Journal of ELECTRONIC MATERIALS, Vol. 42, No. 4, 2013
DOI: 10.1007/s11664-012-2389-7

Effect of Ag on the Microstructure of Sn-8.5Zn-*x*Ag-0.01Al-0.1Ga Solders Under High-Temperature and High-Humidity Conditions

T.K. YEH,[1] K.L. LIN[1,2] and U.S. MOHANTY[1,3]

1.—Department of Materials Science and Engineering, National Cheng Kung University, Tainan 701, Taiwan, ROC. 2.—e-mail: matkllin@mail.ncku.edu.tw. 3.—e-mail: suryaudit@yahoo.com

The effect of Ag on the microstructure and thermal behavior of Sn-Zn and Sn-8.5Zn-*x*Ag-0.01Al-0.1Ga solders (*x* from 0.1 wt.% to 1 wt.%) under high-temperature/relative humidity conditions (85°C/85% RH) for various exposure times was investigated. Scanning electron microscopy (SEM) studies revealed that, in all the investigated solders, the primary α-Zn phases were surrounded by eutectic β-Sn/α-Zn phases, in which fine Zn platelets were dispersed in the β-Sn matrix. SEM micrographs revealed that increase of the Ag content to 1 wt.% resulted in coarsening of the dendritic plates and diminished the Sn-9Zn eutectic phase in the microstructure. Differential scanning calorimetry (DSC) studies revealed that the melting temperature of Sn-8.5Zn-*x*Ag-0.01Al-0.1Ga solder decreased from 199.6°C to 199.2°C with increase of the Ag content in the solder alloy. Both ZnO and SnO_2 along with Ag-Zn intermetallic compound (IMC) were formed on the surface when Sn-8.5Zn-0.5Ag-0.01Al-0.1Ga solder was exposed to high-temperature/high-humidity conditions (85°C/85% RH) for 100 h. The thickness of the ZnO phase increased as the Ag content and exposure time were increased. Sn whiskers of various shapes and lengths varying from 2 μm to 5 μm were extruded from the surface when the investigated five-element solder with Ag content varying from 0.5 wt.% to 1 wt.% was exposed to similar temperature/humidity conditions for 250 h. The length and density of the whiskers increased with further increase of the exposure time to 500 h and the Ag content in the solder to 1 wt.%. The Sn whisker growth was driven by the compressive stress in the solder, which was generated due to the volume expansion caused by ZnO and Ag-Zn intermetallic compound formation at the grain boundaries of Sn.

Key words: Lead-free solder, intermetallic compound, microstructure Sn-Zn-Ag-Al-Ga, temperature and humidity exposure

INTRODUCTION

Sn-Zn alloy has been considered as one of the most attractive lead-free solder alloys because it can easily replace Sn-Pb eutectic solder without increasing the soldering temperature. Nevertheless, despite its excellent mechanical properties, the eutectic alloy is susceptible to both oxidation and corrosion. Since poor oxidation resistance and poor compatibility with Cu substrate are two of the major problems associated with Sn-Zn solder alloys under high-temperature conditions, a considerable amount of effort has been made by researchers to overcome these drawbacks. Appropriate alloying elements[1] and flux have been used by authors to improve the wettability of Pb-free eutectic solder alloys. Some researchers[2–6] have used a third or fourth element such as Ag, Al, Ga, In, and Bi to improve the soldering properties of Sn-Zn eutectic alloy. Among them, addition of Bi to Sn-Zn eutectic alloy imparted superior soldering properties such as good wettability,

(Received March 7, 2012; accepted December 13, 2012; published online January 24, 2013)