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Tin Whiskers Formation and Growth on Immersion Sn Surface Finish under External Stresses by Bending

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Abstract. Deposited tin (Sn) layers used as lead-free solderable finish on the semiconductor devices are known to form whiskers. These whiskers are a single crystal of tin that spontaneously grows from the surface of tin within weeks to years. Thus, they can cause shorts and the failure of a whole electronic circuit. In this research, the effect of external stresses applied by bending on the tin whiskers formation and growth was investigated on immersion Sn surface finish. The plating time was 10 minutes to produce 1.4 μm coating thickness on the copper substrate and exposed for 1, 4, and 8 weeks under the environment of 30°C/60% RH for bent and non-bent samples. It was found that the non-bent Sn surface had uniform ts distributed on the entire surface. Unlike the non-bent Sn surface, the surface of bent samples had non-uniform tin whiskers distribution. The tin whiskers formed more and grew longer at the lower stress region of the bent surface as compared to the higher stress region, based on the micrograph observed using the field emission scanning electron microscopy (FESEM).

1. Introduction

The initiative of removing lead (Pb) from the materials set within the soldering technology in microelectronics industry has created many challenges in research and development. One of the issues is to replace Pb with other suitable materials. Pure tin (Sn) and alloys with high Sn content have been the leading choices for many manufacturers. Pb was deemed a toxic material in electronic components and was subsequently banned, making pure Sn the right substitute due to its good conductivity [1], good wettability [2], and low cost [3]. These Sn finishes, however, have the tendency to spontaneously grow whiskers on the surface, which is considered by some to be a potential reliability concern as the whiskers can continuously grow and may cause shorting between components. Tin whiskers on Sn surface finish studies have been reported by many researchers [2,4-10] as it has become a major concern in optimizing the use of Pb-free Sn alloys in the electronic industry. Most of the previous studies focused on whisker growth on electroplated tin and almost none used immersion tin plating.

The main purpose of this research is to investigate and understand the effects of external stress under controlled environmental storage conditions such as temperature and humidity on tin whiskers formation and growth, specifically on immersion Sn surface finish since deposition of Sn on Cu using immersion process is a residual stress-free coating. Externally applied stress will be induced by bending to simulate the effect of stress on the formation and growth of whiskers. In this study, as tin whiskers growth is mostly a stress related phenomenon, the findings of Sn behaviour were used to interpret the process of stress build up and relief in both non-bent (as-plated) and bent Sn. The study is taken to understand the mechanism of tin whiskers growth when external stress is applied through the bending process of the coated materials.

2. Experimental Procedure

Whisker growth has been observed on a number of different substrate materials commonly used in the electronics industry. The substrate material used in the experiment was a commercial oxygen-free pure copper with 1 mm thickness, 35 mm width and 50 mm length. Plating process by immersion was conducted by following the method produced by Fadil et al. [11]. Plating bath equipped with stainless steel heating coil was set up for the plating process in order to maintain the temperature of plating. The plating bath was prepared by dissolving 20 g/L of stannous chloride as a tin precursor, 16 g/L of sodium hypophosphite as a reducing agent, 37 ml/L of hydrochloric acid (37% ml), 50 ml/L of Sulfuric acid (50% ml), 200 g/L of thiourea, and 5 ml/L of phenolsulfonic acid in 1L distilled water. The immersion tin process was conducted at temperature of 75 °C and the deposition time was 10 minutes in order to obtain 1.4 μm of tin thickness.

Reflow process was performed in a reflow oven with the peak reflow temperature set at 260°C freshly after the coating process. After the reflow process, the samples were slowly bent to 45° until a crack occurred. The bending process was conducted by following the JEDEC standard, IPC/JEDEC-9702 [12]. Two sets of samples; bent and non-bent samples (Figure 1) were then stored in the humidity chamber for time intervals of 1, 4, and 8 weeks under the environment of 30°C/60% RH. The surface morphologies of the bent samples were examined using field-emission scanning electron microscopy (FESEM) at three different locations; the edge (farthest location from the crack), crack, and center (region between the edge and the crack).

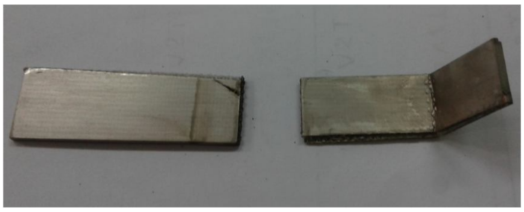

Figure 1. Photo of as prepared sample (left) and bent sample (right).

3. Results and Discussion

Figure 2 shows the whiskers formation for non-bent samples exposed under the environment of 30°C/60% RH for 1 week (Figure 2.a), 4 weeks (Figure 2.b), and 8 weeks (Figure 2.c). From Figure 2, it can be clearly seen that the whiskers have grown longer over exposure time. Non-bent samples were observed at the entire surface and the observation found was that the formation of whiskers were considerably uniform at every area on the samples. This is due to the uniformly distributed stress experienced on the sample rather than the stress caused by bending, which would result in higher stress at the crack region and lower stress at the outer crack region.

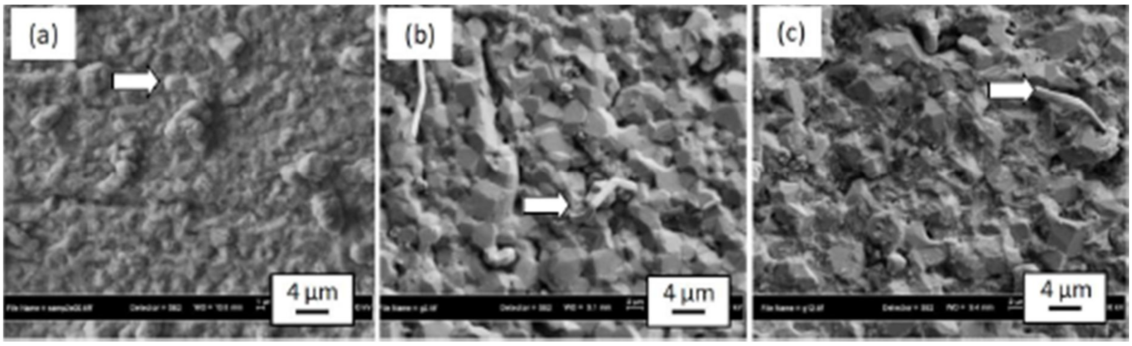

Figure 2. FESEM micrographs of tin whiskers formed on the non-bent surface exposed for (a) 1 week, (b) 4 weeks, and (c) 8weeks under 30°C/ 60% RH.

Figure 3, 4 and 5 show the whiskers formation on the bent samples at selected areas exposed for 1 week, 4 weeks, and 8 weeks respectively. Three different regions were examined under FESEM which

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are the edge (the region farthest from the bent point), the centre (the region between the edge and the bent point), and the crack region (the bent point itself). FESEM observation found that more whiskers formed at the edge area than the crack area after 1 week (Figure 3), 4 weeks (Figure 4) and 8 weeks (Figure 5) exposed under the environment of 30°C/60% RH. This was due to the higher stress concentration at the crack area created by bending.

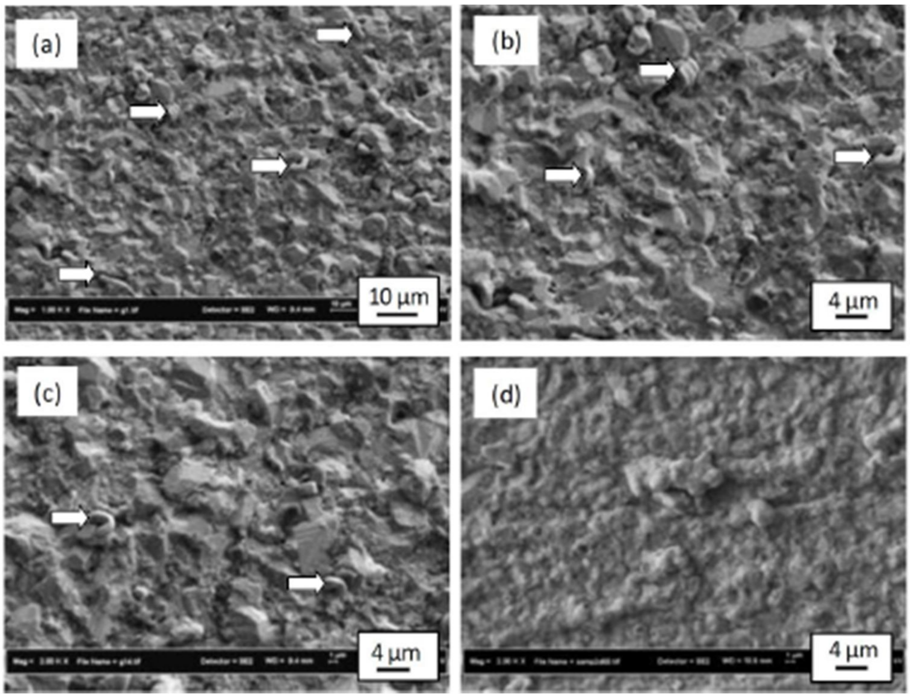

Figure 3. FESEM micrographs of whiskers formed at the (a) edge (low magnification), (b) edge (high magnification), (c) centre, and (d) crack area for bent surface after 1 week exposed under 30°C/ 60% RH.

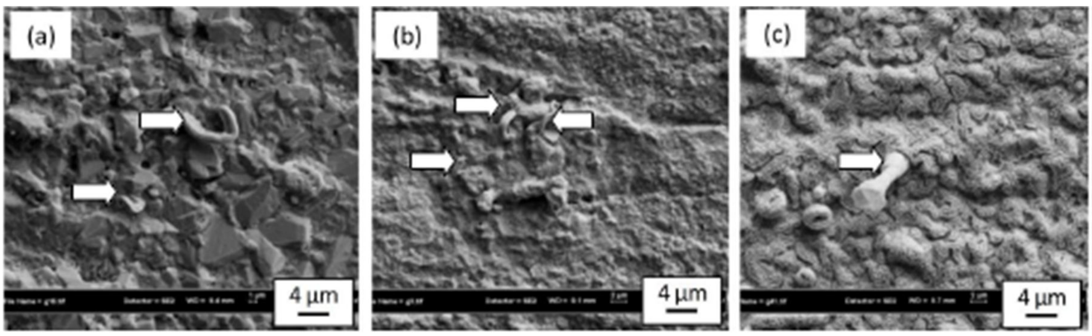

Figure 4. FESEM micrographs of whiskers formed at the (a) edge, (b) centre, and (c) crack area for bent surface after 4 week exposed under 30°C/ 60% RH.

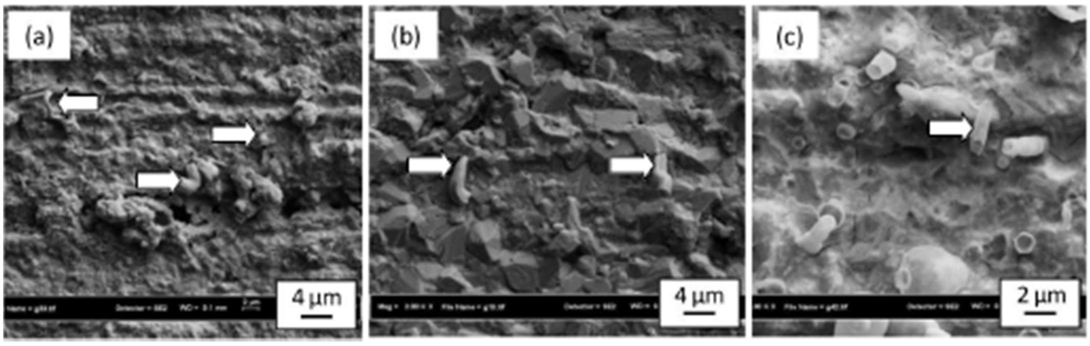

Figure 5. FESEM micrographs of whiskers formed at the (a) edge, (b) centre, and (c) crack area for bent surface after 8 week exposed under 30°C/ 60% RH.

The whiskers formation and growth behavior can be explained clearly by the schematic diagram in Figure 6. The numbers of whiskers formed at the bent area were less than the outside region. This is because the outer region has lower stress compared to the crack area. It should be understood that the bent samples have higher stress concentrated at the crack and stress decreases towards the farther region from the crack area. This resulted in the migration of Sn atoms from higher to lower stress region to release the stress [13].

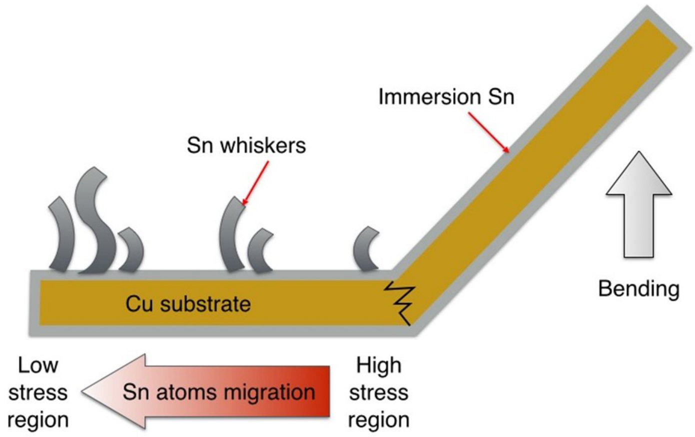

Figure 6. Schematic diagram of stress effect on tin whiskers formation for immersion Sn surface finish.

4. Conclusion

The effect of externally applied stress by bending caused the least tin whiskers formation at the crack region, more at the centre region, and the most tin whiskers formation at the edge region of the Sn surface finish. This is because the crack area has a high stress concentration while the centre and edge has lower stress concentration. The whiskers formation increases with lower stress as Sn atoms migrate from higher to lower stress concentration region to release the stresses. Unlike the bent Sn surface, the non-bent Sn surface has uniform tin whiskers distributed on the entire surface.

Acknowledgement

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