覆晶封裝銲錫技術中熱時效對電遷移效應的影響

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摘　要

隨著電子元件越做越小，每個銲錫球所需承受的電流密度就越大，因此研究如何讓銲錫球可以抵抗電遷移效應是非常重要的課題。由於在迴銲的時候，Under Bump Metallurgy (UBM)層通常是 Ni 或是 Cu，並且會和 Sn 產生介金屬化合物(IMC)，這一層介金屬化合物，不但是銲接上去作爲接合用的介面，更由於它是高電阻的物質，我們推測可以藉由此性質降低電流集中效應，增加銲錫球的使用壽命。因此我們使用熱時效的方式，增加 IMC 的厚度，使用的溫度約爲銲錫溶點絕對溫度的百分之九十。我們使用薄膜 UBM 與厚膜 UBM 兩種試片。薄膜試片的結構是矽晶片上 UBM 層爲 Ti0.1µm /Cr-Cu0.3µm /Cu0.7µm 薄膜，在基板上的金屬層爲 Au0.025µm / Ni(P)5µm/Cu20µm，銲錫球爲 Sn63Pb37 共晶銲錫結構由於溶點爲 183℃，所以我們使用的熱時效溫度是 150℃； 而厚膜試片結構是 UBM 層爲 Ti 0.5µm/ Cu 0.5µm / Cu 5µm / Ni 3µm，而使用在基板上的金屬層爲 Au1µm /electroless Ni5µm，銲錫球爲 Sn80Pb20 的成分，溶點爲 208℃。所以使用的熱時效溫度爲 170℃。我們發現在薄膜試片中熱時效會降低銲錫球在電遷移測試當中的 life time，而在厚膜試片當中，適度的熱時效則會增加銲錫球的 life time，沒有熱時效的平均壞掉時間是 430hr，而在熱時效 25hr 的時候壞掉時間可以達到 858hr。我們推測薄膜試片由於熱時效在界面反應後容易造成孔洞，會使銲錫球降低電遷移測試的 life time；而厚膜試片則會產生較厚且穩定介面的 IMC 在 UBM 與銲錫球中間，減緩因爲電流集中移效應產生的空孔，增加銲錫球抗電遷移能力。我們使用紅外線觀察試片在電遷移測試後的損壞的情況觀察是否是真的壞在銲錫球上面而不是鋁導線。我們發現不同的破壞機制在有熱時效與沒有熱時效在試片整個損壞前，由於厚膜試片有著 Kelvin probes 結構，所以我們可以使用四點量測去測量試片中因爲電遷移孔洞造成銲錫球電阻增加情形，觀察其中的破壞機制，我們發現熱時效過後的試片，在電遷移測試中容易產生 IMC 橋連接晶片端與基版端使電子通過，可能也是增加試片 life time 的重要因素之一。

Effect of Aging on Electromigration of Flip-Chip Solder Joint

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Abstract

Due to the trend of miniaturization and the high 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. As a result of the high current density, minimization of electromigration effect becomes the key to achieve high reliability. In flip chip technology, UBM (Under Bump Metallurgy) is often used to connect chip, solder and board. UBM is mostly composed of Ni or Cu which reacts with Sn to form IMC (Intermetallic compound). IMC is usually composed of Ni_3Sn_4 or Cu_6Sn_5 and is used to joint chip and solder. We conjecture IMC can reduce current crowding effect during electromigration test because of its higher resistivity than solder. For the reasons above, our goal is to make the IMC layer as smoothly as possible in order to achieve a longer life time for solder. In our experiment, two types of samples are used; both are aged at 90% of its melting point. One of the samples is thin-film UBM bump. Its structure is Ti0.1μm /Cr- Cu 0.3μm/Cu0.7μm/Sn63Pb37/Au0.025μm / Ni(P)5μm/ Cu20μm. Because solder ball is eutectic SnPb, its melting point is 183℃. We used 150℃ to age it. The other was thick -film bump, its structure was Ti0.5μm /Cu0.5μm/Cu5μm /Ni3μm/Sn80Pb20 /Au1μm/ electroless Ni 5μm. Sn80Ni20 its melting point is 208℃. We used 170℃ to age it. At the end of the experiment, we found aging effect reduces solder ball life time under 0.28A and 150℃ during electromigration test in thin film structure. On the other hand, we observed an opposite result for thick-film bump structure under 0.75A and 150℃. We speculated that voids form between UBM and solder in thin-film under thermal aging. However, complete and successive IMC formed in thick-film UBM. We used infrared ray to exam the sample failure in the Al trace or solder bump after electromigration test. Because thick-film UBM has Kelvin probes structure, we also used 4-point probe to measure bump resistance in thick-film bump. Before bump open, we found different failure mechanisms between aging-free and aging solder joint. Sample which age may form IMC bridge between chip and board during electromigration test. It may be an important reason to prolong the sample life time.

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