覆晶接點與錫電路之電遷移微結構變化模式研究

摘要

電遷移效應對金屬導線的影響，一直被人們重視，近年來由於半導體與微機電工業之興起，大電流對微細化電路之影響，顯得特別重要，本文針對微細之錫導線與覆晶式共晶錫鉛接點在常溫下(30oC)與高溫下(100oC，70 oC)通入電流密度 4 104 A/cm2 之電流，並分別以即時與間時的實驗方式，進行微結構變化觀察，因電遷移效應所造成孔洞之形成與衍生失效之機構之研究。

研究發現，錫導線方面，最初時，在晶界之交界處，會有結構之變化，而使部分晶體結構產生重組，至一段時間後，因其爲多層晶體排列結構，並無錫鬚之生成，而觀察到的現象爲先行成累積的晶粒突起後，孔洞相伴生成。在研究中發現了電流對錫導線影響中，錫晶粒會因電流作用下產生反轉現象，經 x-ray microdiffraction 確認，晶體結構朝向電阻梯度產生的方向變化。

在覆晶接點方面，研究中同樣發現銲料中微結構因電遷移而產生孔洞與凸起之結構變化，但在研究過程中，也發現到晶片端之銅導線部分擴散至銲料中生成大量 Cu6Sn5，並造成銅導線之尺寸變小後，引發電流聚集效應，使銅導線產生因溫度之劇升而溶解之現象，最後產生斷路之失效模式。以即時試驗觀察發現，在通電過程中，覆晶接點之銲料中，經 EPMA 觀察，確認有銅化合物之成分存在，確認此部份之銅原子電遷移現象。

另一方面，爲得到接點的溫度分布，使用熱流計法來量測，其實驗方式爲使用一端加熱，量測另一端之溫度分布變化，並由文獻得到各成分之熱傳導係數值，經計算後得到接點實際之溫度狀況，釐清熱遷移與電遷移之區隔。結果發現，在實驗中之尺度下，本研究之實驗模組，熱遷移之效應並未發生，僅觀察出電遷移的影響模式。

本研究提供了評估覆晶式接點之實際壽命的方法，並觀察到幾種利用加速模式得到之失效機制，並仔細地觀察介面之行爲，得以提供相關學者參考。

Electromigration Induced Microstructure change in Flip Chip Solders Joint and Tin Stripe

Abstract

The electromigration failure mechanism in conducting wire and solder joints through the large current density was studied in detail. When environmental temperature was changed to room temperature, 70 oC and 100oC with a nominal current density of 4 104 A/cm2, the time to failure increased. The void formation-and-propagation failure mechanism was observed in situ and free time.

Under constant current electromigration, white tin exhibited grain growth. We observed that high-resistance grains reorient with respect to the neighboring low resistance grains, most likely by grains growth of the latter. Microstructure evolution under electromigration could be responsible for the resistance drop.

The electromigration failure mechanism in flip chip solder joints through the rapid dissolution of the Cu metallization on the cathode side. The average dissolution rate was about 1 m/min. The results of this study indicate that temperature, as an experimental variable, is not less import than the current density in electromigration study. The surface temperatures of the chip and substrate during electromigration were also measured. The temperature distribution of the Si chip was reasonably homogeneous due to the fact that Si is a very good thermal conductor. It was also reasoned that the high thermal conductivity of the PbSn solder could not support a temperature gradient large enough to induce thermomigration across the solder joint in the present study. Experimentally, no evidence of mass transport due to thermomigration was observed.

A different mechanism of failure under electromigration from grain growth and Cu dissolution, shows that the incubation time of void nucleation is a good indicator of the real lifetime of a joint under current-stressing.