In-Situ Investigation of the Interfacial Reaction in Sn/Cu System by Synchrotron Radiation

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Two kinds of temperature profiles were used for the in-situ interfacial reaction. One was solid-solid reaction (aging) from room temperature (24°C) to 150°C for 10 min and then held at 150°C for 1 hr. The other one was liquid-solid reaction (reflow) from 24°C to 240°C for 10 min and from 240°C up to 260°C for 4 min and then air cooled to 24°C.

Figure 1 reveals the in-situ XRD patterns for aging reaction. Only Cu and Sn peaks were observed after sputtering. When the temperature was increased to 136°C, Cu_6Sn_5 was first formed as shown in Fig. 1(a). In the magnified XRD pattern (Fig. 1(b)), the Cu_6Sn_5 peak also showed up. The intensities of Cu_6Sn_5 peaks were raised rapidly when Cu_6Sn_5 was first formed at the interface. It was suggested that Cu_6Sn_5 grew quickly when the aging temperature was higher than 136°C. The growth of Cu_6Sn_5 between Sn and Cu was diffusion controlled. The interdiffusion coefficient in Cu_6Sn_5 was 1.1×10^{-13} cm^2s^{-1} at 70°C, and was two order of magnitudes larger at 170°C.[1] The interdiffusion coefficient in Cu_6Sn_5 increased quickly with the aging temperature. Therefore, the thickness of Cu_6Sn_5 was enlarged rapidly, resulting in the intensities enchantment of Cu_6Sn_5 peaks when the aging temperature was higher than 136°C.

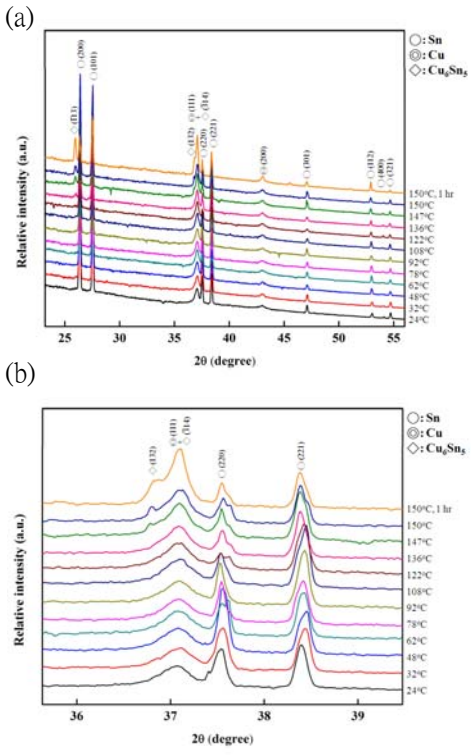

Fig. 1: (a) The in-situ XRD patterns of Sn/Cu joint system under aging reaction from RT to 150°C, and (b) the magnified XRD patterns between 36 and 39°.

From the Sn-Cu phase diagram, both Cu_6Sn_5 and Cu_3Sn should exist at interface between Sn and Cu. [2] However, no Cu_3Sn peak was observed in the XRD pattern even after aging at 150°C for 1 hr (Fig. 1). It was argued that Cu_3Sn was too thin to be detected or it was difficult to nucleate because of the high activation energy for formation (119 KJ/mole). [3] Therefore, Cu_3Sn was not observed at interface when aging at 150°C for 1 hr.

The reflow reaction was also in-situ investigated as shown in Fig. 2. It was revealed that Cu_6Sn_5 grew rapidly after 150°C, which was identical as the aged one. When the temperature was up to 233°C, the Sn peaks disappeared, for Sn was melted (melting point 232°C) and the ordered structure was broken. Therefore, no Sn peaks showed up when the temperature was higher than melting temperature. Besides, the Cu_3Sn peaks were revealed when the temperature was up to 233°C. As described above, Cu_3Sn would not form at interface due to high formation energy, so the observed Cu_3Sn was caused by the transformation of Cu_6Sn_5. The thick Cu_6Sn_5 layer suppressed the interdiffusion of Cu and Sn in Cu_6Sn_5, which resulted in the increase of Cu concentration at the interface of Cu_6Sn_5/Cu. Then, Cu_6Sn_5 was transformed to Cu_3Sn, i.e. $Cu_6Sn_5 + 9Cu \rightarrow 5Cu_3Sn$. Consequently the Cu_3Sn peak was revealed at 233°C.The phase evolution of Sn/Cu thin film during reflow could be clearly evaluated by this technique as shown in Fig. 2. Therefore, the in-situ observation of the interfacial reaction in solder joint system was successfully achieved for both aging and reflow process.

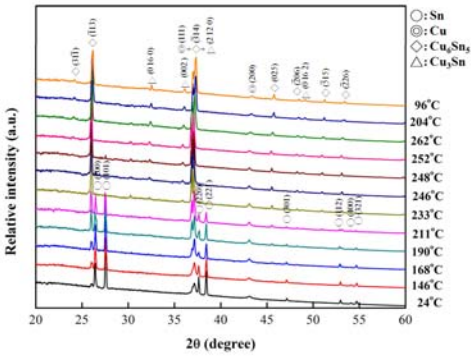

Fig. 2: The in-situ XRD patterns of Sn/Cu joint system under reflow process from RT to 260°C and back to RT.

References

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[2] T. B. Massalski and H. Okamoto, Binary alloy phase diagrams, ASM International **2nd** ed., 1481 (1990).

[3] W. Peng, E. Monlevade, and M. E. Marques, Microelectronics Reliability **47**, 2161 (2007).