Elastoplastic Modeling and Experimental Verification of Solder-Substrate Interaction

C. Karl[1], C. Slater[1], M. Strangwood[1], K. Tank[2], S. O'Connor[2]

[1]University of Birmingham, Birmingham, UK
[2]Strip Tinning Ltd, Birmingham, UK

Abstract

Solders are typically used to join similar or dissimilar metals, referred to as substrates. In some cases solders are also used to join completely different classes of materials. For example, a joint between copper busbar and silicon solar cell represents a set of dissimilar substrates.

In the formation of a solder-substrate couple, the system must have been subjected to at least a single thermal cycle, i.e. when cooling from melting temperature of the solder to ambient temperature. During this temperature change and due to differences in the thermo-mechanical behaviour of the two materials (coefficient of thermal expansion, elastic modulus, yield behaviour), internal stresses are built up, which may lead to elastic distortion, plastic deformation or fracture.

In optimising the performance of various soldered joints, then it is necessary to accurately simulate the generation of residual stresses during the soldering thermal cycle for dissimilar substrates.

This study aimed to simulate the generation of residual stresses in a tri-material strip (i.e. metal-solder-glass) during cooling from the solders melting point; from the thermo-mechanical behaviour of the individual component, from literature and experimental tensile testing studies, the overall behaviour, e.g. distortion of the sandwich structure was also simulated.

Sandwich structures consisted of 5 mm wide, 100 mm long and 0.6 mm thick C101 ETP copper strips joined to 1 mm thick float glass by either lead free solders SAC305 or Sn3.5Ag, or the lead containing solder 60-40. The strains resulting from cooling the strip were measured using strain gauges.

The material models for the different solders and the copper were input into COMSOL Multiphysics® version 4.4. using an isotropic hardening model accessing the von-Mises stress as yield function and using non-linear work hardening functions. Glass was treated as a linear elastic material.

These results were then compared to experimental data for the sandwich geometries and materials.