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Modern semiconductor devices in many applications require a thermal solution to remove the heat away from the device and maintain a certain operating temperature. These thermal solutions typically use a heat sink and a thermal interface material (e.g. thermal grease) between the device and the heat sink. A compressive load is applied to reduce the thermal resistance of the interface and facilitate better heat transfer from the device to heat sink. Depending on the magnitude, this compressive preload may affect the fatigue behavior of second level solder joints connecting the device to PCB in a thermal cycling environment. This paper describes the experimental setup and test results to evaluate the reliability of solder joints in the presence of a preload. 3-D nonlinear finite element analysis is performed to simulate the effect of compressive load in thermal cycling. Both SnPb and SnAgCu solder alloys are studied with various levels of preload.

Higher performance, feature integration, and new applications for semiconductor devices require high efficiency thermal solutions to remove the power dissipated and maintain the device operating temperature. A common thermal solution uses a heat sink and a thermal interface material between the electronic package and the heat sink. In order to reduce the thermal resistance at the interface, a compressive load is maintained between the package and the heat sink, via a heat sink spring clip or similar means. This compressive preload affects the deformation behavior of the package/board assembly in a thermal cycling environment, which, in the absence of this preload, is controlled only by the coefficient of thermal expansion (CTE) mismatch between the package and the board. Therefore predicting the low-cycle fatigue life of solder joints in preloaded electronic packages has remained a challenge.

Experimental data for Flip-Chip Ball Grid Array (FC-BGA) packages shows that solder joint fatigue life and failure location can change when a preload is applied [1][2]. This paper describes the experimental setup which simulates the thermal preload during reliability testing. Test data for BGA packages under different levels of preload during thermal cycling is presented. 3-D nonlinear finite element analysis is performed to simulate the behavior of solder joints for SnPb and SnAgCu alloys. Unlike conventional solder joint finite performance of solder joints. The test package and board design ensures that all solder joints in critical areas can be fully tested electrically. The dye & peel analysis provides an accurate measurement of solder joint crack area.

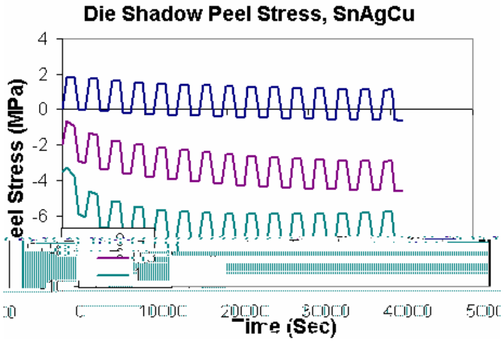
FC-BGA test data with preload has been reported in [2]. The crack area as percentage of total solder joint area is plotted in Figure 2. It can be seen that the solder joint crack % area under the die region is relatively higher than at package corner when there is no preload is applied. This shows that critical solder joint is under the die region.

When compressive preload is increased to normalized value of 0.5, solder joint crack % area under the die region and at the package corner beco where the support point is located is constrained in the vertical direction to simulate the fixture setup described in Figure 1. Three normalized preloads are investigated: 0 (no-preload), 0.5, and 1.0.

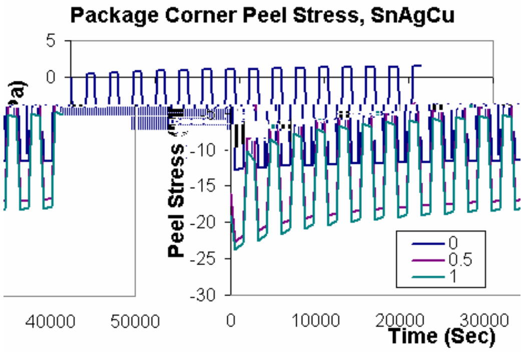
Thermal cycle range studied in the paper is -25 to 100°C. The dwell time is 15 minutes for both high and low temperatures, and the ramp up & down time is 8 minutes each. The total cycle time is 43 minutes. The preload is ramped up during a 1 minute interval at 100°C (to accelerate creep/stress relaxation at room temperature storage) and then thermal cycle loading is applied.

Table 1 Material Properties

life and can even change the failure location in the package. This analysis indicates that a more advanced fatigue law is needed for the preload case which accounts for both the conventionally used damage parameters (accumulated creep strain or strain energy per cycle) and the nature of peel stress in the solder joints. Such an enhanced model may even make life prediction for no preload case more accurate.



(a) Corner of die shadow



(b) Package corner

Figure 17: Peel stress history of SnAgCu solder

Empirical data shows that the existence of compressive