Vibration Durability Models for Pb-free (Sn3.0Ag0.5Cu) and Pb-based (Sn37Pb) Solders

Y. Zhou, M. Al-Bassyiouni, and A. Dasgupta[1]
CALCE Electronic Products and Systems Consortium
www.calce.umd.edu
Mechanical Engineering Department,
University of Maryland, College Park, MD 20742
1. *Corresponding Author*

A physics of failure (PoF) study is conducted to identify vibration durability fatigue model constants for selected solder materials and to examine their sensitivity to the stress-strain properties of the solder materials. The elastic-plastic stress-strain properties for these solders are modeled with a power-law relationship, as in the Ramberg-Osgood constitutive model.

The vibration durability of printed wiring assemblies (PWAs), consisting of surface mount interconnects made from a Sn3.0Ag0.5Cu (SAC305) hypoeutectic Pb-free solder and a Sn37Pb eutectic solder, was investigated. The vibration test used constant-amplitude, harmonic excitation at the first natural frequency of the test specimen. Fatigue properties of the solder materials were extracted from the test results with the help of finite element analysis (FEA) of the test article. A time-domain approach was adopted in this study for the fatigue analysis. The SAC305 interconnects were found to have lower fatigue durability than comparable SnPb interconnects, at the excitation levels used in this study, which is consistent with most results from broad-band vibration tests and from repetitive mechanical shock tests, but counter to findings from quasi-static, cyclic mechanical low-cycle fatigue studies. Two competing failure modes were identified: solder fatigue and copper-trace fatigue. Failure data for the LCR components exhibiting the highest incidence of solder failure were therefore used in this study.

The scatter in the material properties for solder alloy, especially for the Pb-free solder material, motivates the second task in this paper, since the durability model derived from PoF analysis is quite dependent on the stress-strain properties used in the finite element models. Stress-strain behavior reported in the literature show significant variability, depending on test methods. In this study, several sets of stress-strain properties from the literature were used to identify a reference range and the material constants were varied parametrically within these ranges, to explore the sensitivity of the durability model constants. The process was then repeated for random (broad-band), step-stress excitation. The results show that the agreement between harmonic and random fatigue model constants improves as the stress-strain curves of solder are parametrically softened. The results also show that the durability model is more sensitive to the plastic hardening exponent than to the young's modulus. The confidence in these model constants must be interpreted within the context of the results.