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The effects of humidity on tin whisker growth by immersion tin plating and tin solder dipping surface finishes

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Abstract

The drive to replace lead (Pb) from electronics has led to the replacement of tin (Sn) alloys as the terminal plating for electronic devices. However, the deposition of Sn based alloys as the component surface finish tends to induce Sn whisker that causes unintended electric shorts when the conductive whiskers grow across to the adjacent conductor. Internal stress is considered as the driving force that causes the growth of Sn whiskers. In this study, stress type of elevated temperature/ humidity exposure at 55°C/ 85%RH with the storage for up to 24 months was conducted to define the acceleration factor in samples with deposition of immersion Sn plating and Sn solder dipping. The addition of Nickel (Ni) under-layer was also applied to examine the correlation to field conditions. The results showed that the whisker length increased in high humidity irrespective of the deposition methods. It was also shown that pure Sn solder dipping mitigated the whisker growth but does not completely prevent it when alloying Sn with 0.4%wtCu. Additionally, Ni under-layer was indicated to be more efficient in mitigating the growth of whisker by prolonging the incubation time for whisker formation.

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Keywords: Immersion tin; solder dipping; tin whisker; humidity

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1. Introduction

The move to ban the use of Pb in the electronics industry has precipitated the selection of pure Sn and Sn-based Pb-free alloys as the component terminal plating especially for printed circuit board (PCB) surface finish when the Restriction of Hazardous Substances Directive (RoHS) took effect on 1 July 2006. Pure Sn is increasingly adopted to replace Pb among various Pb-free surface finishes due to the promising compatibility with existing Sn-Pb assembly processes and systems. Sn is non-toxic, low cost and able to exhibit excellent solderability [1]. Reliable solder joint is indicated by the metallurgical interaction between the component surface finish and the solder alloy. However, the reliability of using pure Sn and Sn based Pb-free alloys in high density PCB assembly is a major concern for many PCB manufacturers because of the spontaneous growth of Sn whiskers protruded out of the Sn layer surface leading to short circuits, system failures and severe loss to electronics devices. The currently accepted theory states that the factors of these Sn whiskers growths are including elevated temperature at relative humidity, residual stress, mechanical force, intermetallic compounds (IMC) formation and oxide layer [2]. Additionally, increasing temperature will accelerate diffusion rate of atoms with Sn plated surface finish. Nevertheless, elevated temperature without humidity conditions did not result in stimulating whisker growth which had been reported by Dittes et al. [3]. Further study on the humidity effects on Sn whisker formation suggested that high humidity conditions induce severe oxidation and corrosion [2]. High humidity was accelerated by the condensation process, and as a result increased the volume in the Sn layer and formed compressive stress on the surface finish. Thus, the present study was carried out to further investigate the effects of humidity and addition of Ni under-layer on Sn whiskers formation for Sn plated surface finishes.

Nomenclature

RH	relative humidity
PCB	printed circuit board
RoHS	Restriction of Hazardous Substances Directive
IMC	intermetallic compounds
JEDEC	Joint Electron Device Engineering Council
FESEM	field emission scanning electron microscope
EDX	energy dispersive x-ray analysis
FIB	focused ion beam

2. Experimental Methodology

The copper (Cu) based substrates were first subjected to a series of pre-treatment procedures followed by deposition of immersion Sn plating, pure Sn solder and Sn0.4Cu solder dipping. Electroless Ni under-layer was deposited as the mitigation method. JEDEC standard JESD22-A121A was applied as a guideline to investigate the Sn whiskers formation [4]. In this study, the accelerated whisker test was conducted by storing the samples deposited with and without Ni under-layer at high temperature with relative humidity of (55 °C/85 %RH) for up to 24 weeks (approximately 4000 hours) to promote atomic diffusion in a humidity chamber. Additionally, a set of Sn plated Cu substrates with the same deposition parameters were prepared and stored under ambient conditions (28°C±2 with uncontrolled humidity) as reference. Whiskers growth was examined at various time intervals using field emission scanning electron microscope (FESEM) and energy dispersive x-ray analysis (EDX). Due to the large number of whiskers, the average of five longest whiskers per sample was recorded. The length of a whisker is defined in accordance to JEDEC standard No. 22-A121A with a single measurement of the effective shorting distance [4]. Whisker length was measured as the straight line distance from the termination surface to the most distant point on the whisker where the radius of sphere containing the whisker with its centre located at the point of emergence. A focused ion beam (FIB) methodology was used to examine the microstructure of intermetallic compounds (IMC) by preparing cross-sections from selected samples to observe the IMC layer, grain structure of the Sn layer and grain structure at the base of the Sn whisker.