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# Interfacial reaction between Sn-3.0Ag-0.5Cu solder / Co-P plating<sup>†</sup> and Ni-Co-P plating<sup>†</sup>

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**KEY WORDS:** (Lead-free solder) (Intermetallic compound) (Reaction layer) (Under bump metallurgy)  
(Co-P plating) (Ni-Co-P plating)

## 1. Introduction

In response to health and safety concerns, lead-free soldering has become a popular technology in electronics packaging. Compared with the lead-containing solders, Sn-3.0mass%Ag-0.5mass%Cu (SAC, all mass% unless specified otherwise) solder widely used in Japan has a relatively low impact reliability owing to the solder alloy hardness that induces a high stress concentration at the interface. In general, there is a correlation between the impact reliability and the morphology and thickness of the reaction layer formed at the solder/under bump metallurgy (UBM) interface. The most common UBM is electroless Ni-P plating over copper pad. Electroless Ni-P acts as a diffusion barrier layer between the copper and the solder. However, due to nickel diffusion, P-rich layers form at the interface between the solder and electroless Ni-P. Solder joint failure is related to the growth of these layers and to their brittleness and affects the mechanical reliability of joints. Recently, a new composition of UBM is proposed as diffusion barrier<sup>1-4)</sup>. For instance, Magagnin et al. reported that electroless Co-P strongly limits interdiffusion and intermetallic compounds formation as compared with the electroless Ni-P with Sn-Ag-Cu alloy. Furthermore, in the Co-P samples, P-rich layers did not form at the interface<sup>4)</sup>.

It is important to investigate the relationship between morphology of reaction layer and UBM. This study aims to clarify the effect of Co-P and Ni-Co-P on the morphology of reaction layer formed at the solder/UBM interface.

## 2. Experimental

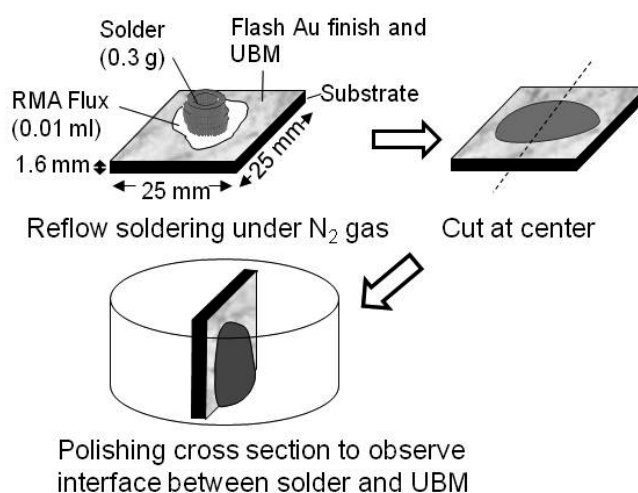
SAC solder (0.3 g) was used in this study. Electroless Co-P(Au) (3.1  $\mu$ m) and electroless Ni-Co-P(Au) (5.2  $\mu$ m) finished Cu plates on FR-4 PCBs (25.0 $\times$ 25.0 $\times$ 1.6 mm) were prepared as UBM. Electroless Ni-P(Au) (5.0  $\mu$ m) substrate was also used as a reference substrate. These substrates were plated with gold to avoid oxidation of the cobalt and nickel surface.

The experimental procedure is shown in **Fig. 1**. The substrate was immersed in 4% HCl solution for 120 s and then rinsed with deionized water. Then, solder was put on

the center of the substrate and activated flux (0.01 ml) was dropped on the solder. The test specimen was put into a radiation furnace in a nitrogen atmosphere and heated according to the temperature rise profile shown in **Fig. 2**. The reflow peak temperature was 513 K with the sample above 490 K for 115 s. After soldering, the spreading area of the solder on the UBM was measured by using the optical microscope (OM). Three tests were conducted to obtain an average value for each specimen. Then, specimens were cut and the cross-section of the specimens was polished to observe the interface between the solder and UBM. The reaction layer at the interface was observed by scanning electron microscope (SEM).

## 3. Result and discussion

A spreading test was carried out to examine the wettability of solders on UBMs and to clarify the interfacial reaction between the solder and UBMs after soldering. The wettability of solder was experimentally assessed by measuring the spreading area of solders on the UBMs.



**Fig. 1** Experimental procedure of this study.

<sup>†</sup> Received on 30 September 2010

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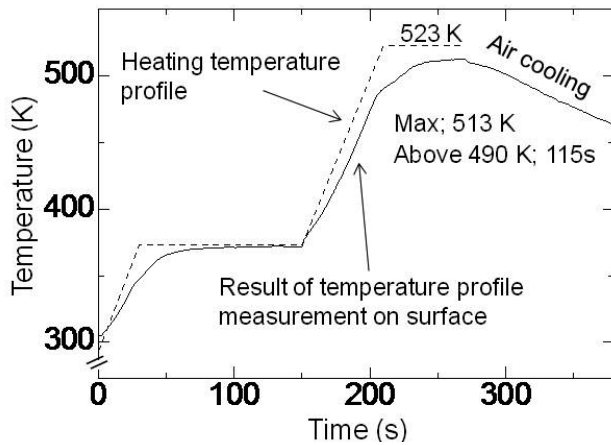


Fig. 2 Temperature profile in reflow soldering.

Figure 3 shows the appearance of a typical spreading test specimen after soldering. It is clear that the spreading area of solder on electroless Co-P was greater than that on electroless Ni-Co-P and Ni-P. Figure 4 shows the results of spreading area measurements for SAC solder on the three types of UBMs. The spreading area of the solder on the electroless Co-P was larger than that of the solder on the electroless Ni-Co-P and Ni-P. This results show that the electroless Co-P had better wetting characteristics than the electroless Ni-Co-P and Ni-P.

Then, the morphology of the reaction layer at the interface was observed by SEM. Figure 5 shows the SEM image of the reaction layer at the interface between SAC solder and UBMs after soldering. It is clear from Fig. 5 that the morphology of the reaction layers at the interface changes depending on the UBMs. While the layer-like IMC with 1.6  $\mu\text{m}$  in average thickness was formed at solder/Ni-P interface, in the electroless Co-P sample, the thin continuous layer attached to electroless Co-P layer and the fine needle-like IMC in contact with the solder was observed at the solder/Co-P interface. In the electroless Ni-Co-P sample, the thin continuous layer attached to electroless Ni-Co-P layer and the large needle-like IMC with more than 10  $\mu\text{m}$  thickness in contact with the solder was observed.

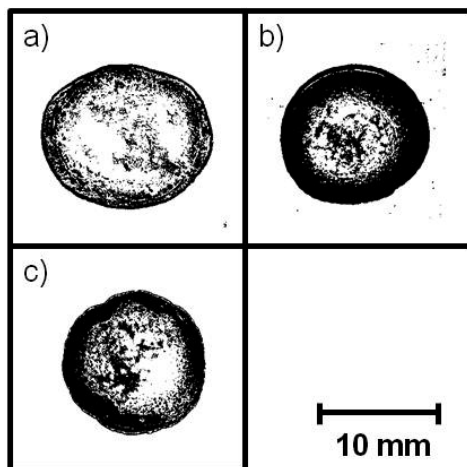


Fig. 3 Appearance of typical spreading test specimen after soldering. a) electroless Co-P, b) electroless Ni-Co-P, c) electroless Ni-P

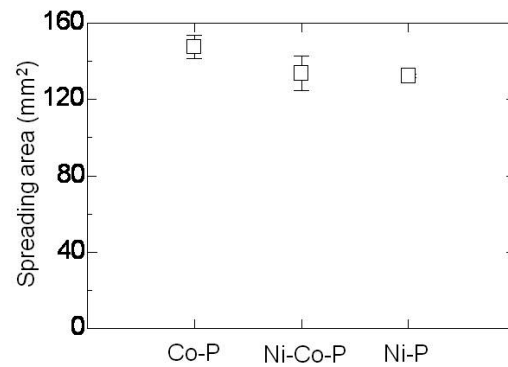


Fig. 4 Effect of UBMs composition on spreading area.

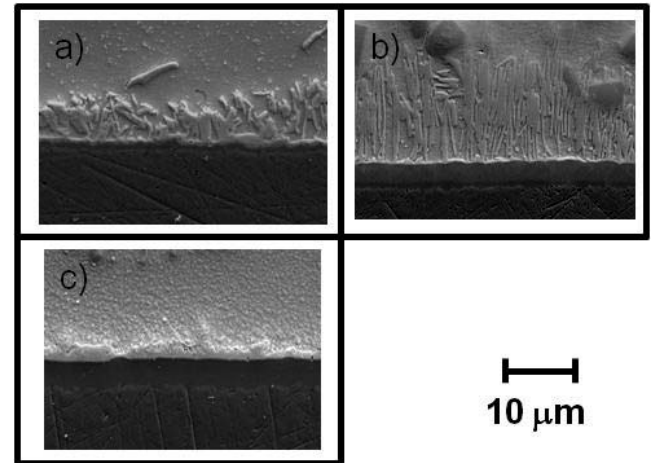


Fig. 5 SEM images of reaction layer at the interface between SAC solder and UBMs after soldering. a) electroless Co-P, b) electroless Ni-Co-P, c) electroless Ni-P

#### 4. Conclusion

This study aims to clarify the effect of electroless Co-P and Ni-Co-P on the morphology of the reaction layer formed at the solder/UBM interface. The results obtained are summarized as follows.

- (1) The spreading area of the solder on the electroless Co-P was larger than that of the solder on the electroless Ni-Co-P and Ni-P. These results show that the electroless Co-P had better wetting characteristics than the electroless Ni-Co-P and Ni-P.
- (2) While a layer-like IMC was formed at the solder/Ni-P interface, fine and large needle-like IMCs were formed at the solder/Co-P and solder/Ni-Co-P interface, respectively.

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