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Magnetic nanoparticle-based solder composites for electronic packaging applications

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ABSTRACT

Sn–Ag–Cu (SAC) alloys are regarded as the most promising alternative for traditional Pb–Sn solders used in electronic packaging applications. However, the higher reflow temperature requirement, possible intermetallic formation, and reliability issues of SAC alloys generate several key challenges for successful adoption of Pb-free solder for next generation electronic packaging needs. Localized heating in interconnects can alleviate thermal stresses by preventing subjection of entire package to the higher reflow temperatures associated with the SAC solders. It had been demonstrated that SAC solder–FeCo magnetic nanoparticles (MNPs) composite paste can be reflowed locally with AC magnetic fields, enabling interconnect formation in area array packages while minimizing eddy current heating in the printed circuit board.

Solder/magnetic nanocomposite pastes with varying MNP concentration were reflowed using AC magnetic fields. Differential scanning calorimetry results show a reduced undercooling of the composite pastes with the addition of MNPs. TEM results show that the FeCo MNPs are distributed in Sn matrix of the reflowed solder composites. Optical and SEM micrographs show a decrease in Sn dendrite regions as well as smaller and more homogeneous dispersed Ag_3Sn with the addition of MNPs. The MNPs promote Sn solidification by providing more heterogeneous nucleation sites at relatively low undercoolings. The mechanical properties were measured by nanoindentation. The modulus, hardness, and creep resistance, increase with the MNP concentration. The enhanced mechanical properties are attributed to grain boundary and dispersion strengthening.

The reflow of solder composites have been modeled based on eddy current power loss in the substrate and magnetic power losses

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in the solder bumps. Induction reflow of pure solder bumps (<300 μm) in an area array package using 500 Oe magnetic field at 300 kHz requires excessive eddy current power loss in the substrate, resulting in extreme temperatures that lead to blistering and delamination of the substrate. Solder–MNP composites with modest MNP loading showed temperature increases sufficient to achieve solder reflow when subjected to the same AC magnetic fields. Thermomechanical behavior of a solder joint was also modeled under cyclic temperature variations. The stress and strain are highly localized at the interface between solder and substrate. Plastic work accumulated per cycle can be used for lifetime prediction.

In this article we review lead-containing and lead-free solder systems, and the electronic packaging technologies pertinent to soldering process. Recent research on the effects of MNPs on localized heating, microstructure evolution, mechanical properties, and thermomechanical reliability are summarized.

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