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Isothermal Aging of Low-Ag SAC with Al addition

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Abstract

Zinc sulfide (ZnS) thin films have been successfully deposited via spray pyrolysis using an aqueous solution of thiourea and zinc Amongst the candidates of lead-free solders, eutectic or near eutectic Sn-Ag-Cu or SAC has been found to be the most suitable candidate to replace the traditional tin-lead (Sn-Pb) solder. However, due to the higher cost of SAC (expensive Ag), research have now been directed to find a lower cost lead-free solder with comparable or better performance to the Sn-Pb or SAC, i.e low Ag SAC or Sn-Cu solders. The solder alloys developed in this work were SAC 0305 (0.3 wt% Ag, 0.5 wt% Cu and bal. Sn) and SAC0305 with 1 wt% Al and 2 wt% Al. The addition of Al is expected to refine the β-Sn grains and contribute to higher solder strength. Characterization of the solder alloys focused on the bulk solder microstructure, intermetallic compound (IMC) evaluation and wettability of solder alloys in reflowed and aged conditions. Reflow temperature was 270°C while aging was done isothermally in normal atmosphere for 100, 200 and 500 hours at 100°C and 150°C. Microstructure of bulk solder and the IMC formed at interface between solder and Cu substrate were observed using SEM equipped with EDX. Wettability of solder was evaluated via wetting force and time, and the wetting angle between solder and the Cu substrate. A low Ag content resulted in fine Ag_3Sn IMC as compared to much larger needle Ag_3Sn observed in the commercial SAC 305 (Ag 3.0 wt%). With Al addition, SEM result showed finer β-Sn dendrites with fine Ag_3Sn and Cu_6Sn_5 distributed within the eutectic colony of the bulk solder, and also thinner IMC layer in reflowed samples. Isothermally aged samples on the other hand, showed thicker IMC layer for Al added solder samples. This could be attributed to the finer β-Sn dendrites in the bulk solder providing more diffusion path and increased the thickness of IMC layer. The IMC formed at the interface between solder and the copper substrate was identified as Cu_6Sn_5 in reflowed samples, and both Cu_6Sn_5 and Cu_3Sn when aged. Wettability of the solder alloys decreased with the addition of Al.

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1. Introduction

For centuries, tin-lead (Sn-Pb) solder has been used as the interconnect material in electronic packaging industries due to its excellent soldering properties that gives good solder joint reliability[1]. Nevertheless, the concern over toxicity of Pb in the past few decades has lead to extensive research on lead free solders. Amongst all, the near eutectic SAC305 (Sn- 3wt%Ag-0.5wt%Cu) and SAC405 (Sn-4wt%Ag-0.5wt%Cu) solders were found to be the most suitable candidates to replace Sn-Pb solder especially in surface mount technology (SMT) since Cu and Ag have an outstanding thermal and electrical properties[2]. However, as Ag is very expensive, the price of SAC305 and SAC405 solders are far higher than Sn-Pb solder. Therefore, in order to reduce cost, extreme-low Ag content (0.3 wt% Ag) SAC solder was used as the base material in this project. Previous researchers have reported that reducing the amount of Ag in SAC solder considerably reduced the amount of brittle Ag_3Sn IMC formed in the bulk solder thus gives more ductile and compliant solder for high impact applications[3]. Sufficient thickness of IMC layer is necessary for good wetting but excessive growth of this layer has a detrimental effect to the reliability of the solder joint since IMC is very brittle in nature. Additions of various minor metal alloying elements have been reported to help reducing the thickness of the interfacial IMC layer[4,5]. According to Young-Kun et al.[6], Al could suppress the formation of Cu-Sn IMC in the bulk solder thus it is expected to give thinner IMC layer at the solder joint. Moreover, Al is non toxic and its abundant availability makes it cheaper compared to other metals. There were many works reporting on the mechanical properties and microstructure of bulk solder after the addition of Al into the low Ag content SAC solder [7,8] but to the best of our knowledge, there were no reported works focusing on the interfacial IMC layer at the solder joint before and after isothermal aging and its relation to the microstructure of the bulk solder. Therefore, this paper reports on how the Al addition affects the microstructure of bulk solder and the interfacial IMC layer before and after aging. The wettability of the solders was also reported in this paper as wettability is an important criterion to assess a solder.

1. Materials and Method

Three types of solders were fabricated via casting; SAC0305 (0.3 wt% Ag, 0.5 wt% Cu and bal. Sn), SAC0305-1Al (SAC 0305 with 1 wt% Al) and SAC0305-2Al (SAC 0305 with 2 wt% Al). Sn ingot, Cu shots and Ag beads were melted in a box furnace at 350°C initially, followed by 500°C, before poured into a preheated mild steel mold at 350°C. The soaking time was set for 1 hour at each stage. Meanwhile, for SAC0305-1Al and SAC0305-2Al solder alloys, 1 wt% and 2 wt% Al were added into SAC0305 at 600°C followed by 700°C with 1 hour soaking time each. The solder alloys were ground with SiC abrasive paper grit 100 until 2000 before polished using 1 µm alumina powder. Samples were then chemically etched with 5 % HNO_3 -2 % HCl-93 % CH_4O to reveal the microstructure before observed using Field Emission Scanning Electron Microscope (FE-SEM) equipped with Energy Dispersive X-Ray spectroscopy (EDX). The wettability was determined using a solder checker model SAT-5100 from Rhesca Co. Ltd. The temperature was set at 270°C with 2 mm immersing depth and 10 seconds immersing time. Maximum wetting force and wetting time were obtained from the wetting balance curve that was plotted automatically by the embedded software. To make solder joint, solder alloys were cold rolled to form sheet with a thickness of 0.5 mm. The sheet was punched to form a solder disk with 6 mm diameter. Cu sheet of 0.5 × 10 × 10 mm was applied with activated rosin (RA) flux to remove contaminants prior to reflow. Reflow process was done inside a reflow oven with the reflow temperature set at 270°C. Reflowed solders were then isothermally aged at 100°C and 150°C for 100 hours, 200 hours and 500 hours. Subsequently, reflowed and isothermally aged solders were cut cross-sectionally before mounted using epoxy resin. Wetting angle was measured after grinding and polishing process while IMC analysis via FE-SEM was done after the joint was chemically etched with the same solution as mentioned above. The IMC thickness was measured using i-Solution DT image analyzer software.

2. Results and discussion

2.1. Microstructure of bulk solder

Figure 1(a), (b) and (c) show the microstructure of SAC0305, SAC0305-1Al and SAC0305-2Al bulk solder alloys, respectively. It could be clearly seen in the figure that the size of β-Sn dendrites as well as the interdendritic