Developing Damage Models for Solder Joints Exposed to Complex Stress States: Influence of Potting, Coating, BGA Mirroring, and Housing on Solder Joint Fatigue

Existing stress and damage models designed to capture solder fatigue behavior are almost exclusively based on a pure shear condition at the solder joint. While these assumptions were generally valid under early generation, low-density designs, more complex systems are driving multi-axial loading into an increasing number of electronic packages. The result is unexpected results once coupon testing is migrated into product validation testing, with early life failures and limitations on promising mitigations (such as underfill). This paper will discuss the experimental, analytical and theoretical efforts to develop a universal low-cycle solder fatigue model that accounts for tri-axial loading. Initial experiments focused on developing a zero shear stress test coupon so as to isolate tensile and compressive stress effects. Influence of loading conditions and possible effects of mean stress state were observed. Further experimentation on BGAs underfilled with conformal coating provided opportunities to correlate time to failure to magnitude of stress vectors. Based on these experimental observations and review of mechanics literature, a new damage law approach that partitions directionality of strain energy was developed. Execution of this new damage law through the use of FEA-based elastic strain analysis is described and validation data is presented. The talk will conclude with a demonstration of this new approach on the prediction of the most common tri-axial drivers, including coating, mirroring, and over-constrained boards.