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Crack Propagation in Solder Joints During Thermal-Mechanical Cycling

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ABSTRACT

Differential expansion induced creep-fatigue resulting from temperature cycling is an important cause of solder joint failure. The deterioration of solder joint integrity typically involves a sequential development of local stressing, microcracks, crack initiation and crack propagation, ultimately resulting in electrical open-circuiting by total joint separation from the PWB footprint.

To better understand the failure process, a series of combined analytica and experimental investigations have been performed on gull-wing flat-pack components having near eutectic tin-lead solder joints. JPL's unique non-linear finite element computer program has been modified to dynamically simulate the crack propagation process. Solder creep properties, including the effect of grain growth, are also incorporated into the model. The program computes the stress/strain variation during each thermal-mechanical cycle (e.g. 3-hour cycle from -25°C to 100°C); after each cycle, the program assesses the amount of crack growth in every solder element according to a damage function based on the computed plastic strain range and creep ratcheting using a Coffin-Manson type correlation and Miner's rule. The amount of crack growth in each solder element is in turn used to continuously update the solder finite element mechanical properties. Depending upon the system geometry and materials proper ies, the crack development may have either a positive or negative effect on the rate of cracking of the neighboring solder elements. Consequently, the crack propagation process may accelerate or decelerate as cycles progress.

The present investigation focuses on flat-pack parts with gull-wing leads ranging in height from 10 to 56 mils. Analytical simulations of crack propagation are compared with SEM photographs obtained at different stages of testing. Fast failures, e.g. less than 50 cycles, were observed for the 10-mil lead height. On the other hand, the damage with high leads (e.g. 56 mils) is strongly affected by slowing of the crack propagation as the crack progresses from heel to toe. As a result, the solder joint may remain intact for over 4000 cycles even when a heel crack develops early in the cycling.