RECENT TRENDS IN ELECTRODEPOSITED LEADFREE SOLDERS FOR FLIP-CHIP INTERCONNECTS

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The most widely used solders for flip-chip (FC) interconnects are based on metallic lead combined with tin. However, there is currently substantial interest in looking for lead-free solders due to legislation on lead. Another benefit of a lead-free FC interconnect is the reduction of ^{210}Pb-created alpha particle radiation.[1] Pure tin is considered one type of lead-free material which is non-toxic, is easy to deposit, and has good wettability. However, pure tin has been restricted in its applications due to tin whiskers which bridge leads and thus cause short circuits.[2] Although promising results have been shown with pure tin,[3] many of the large semiconductor companies have have not accepted pure tin as a metal finish. Therefore tin-based alloys such as SnAgCu, SnCu, SnAg, and SnBi have gained interest.

Since the National Electronics Manufacturing Initiative (NEMI) and the Japan Electronics Industry Development Association (JEIDA) recommended ternary SnAgCu alloys ($SnAg_{3.9}Cu_{0.6}$ and $SnAg_{2-4}Cu_{0.5-1}$, respectively),[4] some reported the plate-ability of these alloys.[5-8] Fukuda *et al.* showed beaker-scale deposition using a H_2SO_4-based bath containing thiourea and polyoxyethylene lauryl ether (POELE) which are important for surface smoothing and uniform eutectic composition.[5] We have examined the deposition mechanism and deposit properties of near-eutectic SnAgCu alloys using an alkaline bath.[6-7] We defined the relationships among polarization behavior, surface morphology, and composition, and presented wafer-scale plating results. Karim, *et al.* achieved ternary alloys using sequential plating from two separate binary SnCu and SnAg plating solutions.[8] However, ternary alloys may not be practical as it is hard to maintain bath and alloy composition under manufacturing conditions. Short bath lives are another problem. Since 2000, several chemical vendors have reported the development of binary alloys such as SnBi, SnCu, and SnAg.[8-10] SnBi was initially regarded as a good alternative because a wide range of acceptable melting points can be achieved. However, ^{210}Bi may cause soft errors and a brittle Bi-Pb compound is formed if it is combined with a Pb-containing solder.

Motorola compared the material properties of $SnAg_{3.5}$, $SnCu_{0.7}$, and $SnAg_{3.8}Cu_{0.7}$ alloys deposited by paste stencil printing.[11-12] They concluded that the optimal lead-free solder alloy for FC interconnects is $SnCu_{0.7}$ which has lower shear strength and superior thermomechanical fatigue performance. However, this alloy is hard to electrodeposit in manufacturing due to poor bath life (resulting from the accelerated oxidation of Sn(II) by copper ions) and difficulty in controlling, measuring, and maintaining copper content in the deposit and bath. No chemical vendors yet supply a SnCu bath with good bath stability. Due to these factors, many companies have selected near-eutectic SnAg alloys. Advantages over SnCu processes include (*i*) the silver content in deposits is high enough to be measured non-destructively, (*ii*) a bath with an acceptable lifetime is commercially available, and (*iii*) bath composition can be easily maintained.[13] Successful plating results are reported by several groups.[13-15] Low silver compositions (< 2.7wt%) are generally preferred as Ag_3Sn compounds (plates/needles) can protrude from the solder bumps during reflow, even shorting to adjacent bumps.[13]

We have also compared the bath life, plate-ability, and reflow-ability of near-eutectic SnAgCu, SnCu, and SnAg processses. We have observed that the plate-ability and reflow-ability (based on a single reflow) are similar to each other, but SnAg baths have the longest lifetime.[16] We recently compared the performance of various SnAg baths[17] to further improve bath life and performance, and then optimized deposition conditions. Figure 1 shows the as-plated (at 2µm/min) and reflowed $SnAg_{2.5}$ bumps achieved with optimized conditions.

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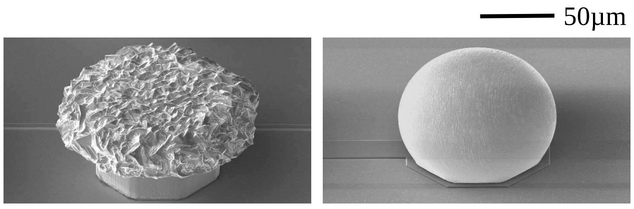

Figure 1. As-plated and reflown bumps.