Journal of ELECTRONIC MATERIALS, Vol. 42, No. 2, 2013
DOI: 10.1007/s11664-012-2247-7

Effect of Alloying Elements on the Electrification–Fusion Phenomenon in Sn-Based Eutectic Alloys

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The effect of alloying elements on the electrification–fusion phenomenon in Sn-based eutectic alloys (Sn-9Zn and Sn-37Pb) under alternating current was investigated in this study. Experimental results showed that the critical fusion current densities (CFCD) of Sn-based alloys were closely related to both the conductivity of the individual phase and the eutectic temperature. While the electrical current density value required to trigger microstructural evolution for the Sn-9Zn alloy was larger than the CFCD of pure Sn (1399 A/cm^2), that for the Sn-37Pb alloy was not. Through *in situ* examination of the microstructural evolution during electrification–fusion tests, the initial liquation site emerged from individual Sn-based eutectic phase (i.e., the Sn/Zn eutectic phase or Sn/Pb eutectic phase); The liquation regions in the Sn/Zn eutectic phase and β-Sn phase of the Sn-9Zn alloy were not concentrated over the observation area. The liquation regions in the Sn/Pb eutectic phase and β-Sn phase of the Sn-37Pb alloy were extensively distributed over the observation area. According to the fusion distributed density at the observation area, the Sn-9Zn alloy has great potential to replace the Sn-37Pb alloy in future electrification applications.

Key words: Lead-free solder, electrification–fusion-induced fracture, critical fusion current density, liquation

INTRODUCTION

The Sn-Pb system has been used as a traditional solder alloy for many years because of its excellent wetting behavior. However, in terms of environmental protection and the de-leading bill, searching for lead-free solder alloys for use in the electronic packaging industry is imperative. One of the widely discussed elements that can combine with Sn to form solder alloys is Zn. Sn-Zn alloys have been considered as potential candidate lead-free solder materials because of their low eutectic point (9 wt.% Zn, 198°C) close to that of Sn-37Pb (183°C), low cost compared with other binary lead-free solder alloys, and excellent mechanical properties.[1,2] Electromigration (EM) effects occur between the interface of Sn-9Zn solder and Cu under direct-current (DC) electrical current stressing.[3,4] In general, stressing solders with a current density above 10^4 A/cm^2 for several hours will trigger EM,[5,6] or even lower levels of current density for some solders.[7–9] However, although the EM effect can be hindered in the case of alternating current (AC) in Pb-Sn solder joints,[10] AC will cause EM failure due to nonhomogeneous current distribution and suffer longer lifetime than DC.[11]

With the microminiaturization and increasing operational efficiency requirements of electronic devices, solder joints are inevitably subjected to higher electrical current densities. Therefore, failure of solder joints during electrification is highly possible and can be attributed to greater Joule heating. Moreover, Bi segregation may cause more severe Joule heating because of the higher resistivity of Bi in the Sn-Bi eutectic alloy.[12] Therefore, the relationship between microstructural variation and the applied electrical current density plays an important role in the electrification–fusion phenomenon of solder joints. Given the dearth of

(Received April 4, 2012; accepted August 26, 2012; published online October 19, 2012)