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Effect of Corrosion in Alkaline Solution to the Microstructure and Mechanical Properties of Cu/Sn-9Zn/Cu

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Abstract

Corrosion resistance performance of binary eutectic tin-zinc (Sn-9Zn) solder was investigated in 6 M potassium hydroxide. The corrosion resistance performance of the solder was studied through potentiodynamic polarization. Double dissolution peaks were seen during polarization, indicating preferential dissolution of elements from this solder. Tensile strength measurement shows substantial loss of ultimate tensile strength (UTS) of the joint made after polarization. Microstructure characterization proved that weak spots were introduced as active elements removed during polarization. This showed that microstructure alteration contributed to the loss of UTS after polarization.

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Keywords: Lead-free solder; Sn-9Zn; Corrosion; Joint; Alkaline.

1. Introduction

Accumulated evidence on lead (Pb) toxicity raised concerns on the presence of this metal in the environment and had prompted legislative effort to limit or ban the use of Pb-containing solders in all applications[1]. This ban became a global issue because of its effect on the entire electronics industry. It also led to intensive research on the

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development of suitable alloys to replace Sn–Pb solders. The tin-zinc (Sn-9Zn) solder is one of the most famous lead-free (Pb-free) solders as it possess comparable melting temperature with the traditional yet toxic Sn-Pb solders[1]. The mechanical properties of Sn-9Zn solder is also reported adequate to be used in electronic industry[2, 3]. However, the application of this solder was found to be limited due to the inferior corrosion resistance with that of Sn-Pb solders[1].

Most of the literatures on the corrosion properties of Sn-9Zn were reported to utilize sodium chloride (NaCl) as the corrosive electrolyte. For example, Hu et al.[4] studied the effect of reflowing process on the potentiodynamic polarization behavior of Sn–*x*Zn deposits (x = 2, 5, 9, and 13 wt. %) in 3 wt. % NaCl at constant scan rate of 1 mV s^{-1}. It is described that the distributions of Zn atoms due to the reflowing process significantly affect the passivation properties of Sn-*x*Zn solders. Meanwhile, Wu et al.[5] exposed that needle-like and sheet-like corrosion products as well as a number of localized pittings were shown to cover parts of the surface this binary alloy solder after immersion in 3.5 wt. % NaCl.

Until recently, the study of corrosion properties of Sn-9Zn in other solutions, especially alkaline solution was found to be very limited. Electrolyte for alkaline batteries such as potassium hydroxide (KOH) is known to be very corrosive due to aggressive nature of its ions[6-8]. Furthermore, Sn-9Zn was described to experience localized corrosion under the attack of this solution at the concentration of 6 M in both open-circuit potential[9] and polarized[10] corrosion analyses. Though, the correlation between different corrosion conditions to the mechanical properties of Cu/Sn-9Zn/Cu solder joint due to the interaction with 6 M KOH is scarcely reported. This work aims to investigate the effect corrosion Sn-9Zn solder alloy in 6 M KOH by means of the potentiodynamic polarization analysis on the mechanical and microstructure analyses.

Nomenclature

Sn-9Zn	Tin-zinc
UTS	Ultimate tensile strength
Cu	Copper

2. Methodology

Pure Sn (Malaysia Smelting) and Zn (Sigma-Aldrich) were cleaned, weighed, and co-melted in a porcelain crucible using an induction furnace at 600 °C in the presence of nitrogen (N_2) gas. To ensure homogenization, the molten solder was thoroughly agitated during melting. The molten Sn–9Zn solder was cast and air-cooled to room temperature for solidification.

The Cu/Sn-9Zn/Cu butt joint for tensile strength measurement was prepared by using two Cu plates, each measuring 50.00 mm x 1.00 mm x 5.00 mm, and were joined using a solder alloy (1.00 mm x 1.00 mm x 5.00 mm). The setup and procedure for the joint making process were carried out as previously reported[11]. The soldered joint was air cooled to allow the joint to solidify on a hot plate. Excess alloy on the Cu plates was removed after solidification. To determine the tensile strength of the joint, INSTRON Advanced Mechanical Testing System 5900 series was used at a crosshead speed of 2 mm/min. The images of the joint prior and after the tensile test were taken using a Hitachi TM 3000 table-top SEM to further investigate the fracture surface.

The electrochemical characterizations of Sn-9Zn-*x*In solder alloys were carried out in a single compartment cell. A three-electrode system was used with the mounted sample as the working electrode having an exposure surface area of 0.196 cm^2; a platinum rod and Hg/HgO were used as the counter electrode and reference electrode in 6 M KOH electrolyte, respectively. The selection of Hg/HgO electrode was due to its excellent stability in alkaline solutions. The measurement was performed using AUTOLAB PGSTAT 30 and controlled with General Purpose Electrochemical System (GPES) interface software. The scanning rate used was 2.50 mV s^{-1} after the steady-state