Abstract

The flip chip technology has been the dominating packaging solution for high performance chips and will remain so in the foreseeable future due to its shorter electrical connection length between the chip and substrate. As the chip complexity increases, the I/O density on each chip also increases. To accommodate the continuing rise of the I/O density, the diameter of the flip chip solder joints must shrink. At present, the diameter of a solder joint is about 100 μm, and it will be reduced to 50 μm soon. It means that the average current density in such a 50 μm joint is about 10^3 A/cm^2 when a 0.02 A current is applied. Electromigration in flip-chip solder joints has become a serious reliability concern when the current density reaches the 10^3 A/cm^2 level, which is about two orders of magnitude smaller than that in Al and Cu interconnects. The reason for this lower threshold current density to cause electromigration in solders has been pointed out to be the combination of several factors in the "critical product" of electromigration, including the higher resistivity, the smaller Young's modulus, and the larger effective charge of solders. This lower threshold makes electromigration in solders now one of the major reliability threats to microelectronic devices.

This investigation studies how electron flow distribution and vacancy concentration gradient affect the diffusion of solder atoms in a flip-chip solder joint under current stress. The migration of materials was traced by monitoring the positions of 21 Pb grains of the eutectic PbSn solder joint. Experimental results indicate that the displacements of the Pb grains were not uniform along in the electron flow direction. Additionally, certain Pb grains exhibited lateral displacements. The non-uniform material migration is attributable to the

combined effect of electromigration and the vacancy concentration gradient, which was caused by electromigration.

The combined effects of electromigration and thermomigration on material migration were also examined in this study. When the direction of electron flow is the same with temperature gradient, more solder atoms migrate. When the direction of electron flow is opposite with temperature gradient, less solder atoms migrate. Considering the effect of thermomigration in solder bump, the displacements of the Pb grains were measured, and the DZ* value of Sn in eutectic SnPb solder estimated to be -3.4×10^{-10} cm^2/s. The calculated Z^* value is about -34.

This study also reported that the solder joints failed by local melting of PbSn eutectic solder bump. The local melting occurred due to a sequence of events induced by the microstructure changes of the flip chip solder joint. The formation of a depression in current crowding region of solder joint induced a local electrical resistance increased. The rising local resistance resulted in a larger Joule heating, which, in turn, raised the local temperature. When the local temperature rose above the eutectic temperature of the PbSn solder, the solder joint melted and consequently failed. This result also shows that several points need to be considered when we face the issues of electromigration on reliability of flip chip solder joints. Firstly, the geometry of flip solder joints should be designed to avoid the formation of current crowding region in solder bump. Secondly, in order to resist the microstructure change, the higher mechanical intensity solder need be chose. Thirdly, increasing heat dissipation of solder joint under current stressing or choosing the solder which has higher melting point in order to prevent the melting phenomenon occurred.