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碩士論文

半導體晶圓測試之懸臂式探針卡修復之半自動精密系統開發

Development of the automated precision system for cantilever probe card repair for semiconductor wafer testing

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摘　　要

在IC製程中，晶圓針測是IC進行封裝製程前，用以把關晶粒良率的重要流程。

晶圓針測的設備主要由針測機(Prober)、測試機(Tester)、探針卡(Probe Card)等三項設備組成。其中，探針卡作為晶圓和測試機之間的重要媒介，固定在針測機上並與測試機的測試頭進行連接，用於對晶粒的電性功能進行測試。

在晶圓針測時，探針卡上的探針針尖會快速且連續的接觸多片晶圓，使探針本身承受多次的循環負載，而產生高週期疲勞的破壞，讓探針針尖無法保持水平度和產生偏位，進而影響晶圓測試結果、增加測試成本甚至造成晶粒損壞。因此，探針卡在下針約40,000至80,000次後，需要下產線進行檢修。

在傳統的探針卡檢修作業中，具多年經驗的探針卡工程師會操作調針機，並將印刷有探針針尖標準位置的Mylar校準片和探針針尖對齊，以此來對探針針尖的偏位進行檢查與調整。然而，由於傳統調針作業，需要探針卡工程師手動向上翻轉調針機上的翻轉機構，調整探針針尖的位置，再向下轉動翻轉機構檢查調整結果。這種反覆輪換的動作，占整體調針作業時間約30 % ，進而導致探針卡工程師調針效率無法提升。完成一張探針卡的調針作業，平均需耗費約8個小時，進而拉長探針卡投入產線的時間。

在新一代半動化調針機設計中，引入了 X-Y 精密定位平台技術，結合探針卡的標準針位座標和改良的顯微鏡系統，以取代了翻轉機構和Mylar校準片的使用，同時提高探針卡工程師之調針效率並減少 Mylar 校準片的消耗品成本。

在導入調針作業前，考慮到傳統調針作業之現況，半自動化調

針機整體系統精度需要確保能夠讓每根探針針尖之定位精度達到±2.5 μm之範圍內。然而，根據研發團隊經驗的評估，半自動化調針機整體系統精度可能受到 X-Y 精密定位平台系統、光學系統、整體系統三大方面之影響而失準。因此，在半自動化調針機研發中，如何找出影響半自動化調針機整體系統精度的關鍵問題並予以解決，將是一項重大的挑戰。

本研究根據半自動化調針機之精度魚骨圖，進行了總共七個階段的實驗，並找出了對半自動化調針機整體系統定位精度影響最大的兩項問題：探針卡放置引起的旋轉問題及光學系統的旋轉問題。同時，提出具體解決方案並對其之可行性進行驗證。除此之外，通過兩項實驗，證明了半自動化調針機之定位精度重複性及穩定性，並且不受到個體差異性所影響。最終，實現了半自動化調針機整體系統精度從原先大於 25 μm之定位精度偏差，控制在±2.5 μm於X、Y軸5 mm行程範圍內之定位精度。

關鍵詞：調針機、懸臂式探針卡

Abstract

In IC manufacturing processes, wafer probing is an important step to acquire the functional yield of the IC before the packaging process. The wafer probing equipment consists of three main devices: the prober, tester, and probe card. The probe card (PC) serves as a crucial interface between the wafer and the tester, fixed on the prober and connected to the tester's test head. It is used to test the electrical functionality of the IC.

During wafer probing, the probe tips on the PC make rapid and continuous contact with multiple wafers, subjecting the probe itself to repeated cyclic loads that generate high-cycle fatigue damage. This leads to a loss of probe tip flatness, and misalignment, and ultimately affects the accuracy of wafer testing, increases testing costs, or even causes damage to the IC. Therefore, after approximately 40,000 to 80,000 probe insertions, the PC must be removed from the production line for maintenance.

In traditional PC maintenance operations, experienced probe card engineers use a PC adjustment machine to adjust the probe tips with Mylar reference. However, the engineers need to manually adjust the displaced probe tip with the flipping arm upwards and then check the adjustment result by rotating the flipping arm again. This rotating operation costs approximately 30 % of the time and hinders the efficiency of probe card engineers. On average, it takes around 8 hours to complete the adjustment of a probe card, thereby prolonging the time for the probe card to return to the production line.

X-Y precision positioning platform technology is introduced in the design of the new generation semiautomatic PC adjustment machine. This, combined with the standardized probe tip positions of the PC and an improved microscope system, eliminates the need for a flipping arm and Mylar reference. It simultaneously improves probe card engineers' efficiency and reduces consumables cost like Mylar reference.

Considering the current situation in traditional PC maintenance operations, the overall system accuracy of the semiautomatic PC adjustment machine needs to ensure that the positioning accuracy of each probe tip is within a range of ± 2.5 μm. However, based on the evaluation by the research and development team, the overall system accuracy of the semiautomatic PC adjustment machine may be affected by three major factors: the X-Y precision positioning platform system, the optical system, and the overall system alignment. Therefore, in the development of the semiautomatic PC adjustment machine, identifying and addressing the key issues that affect the overall system accuracy will be a significant challenge.

In this study, based on the accuracy fishbone diagram of the semiautomatic PC adjustment machine, a total of seven experimental stages were conducted to identify the two main issues that have the greatest impact on the positioning accuracy of the overall system: rotation caused by probe card placement and rotation in the optical system. Concrete solutions were proposed, and their feasibility was verified. Furthermore, through two experiments, the repeatability and stability of the positioning accuracy of the semi-automated needle calibration machine were demonstrated, showing that it is not affected by individual variations. Ultimately, the positioning accuracy of the overall system of the semi-automated needle calibration machine was improved from an initial deviation of over 25 μm to within ± 2.5 μm in a 5 mm travel range along the X and Y axes.

Keywords: Probe card adjustment machine、Cantilever probe card