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ScienceDirect

Procedia Engineering 184 (2017) 214 – 222

Procedia Engineering

www.elsevier.com/locate/procedia

Advances in Material & Processing Technologies Conference

Effect of Bonding Time and Bonding Temperature on Lead-Free Solder Joints Dispersed Pillar Shaped IMCs

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Abstract

The effects of the bonding time and temperature on microstructures and the joint strength of solder joints dispersed pillar shaped intermetallic compounds (IMCs) with Sn-3.0Ag-0.5Cu (mass%, SAC) and Sn-3.0Ag-0.7Cu-5.0In (mass%, SACI) alloys were investigated. The effects of the electrode type and the joint height on them were also investigated. In the Cu/Cu joint with SAC, the length of the pillar shaped IMC increased with increasing the bonding time although the effect of the bonding temperature on it was negligible. The thick joint height was effective to form pillar shaped IMCs in the joint. In the Cu/Ni joint with SAC, thin pillar shaped IMCs formed in the joint. In the joints with SACI, the high bonding temperature was effective to generate a large quantity of pillar shaped IMCs regardless of the electrode type. The small amount of In addition is effective to increase the nucleation site of the primary IMC and the thick joint height is effective to form finer pillar shaped IMCs in the joint. The die shear force measurement revealed that the pillar shape IMC such as to connect both sides is effective to improve the joint strength.

Peer-review under responsibility of the organizing committee of the Urban Transitions Conference

Keywords: Lead-free solder; IMC; Microstructure; Interfacial reaction layer; Automotive application

1. Introduction

Due to RoHS restriction in EU, lead-free soldering has spread in assembly technology of electronic equipment and many studies on lead-free solder have been conducted all over the world [1]. Sn-Ag-Cu lead-free solder such as Sn-

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Peer-review under responsibility of the organizing committee of the Urban Transitions Conference
doi:10.1016/j.proeng.2017.04.088

3.0Ag-0.5Cu (mass%) has spread in various electronics products as the substitute of Sn-Pb eutectic solder [2-9]. For automotive applications used under severe conditions, Pb-rich high-temperature solder have been used. Although such Pb-rich solder has not been regulated by RoHS restriction yet, the use of lead-free solder as a substitue of Pb-rich solder has been expected [10-14]. In power modules used in automotive applications, a relative large joint for die bonding is required compared with ordinary products for surface mount electrical components. In such a large joint, inhibition of both generation and growth of the crack in the solder joint is very effective to acheive a high reliable joint. In particular, the propagation of the crack is issue rather than the occurrence of it. The authors have reported that pillar shaped IMCs formed in the joint are effective to inhibit the progress of the crack [15]. Moreover, the effects of the solder type and the electrode material on the microstructure and joint strength of the joint with dispersed pillar shaped IMCs have been reported [16]. The aim of this study is to investigate the effects of the bonding time and temperature on the microstructure and the joint strength of the lead-free solder joint dispersed pillar shaped IMCs with Sn-Ag-Cu-In and Sn-Ag-Cu alloys. The effects of the electrode type and the joint height on those of the joint were also examined.

2. Experimental procedure

Two types of lead-free solder were prepared as foil with approximately 0.4 mm thick. Table 1 shows chemical compositions and melting properties of solder investigated. The melting properties were investigated by differential scanning calorimetry (DSC) at a heating rate of 10 °C/min [16]. The sandwiched joints with lead-free solder foil shown in Fig. 1 were fabricated. The thickness of an electroplated Ni layer was 3 μm. For a Cu plate, the surface of it was polished with a #800 abrasive paper and cleaned with methyl alcohol before bonding. The surface of solder foil and a Ni-electroplated Cu plate were also cleaned with methyl alcohol before bonding. The sandwiched joint was loaded at 490.5 N for 60 s and immediately it was fixed by a jig. Bonding was conducted in a furnace in the atmosphere. The sandwiched specimen with the jig was put in the furnace which temperature was controlled at 300 °C and 330 °C for 10 min, 20 min and 30 min. Bonding temperature which is a peak temperature in bonding was changed from 270 °C to 300 °C. Bonding time which corresponds to the holding time at the bonding temperature was changed from 3 min to 15 min. For the specimen to investigte the microstructure, bonding was conducted with Al wire of 0.4 mm in diameter as shown in Fig. 1(a). Microstructural observation for the cross section of the joint was conducted using an electron probe X-ray microanalyzer (EPMA). Etching treatment for Sn which is the matrix was conducted to investigate morphology of IMCs formed in the joint. The etching solution contained 100 ml H_2O, 2 ml HCl (35%) and 10 g $FeCl_3$. After etching treatment, microstructural observation was conducted using the EPMA. Furthermore, a die shear test was conducted with the sandwiched joint shown in Fig. 1(b) to investigate the joint strength. The test was conducted at a shear rate of 0.5 mm/s with a bonding tester (RHESCA PTR-1102). The shear height was 0.6 mm in the test. After the die shear test, the fracture surface was observed with the EPMA.

Table 1 Chemical compositions and melting properties of solder investigated.

Solder type (mass%), abbreviation	Solidus temperature (°C)	Liquidus temperature (°C)
Sn-3.0Ag-0.5Cu, SAC	218.8	218.8
Sn-3.0Ag-0.7Cu-5.0In, SACI	206.2	214.6

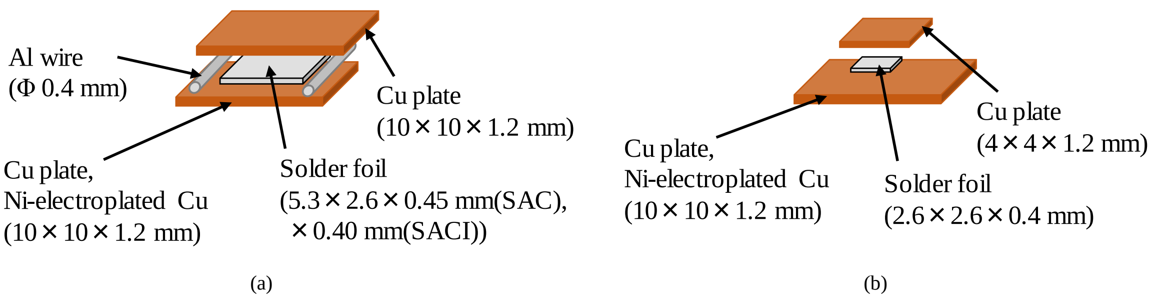

Fig. 1 Shape and dimensions of specimens for microstructural observation (a) and die shear test (b).