activate the Cu surface. After the Cu substrate was ground by using silicon carbide paper, the Cu substrate was immersed in alkalinity solution; temperature of 70 - 90°C for 5 minutes, then soak in sodium hydroxide, NaOH solution; 60°C for 3 minutes, followed by immersed in 10% sulphuric acid, H_2SO_4 solution for 1 minute, and lastly soak in Palladium Chloride solution for 3 minutes to activate the Cu surface. The Cu substrate was rinsed in distilled water after every single step of pre-treatment. Then the samples was immersed in tin solution for 8 minutes, 12 minutes, and 20 minutes to get three different thicknesses of tin coating. The chemical composition of tin solution is as in Table 1. After plating process was completed, the samples were dried and stored in humidity chamber with environmental condition of 30°C/60% RH for up to 12 weeks. The fresh plated samples for each three different thicknesses were cut, mount, grind, and polish to provide the cross-section samples in order to measure the thickness of tin coating. The samples were checked by using FESEM according to certain interval periods; 1 week, 4 weeks, 8 weeks, and 12 weeks. Then the whiskers length was measured by using i-SOLUTION/LITE software based on FESEM micrograph.

3. ANALYSIS

3.1 Effect of tin coating thickness

In this study, the plating time was controlled in order to get three different thicknesses of tin coating. Based on the result, the longer plating time produced thicker tin coating due to more Sn atom deposited on Cu substrate. The plating times are 8 minutes, 12 minutes, and 20 minutes which produced 1.2µm, 1.5µm, and 2.3µm thickness of tin coating respectively. Figure 1 shows the graph of whiskers length over storage time in 30°C/60%RH environmental condition for all three thicknesses which are 1.2µm, 1.5µm, and 2.3µm according to certain interval time (1 week, 4 weeks, 8 weeks, and 12 weeks). Based on the graph, whiskers length is directly proportional to the storage time for all three thicknesses in 30°C/60%RH environmental condition. In 1.2µm tin coating, the whiskers growth from 11.83µm, 15µm, 23.6µm, and 48.96µm for interval period of 1 week, 4 weeks, 8 weeks, and 12 weeks respectively. Same goes to the whiskers in 1.5µm tin coating where the whiskers growth effectively from 13.93µm, 17.13µm, 24.25µm and 54.24µm for period up to 12 weeks. In 2.3µm tin coating, whiskers length was recorded as 15.45µm, 18.38µm, 26.35µm, and 58.58µm according to storage time 1 week, 4 weeks, 8 weeks, and 12 weeks respectively. Based on the results, the thinnest tin coating, 1.2µm has the shortest whiskers length while the thickest tin coating, 2.3µm has the longest whiskers in all interval time up to 12 weeks. Most researchers reported that 1-2µm tin coating thickness would promote the growth of whiskers as more whiskers were found in that thickness (Baated, 2011, Cheng, 2011, Susan, 2013). However Oberndoff *et al.* in (Crandall, 2013) reported that no whiskers were found in 11.6µm tin coating thickness stored in ambient temperature up to 325 days. Cheng *et al.* also reported that number of whiskers drop drastically in 4µm tin coating thickness while there is no whiskers was observed in 8µm tin coating thickness except hillocks whiskers for samples stored in vacuum condition around 10^{-4} Torr at 160°C for 7 days (Cheng, 2011). Jo *et al.* mentioned in his report that the compressive stress in tin whiskers is less in thicker tin coating hence reduce the number of whiskers (Jo, 2013).

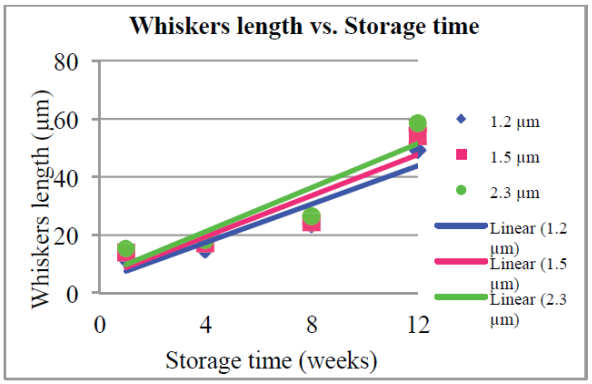
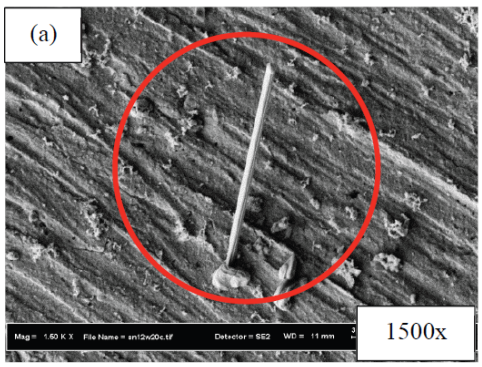
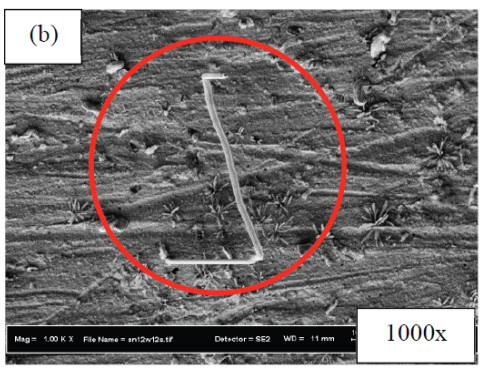


Figure 1 Whiskers length vs. storage time in 30°C/60%RH environmental condition

3.2 Types of whiskers

Whiskers formed in various types and shaped, however it has consistent cross-sectional shape according to the characteristics of tin whiskers given by JEDEC standard No. 22-A121A. In this study, straight, bent, twist, and with striations whiskers were observed and there is no hillocks type was found. Figure 2 (a), (b), (c), and (d) shows the straight, bent, twist, and with striations whiskers respectively. Whiskers are shown as in the circle.





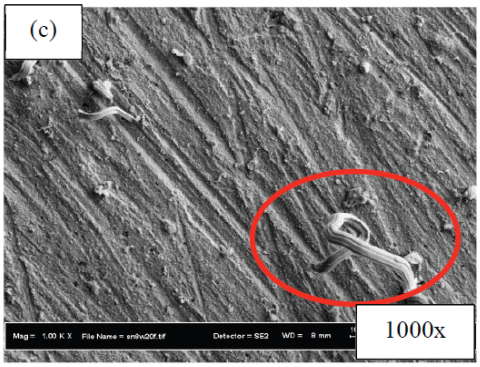


Figure 2 Types of whiskers (a) straight, (b) bent, (c) twist, and (d) with striations.

CONCLUSION

The effect of various tin coating thicknesses towards whiskers formation and growth in 30°C/60%RH environmental condition has been studied for certain interval period from 1 week up to 12 weeks. Based on the results it is clearly shows that the thickness of tin coating affects the whiskers growth which the thickest tin coating (2.3µm) generates longest whiskers compare to the thinnest tin coating (1.2µm) after 12 weeks storage in condition stated as above. Whiskers growth over time of storage for all three different thicknesses as the longest whiskers recorded is 58.58µm growth in thickest tin coating, 2.3µm after 12 weeks storage. Types of whiskers observed in this study are straight, bent, with striations, and twisted.

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