Reliability of Instant Bonding of Cu-Cu joints: Thermal Cycling and Electromigration Tests

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Abstract

This study will investigate the reliability of instant bonding by <111>-oriented nanotwinned Cu (nt-Cu). In previous study, nt-Cu microbumps were proved to achieve Cu direct bonding in 10 s with bonding temperature 300 ℃ and pressure 90 MPa. Based on this result, lower bonding pressure was done and the bonding time was kept in 10 s. The resistance of a Cu-Cu microbump measured by Kelvin structure was about 4 ~ 5 mΩ. After instant bonding process, underfill dispensing process was chose to protect Cu microbumps from oxidation during reliability tests. Besides, coefficient of thermal expansion (CTE) of Cu/underfill structure was like Cu/polymer dielectric hybrid bonding, so the effect of high-CTE dielectrics could be well studied.

Thermal cycling test (TST) was executed to investigate the effect of high-CTE dielectric in Cu direct bonding. The temperature is from – 55 ℃ to 125 ℃; the soak time is 5 min; the ramp rate is 18 ℃/min. Resistance of Kelvin structure was measured pre 250 cycles, and the total test cycles was 1000. The final (1000^{th} cycles) resistance change was about 15 %. Cross section images showed that the crack was concentrated at the center of bonding interface instead of the edge of the bump.

Electromigration (EM) test was the other reliability test. Kelvin bumps were put on a hot plate (150 ℃) and exerted a high current density: $2.12 \times 10^5 A/cm^2$ which was calculated with a 30 μm microbump in diameter. If pressure and time raised to 90 MPa/ 30 s, the life time could be longer than 1500 h. A Cu/Sn/Cu microbump was tested with the same EM conditions, and the life time was 448 h. As a result, the life time of Cu microbump fabricated by instant bonding with bonding condition: 300 ℃/ 90 MPa/ 30 s was at least 3 times larger than traditional solder microbumps.