1. Introduction

Eutectic Sn-Pb solder joints have been widely studied in the microelectronics industry. On cooling after reflow and with cyclic thermo-mechanical fatigue, solder joints are known to undergo spinodal decomposition, intermetallic grain growth, Kirkendall void growth, micro-crack and macro-crack formation, and other processes [1]. Our objective is to demonstrate whether these processes affect the thermal and reliability properties of a 3JPV solder joint, and whether this can be detected in a simple, non-destructive, thermal test during stress cycling.

Multi-junction photovoltaic cells (MJPV) convert concentrated sunlight to electrical power with efficiencies approaching 50%. MJPV cells can also be operated as a self-thermometer and a self-heater, without added structure or componentry, which enables auto-calorimetry using only a programmable source-monitor unit (SMU).

Figure 1: Microstructure of aged Sn-Pb solder on AuPtPd metal. [1]

Previous work in this program [2] used a high-concentration solar simulator to develop cyclic thermal transients of approximately 65K for 8 seconds in 3JPV cells, but device failure was not seen after 7,000 cycles. Solder joint failure has been induced using conventional oven cycled stress [3], where 1,000–2,000 cycles at ramp rates of 7.5 to 140K/min were used.

Preliminary results show useful sensitivity, expected test stage material dependence, sample thermal mass effect, transient time constant structure, and substrate curvature change on shocks. Future work will explore piezoelectric artifacts, cyclic fatigue monitoring, differential structure functions, and other transient parameters.

2. Method

Figure 3: Dark forward I-V curves of some 3JPV cells at room temperature.

· Auto-calorimetry:
  - Segment 1: low-current monitor (10mA) for ambient temperature
  - Segment 2: known energy dose (400mA, 1s) injected into junctions
  - Segment 3: low-current monitor transient response

Figure 4: Junction temperature calibration curve.

Proxy for cyclic thermo-mechanical fatigue:
- Hot shock: 115°C hot plate, 10 seconds
- Cold shock: −196°C liquid nitrogen dip, 10 seconds

Figure 5: Information parameter $\Delta T$ definition.

Figure 6: Energy dose dose uniformity.

3. Preliminary Results

Figure 7: Segment 3 transient suggests several time constants, and test stage effect.

Figure 8: $\Delta T$ across thermal shocks. Piezoelectric effect from plastic deformation not obvious.

Figure 9: Substrate curvature and test stage effects – (a) metal stage; (b) polymer foam stage.

Figure 10: Mass sensitivity (5 samples) – (a) raw data; (b) normalized to sample mass.

References

3. N.S. Bosco et al., “On the effect of ramp rate to damage accumulation in the CPV die-attach” 37th IEEE PVSC, 2012