Field Condition Reliability Assessment for SnPb and SnAgCu Solder Joints in Power Cycling Including Mini Cycles

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Abstract

Actual field conditions that computer components such as microprocessors experience are different from the accelerated thermal cycling tests typically used to perform reliability assessment. Field conditions can include longer dwell times, different temperature ramp rates driven by power ON/OFF events, and temperature fluctuations during the power ON state due to workload patterns. Series of numerical simulations have been performed to study the effect of the field conditions on the solder joint fatigue life of electronic packaging. The simulation results show that SnPb and SnAgCu solders respond differently with respect to dwell time and mini cycles. Without considering the effect of mini-cycles, it is possible that SnAgCu may fail earlier than SnPb with very long dwell time. However, it is important to note if mini-cycles contribute to damage as seen in this analysis, the SnPb solder will probably still fail before SnAgCu solder.

Introduction

Electronic components continue to enter new product applications and markets, while design-to-production cycle is becoming shorter. The reliability of electronic components is usually studied with accelerated tests to reduce the validation time. Specifically for solder joint low-cycle fatigue, a commonly used test is accelerated thermal cycling. However the relationship between field conditions and the accelerated thermal cycling test is not well understood. This is especially true for newer product applications and markets. Simulation can be used to bridge this gap and to investigate the effect of

PCB, and copper pads on both the BGA substrate and the PCB. The solder joints are modeled as solder mask defined (SMD) on substrate side and metal defined (MD) on PCB side. Two different mesh density patterns are used to model

Second, the mini cycles are considered during ON state, as shown in Figure 4. The length of each mini cycle is assumed to be 12 minutes. Therefore, there are total 80 mini cycles for a 16-hour ON period. The details of the mini cycle are plotted in Figure 5. When mini cycles are considered during power cycles, the finite element simulation will run through all 80 mini cycles in the ON state during each power cycle. This requires significant amount of computational resources and time. However, this is necessary to understand how mini cycles affect the solder joint reliability compared to the power cycle without mini cycles.

Figure 3: Power cycle profile without mini cycles

Figure 4: Power cycle profile with mini cycles

Figure 5: Mini cycle profile

Power Cycle Condition without Mini Cycles

A total of 10 power cycles (total physical time: 10 days) were simulated without considering mini cycles first. Figure 6 and Figure 7 plot the time-history of averaged cumulated equivalent creep strain (denoted by CEEQ) and the averaged cumulated creep energy density (ECDDEN) at package side, respectively, for SnPb and SnAgCu solders. The temperature profile is also shown in these figures with light green line. Analysis shows that the per-cycle CEEQ and per-cycle ECDDEN stabilized within two or three cycles for both solder materials. This suggests that 3 cycles will be sufficient in similar studies in the future.

As expected, from Figure 6 and Figure 7, the creep strain accumulation in SnPb is much faster than in SnAgCu, because SnPb is softer and has higher creep strain rates than SnAgCu in the temperature range investigated. However, it should be noted that the creep limit of SnPb is also much higher than SnAgCu.

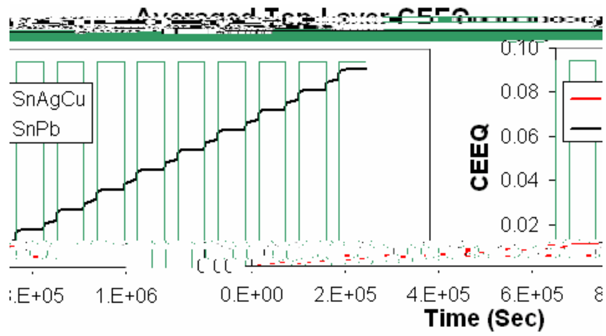

Figure 6: Averaged CEEQ history under power cycle without mini cycles

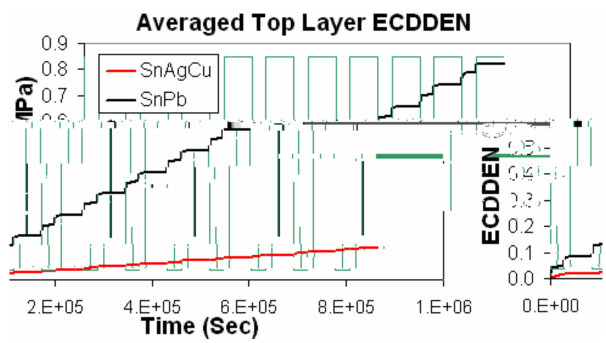

Figure 7: Averaged ECDDEN history under power cycle without mini cycles

Further, in order to understand the effect of dwell time and ramp rate, the CEEQ and ECDDEN accumulation in one cycle (the 10th cycle) are plotted in Figures 8-11. It is noted that, unlike what we observe in accelerated test condition simulations [3], the majority of creep for both solder materials is accumulated during dwell times. This suggests that the dwell time is a dominant factor in the field condition reliability assessment.

Two solder alloys respond differently in creep accumulation during the long dwell time. Because the SnPb solder has higher creep rate, especially at high temperatures, the creep accumulation reaches an asymptotic value at high fully relaxed at low temperature dwell period, and the creep strain continues to accumulate after 8 hours.

SnAgCu solder, on the other hand, is stiffer and has lower creep rate. Even after 16 hours dwell time at high temperature, Figure 9 shows that the creep continues to accumulate and the asymptotic value is not yet reached. The Von Mises stress plot in Figure 13 shows that the residual stress remains at a relative high level. At low temperature dwell period, though

Power Cycle Condition with Mini Cycles

As shown in Figure 5, each power cycle is assumed to consist of 80 mini cycles during the ON state. Figure 14 plots

Superposition Method

It's very time consuming to simulate a power cycle profile with mini-cycles because finite element simulation needs to run through dozens of mini cycles (e.g., 80 mini cycles in our study) to complete one power cycle. The superposition method can be effectively used to simulate this case by combining the results of individual power cycle and mini-cycle analyses.

The mini cycle shown in Figure 5 is simulated without the when a certain threshold value of ON state dwell time is exceeded. However, if the mini-cycles contribute to damage as observed in this analysis, the SnPb solder will probably still fail before the SnAgCu solder for the FCBGA package