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Solidification Behaviour of Lead-Free Alloys and its Relationships to Their Performance as Practical Solders

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Given that many of the properties that made the tin-lead eutectic the solder of choice for the electronics industry for so many years are the result of the way it behaves during solidification it is important to consider that aspect of the alloys that have been proposed as lead-free solders. One example of solidification behaviour that affects the performance of the alloy in wave and reflow soldering processes is whether it behaves as a eutectic, freezing isothermally to produce a fine homogeneous dispersion of phases in a process of coupled growth. If the alloy instead behaves as a hyper- or hypo-eutectic alloy the microstructure is dominated by coarse primary phases with implications for the performance of the alloy in soldering processes. The fact that, in contrast to the tin-lead system, the second and third phases in the eutectics in alloys based on the Sn-Cu and Sn-Ag-Cu systems are faceted intermetallic compounds that are difficult to nucleate means that nominally eutectic alloy such as Sn-0.7Cu or Sn-3.8Ag-0.9Cu do not normally solidify isothermally as eutectics and this has implications for bridging and through-hole filling in wave soldering, spread and fillet formation in reflow and shrinkage cracks in the resultant fillets. In the work reported in this paper the solidification behaviour of some Sn-Cu and Sn-Ag-Cu alloys was studied using high speed video imaging, quenching, dendrite coherency measurements, fluidity measurements, and “icicle” drainage studies. The observed behaviour during solidification was correlated with the resultant microstructures to create a qualitative model of the performance of these alloys in practical soldering processes. The possibility of modifying solidification behaviour of basic alloys to enhance their performance as solders is considered by means of a case study of nickel and germanium additions to the Sn-0.7Cu alloy.