Electrically Mediated Through-Mask Deposition of Solder Bumps for Wafer Level Packaging

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Extensive research has been done regarding the electrically mediated plating, on the grounds that changing the waveform can influence the charging and discharging of the electrical double layer, mass transfer, crystallization, current distribution, and thus film properties.[1-3] However, to date most studies were conducted with rotating disk electrode or small pieces of wafers. This study examines the electrically mediated through-mask deposition of solder bumps in the presence of additives with 200mm wafers for wafer level packaging (WLP).

Experimental

The applicability of electrically mediated deposition for resist-patterned structures was investigated with several plating baths such as a Cu bath (developed for high rate deposition), two PbSn baths ($Sn_{60}Pb_{40}$ and $Pb_{97}Sn_3$) and two leadfree solder baths (eutectic SnAgCu and SnAg). Patterned wafers have the structure of Si(substrate)/SiO_2/ TiW(or Ti)/PVD-Cu(200nm), where the wafers were patterned with Clariant AZP 4620 resists. Semitool's Equinox^{TM} was used to electroplate these wafers.

Results and Discussion

Growth Shape and Surface Interactions : With decreasing duty cycle at a fixed average current density, (1)the growth became more conformal to the resist pattern (figure 1(a)), (2)the wetting of solution to resist was improved, resulting in smooth sidewall with no dendrites (figure 1(b)), and (3)the probability of abnormal growth (such as humps in figure 2) was significantly reduced. It was thought that the higher overpotential, which resulted from the higher peak current density than that of DC plating, improved the mass flow through the mask leading to better conformality and shape. It was found from further studies that the electrical mediation was an effective method to obtain conformal growth when the resist has high surface energy.

Surface Morphology and Roughness : As the higher overpotential enhances the nucleation rate of electrodeposition process,[1-2] the pulse waveform produced finer grained surfaces as shown in figure 3.

Alloy Composition and Thickness Distribution : With decreasing duty cycle, the content of tin in near-eutectic SnPb alloys and the content of silver in near-eutectic SnAg alloys was decreased. With varying duty cycle, the thickness distribution, which was tested with copper and eutectic SnPb bath, changed at a given condition, as the pulse electrolysis changes the current-potential relationships and thus current distribution.[2]

Conclusions

The influence of electrical mediation on through-mask deposition of solder bumps was evaluated with various baths. The applications of electrical mediation for WLP were very diverse. Electrical mediation was helpful (1)to improve growth shape and surface morphology, (2)to suppress abnormal growth, and (3)to modulate alloy composition at a given bath concentration. The thickness distribution in the wafer changed with varying duty cycle at a fixed average current density.

References

1. J.Cl. Puippe, in Electrodeposition Technology Theory and Practice, L.T. Romankiw, Editor, PV87-17, p. 531, The Electrochemical Society Proceedings Series, Pennington, NJ (1987).
2. D.T. Chin et al., AESF Project 68 : Selective Pulse Plating (1989).
3. E.J. Taylor et al., Plating & Surface Finishing, May 2002, p. 88 (2002).

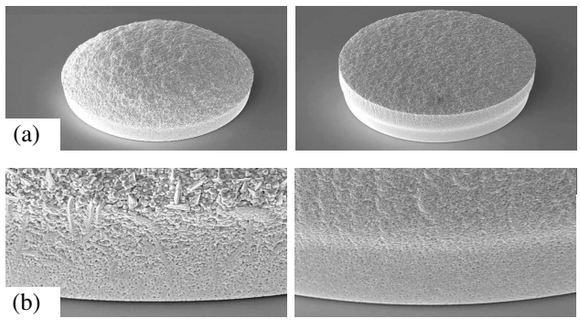

Figure 1. Effect of waveform on the growth of eutectic SnPb solders : (a) growth shape and (b) surface interaction.

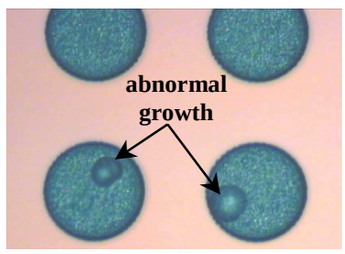

Figure 2. Abnormal growth of eutectic SnPb solder bumps.

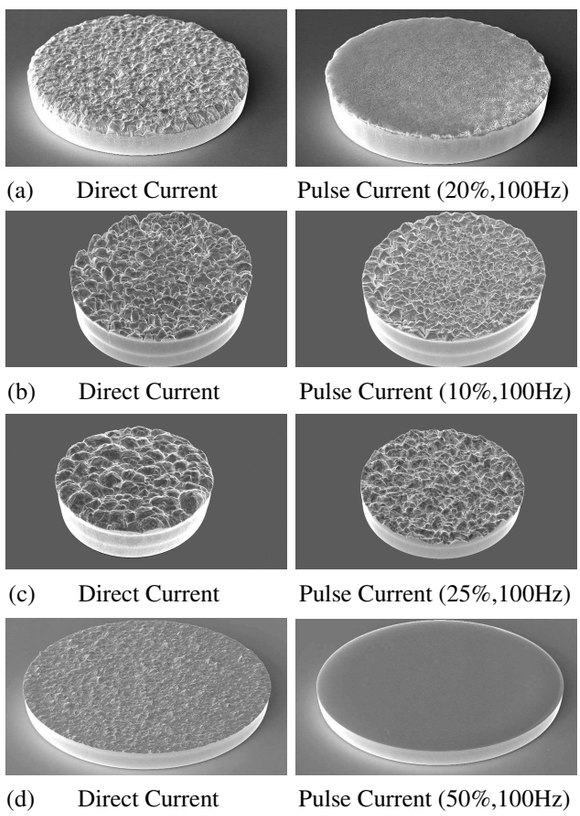

Figure 3. Effect of waveform on the surface morphology of solders; (a)near-eutectic SnAg, (b)near-eutectic SnAgCu, (c)high lead PbSn, and (d)Cu stud.