Journal of ELECTRONIC MATERIALS, Vol. 42, No. 3, 2013
DOI: 10.1007/s11664-012-2343-8

Effect of Ag Content and the Minor Alloying Element Fe on the Mechanical Properties and Microstructural Stability of Sn-Ag-Cu Solder Alloy Under High-Temperature Annealing

DHAFER ABDULAMEER SHNAWAH,[1,5] MOHD FAIZUL MOHD SABRI,[1] IRFAN ANJUM BADRUDDIN,[1] SUHANA BINTI MOHD SAID,[2] TADASHI ARIGA,[3] and FA XING CHE[4]

1.—Department of Mechanical Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia. 2.—Department of Electrical Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia. 3.—Department of Material Science, School of Engineering, Tokai University, Hiratsuka 259-1292, Japan. 4.—Institute of Microelectronics, A_STAR (Agency for Science, Technology and Research), 11 Science Park Road, Singapore Science Park II, Singapore 117685, Singapore. 5.—e-mail: dhafer_eng@yahoo.com

This study compares the high-Ag-content Sn-3Ag-0.5Cu with the low-Ag-content Sn-1Ag-0.5Cu solder alloy and the three quaternary solder alloys Sn-1Ag-0.5Cu-0.1Fe, Sn-1Ag-0.5Cu-0.3Fe, and Sn-1Ag-0.5Cu-0.5Fe to understand the beneficial effects of Fe on the microstructural stability, mechanical properties, and thermal behavior of the low-Ag-content Sn-1Ag-0.5Cu solder alloy. The results indicate that the Sn-3Ag-0.5Cu solder alloy possesses small primary β-Sn dendrites and wide interdendritic regions consisting of a large number of fine Ag_3Sn intermetallic compound (IMC) particles. However, the Sn-1Ag-0.5Cu solder alloy possesses large primary β-Sn dendrites and narrow interdendritic regions of sparsely distributed Ag_3Sn IMC particles. The Fe-bearing SAC105 solder alloys possess large primary β-Sn dendrites and narrow interdendritic regions of sparsely distributed Ag_3Sn IMC particles containing a small amount of Fe. Moreover, the addition of Fe leads to the formation of large circular $FeSn_2$ IMC particles located in the interdendritic regions. On the one hand, tensile tests indicate that the elastic modulus, yield strength, and ultimate tensile strength (UTS) increase with increasing Ag content. On the other hand, increasing the Ag content reduces the total elongation. The addition of Fe decreases the elastic modulus, yield strength, and UTS, while the total elongation is still maintained at the Sn-1Ag-0.5Cu level. The effect of aging on the mechanical behavior was studied. After 720 h and 24 h of aging at 100°C and 180°C, respectively, the Sn-1Ag-0.5Cu solder alloy experienced a large degradation in its mechanical properties after both of the aging conditions, whereas the mechanical properties of the Sn-3Ag-0.5Cu solder alloy degraded more dramatically after 24 h of aging at 180°C. However, the Fe-bearing SAC105 solder alloys exhibited only slight changes in their mechanical properties after both aging procedures. The inclusion of Fe in the Ag_3Sn IMC particles suppresses their IMC coarsening, which stabilizes the mechanical properties of the Fe-bearing SAC105 solder alloys after aging. The results from differential scanning calorimetry (DSC) tests indicate that the addition of Fe has a negligible effect on the melting behavior. However, the addition of Fe significantly reduces the solidification onset temperature and consequently increases the degree of undercooling. In addition, fracture surface analysis indicates that the addition of Fe to the Sn-1Ag-0.5Cu alloy does not affect the mode of fracture, and all tested alloys exhibited large ductile dimples on the fracture surface.

(Received July 19, 2012; accepted October 30, 2012; published online December 8, 2012)