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Low-cycle-fatigue failures of solder material in electronic products: Analytical modeling enables to explain, predict and possibly prevent them

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This presentation is based mostly on the author's recent research and addresses the application of analytical ("mathematical") predictive modeling to understand the physics and mechanics of the behavior and performance of solder materials employed in microelectronic systems. The emphasis is on the design for reliability and, first of all, on the prediction of the thermal stresses and strains in solder joint interconnections. While the overwhelming majority of the numerous studies addressing solder materials are either experimental or based on finite-element-analyses (FEA), the approach considered in this presentation uses analytical predictive modeling techniques to predict stresses and strains and suggest methods for their minimization. Both ball-grid-array (BGA) and column-grid-array (CGA) designs for the second level of interconnections are addressed, and the attributes of flip-chip designs are indicated and discussed. The developed models suggest the most effective design-for-reliability methodologies to relieve stresses in strains in solder joints, and to determine, at the design stage, if inelastic strains in the solder material could occur and be avoided. If not, these models are able to predict the sizes of the inelastic zones at the end portions of the assemblies. The following major efforts are addressed: Analytical modeling, its significance, role, attributes and challenges; Method of interfacial compliance (MIC); Inelastic strains in, and low cycle fatigue of, solder materials; Elevated stand-off heights and application of inhomogeneous solder systems for relieving stress and strain in solder materials; Attributes of solder joints in flip-chip designs; Board level dynamic testing of BGA vs. CGA solder joint interconnections; Novel experimental method of solder material characterization; Accelerated testing of solder joint interconnections: failure-oriented accelerated testing (FOAT) as a possible extension of highly-accelerated-life-testing (HALT); Incentive for mechanical pre-stressing of accelerated test specimens subjected to temperature cycling and; Incentive for using a low-temperature/random-vibrations bias as effective substitute for temperature-cycling tests of solder joint interconnections. It is concluded that all the three approaches of the applied science and engineering—experimental, computer-aided and analytical—are equally important to make a viable device into a reliable product, and that analytical modeling can be effectively used to predict and possibly prevent failures of solder joints in electronic products.

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