Chapter 3

Experiment

We have two kinds of sample, one is thin-film UBM another is thick-film UBM . Why we call it thin-film bump, because its chip side UBM just have 0.7μm Cu contact with eutectic solder. And for thick-film bump, it has 3μm Ni contact with solder. As we know bump usually fail in chip side which electronic from chip side to board side .So it is important for chip side UBM structure. We thick IMC is higher resistance material, it can reduce current crowding and let bump have more life time. And IMC can easily be made under reflow and aging. So before electromigration test, we age sample below its melting point in order to get thicker IMC between the chip side UBM and solder, certainly board side IMC which between UBM and solder would become thicker. After aging, we do electromigration test under high temperature and high current density to get life time of sample. To find if aging can make bump stronger to resist electromiration. Our experiment can describe easily in Fig. 3.1.

3.1 Thin-film UBM sample structure

Its solder is Sn63Pb37 eutectic solder bump. Its UBM of a Ti/Cr-Cu/Cu tri-layer was deposited on the chip side, and a Cu/Ni(P)/Au pad was electroless plated on the BT board side. The solder bumps on the chip were formed by printing solder paste through a metal stencil and were reflowed in a furnace. The chips are then flipped over, aligned to BT substrates, and reflowed again. Afterwards, the package was filled with underfill. The solder bumps were electrically connected by an Al line in the chip, while Cu line was used in the BT board side. A schematic illustration of the structure is shown in Fig. 3-2(a), which shows that the contact window in the chip side was 85μm and 150μm for board side. The pitch for the sample was 400μm.

3.2 Aging and electromigration test for thin-film bump

In thin-film sample, because it is eutectic SnPb, its melting point is 183℃, so we aging it at 150℃ for different time, and do the electromigration test under 150℃ on the hotplate in an ordinary atmospheric conditions and get life time. We use 0.28A its mean current density is 5×10^3 A/cm^2. The electromigration test schematic digram as shown in Fig. 3.3. The current source which we use is Aglient E3642A as shown in Fig. 3.13. Hotplate is YSC HP-303DN.

3.3 Thick-film UBM sample structure

Thick-film UBM sample chip and FR-4 relationship as shown in Fig.3.4. And in the middle of FR-4 board is chip. Each gray circle is solder bump and connect by Al line as shown in Fig. 3.5. The schematic structure of the flip-chip bumps used in this study is shown in Fig.3.7. The UBM was 0.5-μm Ti/0.5-μm Cu/5-μm Cu/3-μm Ni. The Ti layer and the 0.5-μm Cu seed layer were sputtered, whereas the 5-μm Cu and the 3-μm Ni layers were electroplated. The passivation and UBM openings were 110 μm and 120 μm in diameter, respectively. Eutectic SnPb solder was used for the joint. The pad metallization in the FR4 substrate consisted of 1-μm Au and 5-μm electroless Ni layers. The dimension of the pad opening was 300 μm in diameter. The non-solder mask defined process was used. Due to the large opening in the substrate side, the bump height was as small as 25 μm. Both the electroplated and electroless Ni layers reacted with the solder to form

Ni_3Sn_4 IMC, and the average thickness of the IMC was 0.82μm in chip side and 0.52μm in the board side after reflow.

3.4 Aging and electromigration test for thick-film UBM sample

Power supply which we used is aglient E3646A，hotplate is YSC HP-303DN. We use enamel-insulated Cu line no.33. Polish from end to end of it. One side we use solder paste and weld gun put Cu line on Cu pad which on the board and then use PC to get bump life time.

In the beginning we use 0.8A, but sample fail very quickly. Usually fail under 100hr. Base on IR (infrared rays) result, if fail time shorter, maybe fail mechanism is electronic current to high. Because $P=I^2R$ when we put more electronic current to it, P is higher making Al trace in chip side broken. On the country electromigration effect on solder are not fail mechanism.

We use 0.75A to test our sample. The intermediate zone of sample is chip. From up to down is line1 line2 line3 line4 line5 and line 6 as shown in Fig.3.5.We use line 6 bump to do our research. In the line 6, it has four bumps. From left to right we symbol them bump1 bump2 bump3, and bump4, which were connected by an Al trace. The Al trace were 1.5 μm thick and 100 μm wide. The pitch for the solder joints was 1 mm. We just test bump2 and bump3. Electeonic current is from board of bump 3 in and go through Al line in the chip side and go through bump 2 and go out of our sample. The direction of the electron flow of the electromigration experiment is described in the Fig. 3.8. The sample was heated on a hot plat. When we consider mininum of solder which UBM contact solder is 100μm. This sample was current stressed with the current density of 1 × 10^4 A/cm^2 at 150°C. If we consider current crowding effect, current density would become higher. The solder bumps of the flip chip package were cross-sectioned after current stressing. All the samples were examined by SEM and EDX.

We think IMC made by aging can reduce current crowding effect in the solder bump when we give it high current density to test. The possible mechanism which IMC release electromigration effect is shown in Fig. 3.7.

3.5 Four-point probe and bump resistance

We have designed and fabricated Kelvin probes for flip-chip eutectic SnPb solder joints. Figure 3.9(a) shows the plan-view schematic for the structure. Six Cu lines on the FR4 substrate connected to the four bumps, and they were labeled as node 1 through 6, as shown in the figure. The Cu lines were 30 μm thick and 100 μm wide. With these six Cu lines, various experimental setups can be performed to measure the bump resistance for Bump 2 or Bump 3, or the resistance for the middle segment of the Al trace. In this study, current was applied through nodes 3 and 4, i.e. electrons flowing from the chip side to the substrate for Bump 3, and the opposite direction for Bump 2, as illustrated photograph image in figure 3.9(b). The voltage change in Bump 2 was monitored through nodes 1 and 2. Therefore, the change in bump resistance during electromigration for bumps 2 can be monitored simultaneously.

The power supply used in this measurement was a Keitheley 2400, which has a 0.1 μV resolution in voltage measurement. The error in measuring resistance in this study was estimated to be 1 to 10 μΩ. Before solder bump open, we also use grinding and polishing machine to find void in the middle of bump.

3.6 Analysis

Before electromigration test, a solder ball in the sample was cross sectioned and polished by grinding and polishing machine as shown in Fig.3.12. This cross sectioned surface can be examined directly by scanning electron microscopy (SEM) and energy-dispersive x-ray spectroscopy (EDX) as shown in Fig. 3.10. Before we get SEM image, we must coat Pt on our solder bump to keep off charge effect as shown in Fig. 3.11. After eletromigration test, the solder bump was be detected by IR (infrared rays) as shown in Fig. 3.15 to look if sample fail at Al line or bump than cross section again. Certainly, we want our sample fail at solder bump instead of Al line. After IR observation, we also use grinding and polishing machine to find what happen in the solder. Certainly, SEM and EDX also would be used to observe our sample after electromigration test .