Slow Cycle Fatigue Creep Performance of Pb-Free (LF) Solders

Vasu Vasudevan *, Xuejun Fan**, Tao Liu ***, and Dave Young *
Intel Corporation
*5200 Elam Young Pkwy, Hillsboro, OR 97124
*** 5000 Chandler Blvd, Chandler, AZ 85226
*** Dupont, WA,
Vasu.S.Vasudevan@Intel.com

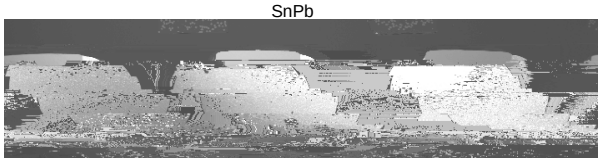
Abstract

Electronics industry is successfully transitioning into Lead-Free (LF) solders to comply with government regulations. There are many challenges associated with reliability life prediction for LF solders such as the selection of temperature cycle test methods, material compatibility issues, and reliability models. This paper focuses on investigating the effect of extended dwell time on LF reliability under thermal cycling for both flip chip BGA packages and sockets. Extensive experimental temperature cycle results for different pitch FC BGAs, and sockets have shown that LF (Sn-4.0Ag-0.5Cu) solder has a better fatigue performance than Sn/Pb over a wide range ofeI00.050.05tk TJT*0.0017 Tc0.3112 Tw[(very)4.7( )-6(l)4.1(ong)-6(dwel)4.1(l)4.1(t)4.1(

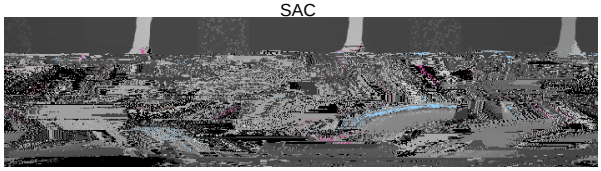
Table 1. Typical physical and mechanical properties of

Figure 8 shows the low magnification SEM images of crack propagation for the selected solder balls under die shadow for the Sn/Pb unit. It indicates that several balls have complete cracks at the board side, and some partial cracks on the package side after 1400 cycles with 4-hour dwell time. The crack propagation is fatigue-type in bulk-solder material. Outside die shadow region, minimal crack propagation was observed. This is consistent with previous observations that the critical solder balls for

SnPb



SAC



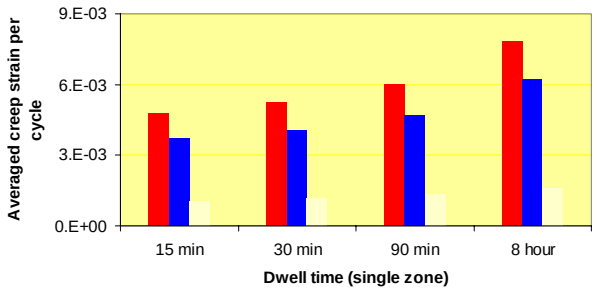
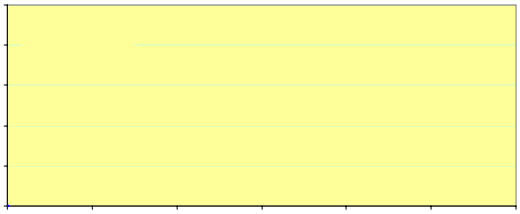


Figure 18: Average creep strain on package side for Sn/Pb solder

Figures 19 and 20 show the accumulated creep strain history with time in the first three cycles for Sn/Pb and SAC, respectively. These graphs show that total creep strain for 15 minutes is much lower than with 8 hour dwell time. Figure 18 shows that for SAC, creep accumulation at low temperature dwell and high temperature dwell is still continuing and no asymptote is evident even at 8 hour dwell time. Figure 20 shows that for Sn/Pb, the stress is completely relaxed at high temperature for Sn/Pb, thus no further creep is accumulated at high temperature dwell. However, due to high stress at low temperature, it is not fully relaxed, and the creep accumulation is still on going after 8-hour dwell time for Sn/Pb.



condition when the peak cycle temperature was at or above 125^0C and the package construction provided little or no compliance (e.g., ceramic package type) in the solder joint interconnects. Our test result in Figure 6 seems to indicate that Tmax plays a significant role in SAC solder fatigue life. This suggests that the accelerated temperature cycle test for LF solder should be performed below 0.8 melting temperature in Kelvin (TM). Syed etal [7] observed this behavior for ceramic package and Osterman et al [20] highlighted this behavior for LCC packages. More future work is needed to explain this behavior for LF solder and understand failure mechanism change if any for temperatures above 0.8 TM. The proposed temp cycle conditions for LF solder is shown in figure 21. The temp cycle results to date show that LF solder show higher fatigue perfotmance when the ramp rate is below <15 ^{o} C/min and Tmax below 125 ^{o} C