Chapter 1

Introduction

In the semiconductor industry, flip-chip technology has been widely used for high-density packaging because of its capacity to handle large numbers of input-output (I/O) [1][2]. Due to the trend of miniaturization and the better performance, the dimension of solder bumps keeps decreasing and the current that each bump needs to carry keeps increasing, causing the current density in the solder bump to increase dramatically. Under the stressing of that high current density, the electrons flowing from the cathode side to the anode side may hit the atoms simultaneously so that atoms would move in the same direction as the electrons do. Gradually, as the atoms keep leaving from the cathode side, voids would be formed and finally make the circuit broken. At the anode side, the extrusion of the atoms, such as hillocks or whiskers, may contact with another circuit. This phenomenon would cause short-cut in the integrated circuit. In 1988, a commercia man-made satellite faied in the universe by whisker grown. Therefore, electromigration (EM) becomes an important reliability issue in flip-chip solder joints[3].

The resistance of Sn is 11.5μΩ-cm, and resistance of Pb is 19.3μΩ-cm. And the solder bump Sn63Pb37 resistance is 14.5μΩ-cm. And IMC like Ni_3Sn_4's resistance is 28.5μΩ-cm. When electrons from very small and very thin Al line irrigate to solder ball, it would have current crowding effect. We speculate IMC can reduce current crowding effect in the solder bump because of its high electronic resistance. Because electrons would more uniform go through UBM and solder bump. Void would not form easily during electromigration test. By technical literature and our previous experiment results, solder usually failed when electron current from chip side to board side. When voids form between UBM and solder, they block the original electrical path and change the current crowding region to travel around the void. The growth of the void reduces the effective contact area at the solder/UBM interface and increases the current density in the remaining contact area. This will make the current density higher than origin and increase the Joule heating inside the solder bump. And than solder bump would be melt, all devices can't work. If we let the region which UBM contact solder has thick IMC, therefore, electron would go through the front side of bump. It is expected that relieving the current crowding effect in solder joints would retard the formation rate of the voids and thus would increase the life time of the solder joints. However, no literature related to this issue has been reported so far.

Our research focus on IMC thickness effect to bump electromigration life time result. There are two kinds of samples in our research. One is thin-film UBM sample which structure is Ti0.1μm /Cr-Cu0.3μm /Cu0.7μm/Sn63Pb37/Au0.025μm / Ni(P)5μm/Cu20μm, the other is thick-film UBM sample which structure is Ti0.5μm /Cu0.5μm/Cu5μm /Ni3μm/Sn80Pb20/Au1μm/ electroless Ni 5μm. We give bump different aging time to get different IMC thickness. And base on Black's equation for Mean time to failure (MTTF)

$$MTTF = Aj^{-n} \exp(Q/kT)$$

A: constant which contains a factor involving the cross-sectional area of the joints

j: current density

n: model parameter for current density

k: Boltzmann's constant

T :average bump temperature in degree Kelvin

We used high temperature and high current density to test bump which have different IMC thickness can use how long under our electromigration test. After bump open we use IR(infrared rays), OM (optical microscope), SEM(scanning electron microscopy) and EDX(energy-dispersive x-ray spectroscopy)to observe the solder bump failure mechanisms.