Lead-free Solders: Still Learning, Adapting, and Working Out the Kinks

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After working several decades with the magical, forgiving, and reliable Sn-Pb solder alloys, we embarked on eliminating lead from electronics beginning July 1, 2006.¹ That was the date of the legislative ban on lead in electrical and electronic equipment throughout the European Union according to RoHS (Restriction of the use of certain Hazardous Substances in Electrical and Electronic Equipment) directives. China, a global leader for both consumption and production of electronic equipment, drafted its own "Management Methods for Prevention and Control of Pollution from Production of Electronic and Information Products."² And in the United States, California³ legislated electronic waste recycling, but not a total ban on lead in electronics. These laws have motivated electronic products manufacturers to implement lead-free solders and to market reliable 'green' products. Yet, a number of questions remain regarding lead-free technology as the drop-in replacement for lead-bearing alloys. Thus, the Electronic Packaging and Interconnection Materials Committee of the TMS Electronic, Magnetic & Photonic Materials Division organized a series of successful symposia on lead-free and lead-bearing solders in the past few years. The symposia were held at TMS annual and fall meetings and results were published.⁴⁻¹⁶

Continuing the trend, the recent "Pb-Free Solders and Emerging Interconnect and Packaging Technologies" symposium held February 14-18, 2010 at the TMS Annual Meeting in Seattle, Washington, attracted a large number

of participants. At the symposium organized by Kwang-Lung Lin et al., more than 70 papers dealing with solderability, solder-substrate reactions, solder-joint microstructure, solder electromigration, and solder-joint reliability for lead-free solders were presented. The three papers selected for this issue of *JOM* deal with reliability modeling, electromigration, and tin whiskers in lead-free alloys.

Many of the electronic interconnects experience mechanical shock due to handling and drops in daily use. To comprehend the impact of such shock on the reliability of electronics, understanding the strain rate behavior of solders is essential. In the first paper, K.E. Yazzie et al. use digital image correlation to quantify local stresses and strains to the shock regime, and develop reliable numerical models of the mechanical shock behavior.

The second paper by S.K. Seo et al. investigates the electromigration (EM) performance of lead-free solder joints in terms of solder composition (Sn-0.5Cu vs. Sn-1.8Ag) and joining path to Cu vs. Ni(P) under bump metallization (UBM). The EM behavior is explained based on microstructural changes such as grain coarsening, crystal orientation, coarsening of intermetallic particles, and growth/dissolution of IMC layers at both UBM interfaces during stressing.

Tin whiskers are a realistic threat to the reliability of lead-free solder interconnects. However, the phenomenon of whisker formation (largely mitigated from lead addition in lead-bearing solders) is still not fully understood. N. Jadhav et al. report on real-time measurements that enable us to watch the morphology of whisker and hillocks forming in real-time, and provide insight into the mechanisms controlling

their growth and initiation.

Many of the remaining papers presented at the TMS 2010 Annual Meeting will be published in the *Journal of Electronic Materials* later this year as a special issue on lead-free solders.

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