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碩 士 論 文

單拍偏振干涉之表面形貌量測技術

Single-Shot Polarization Interferometry for Technique of Surface Profile Measurement

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摘要

本研究開發一種「單拍偏振干涉之表面形貌量測技術」，能精準量測待測物之表面形貌，並改善現有半導體表面形貌量測所遇到的瓶頸：系統架構複雜與量測範圍受限。本技術是基於待測物之反射光與參考面之反射光所形成偏振干涉現象進行表面形貌量測，無需額外壓電調制器的輔助即可完成量測。當偏振干涉現象發生時，兩道反射光之偏振態相互正交，干涉圖像之相位變化由形貌資訊產生。透過本研究提出之偏振干涉解相法，我們能求得待測物之相位差分布，並運用形貌量測方程式，即可計算出相應的表面形貌分布。

本研究量測系統結合「偏振相機」與「偏振干涉術」形成一個非共光程之量測系統，不僅能有效減少架構之複雜度，還能同時擷取四個不同偏振方向之光強度訊號。本量測系統中，藉由半反射鏡與聚合物相位差膜之光學特性，使兩道光束反射後投射在成像系統上，並形成四個相互正交之偏振干涉圖像。相較於移相干涉之形貌量測技術，本系統量測形貌過程中無需相位調制器，或是壓電調制器等改變干涉圖像之相位差，僅需擷取一張干涉圖像，即可計算出待測物之表面形貌分布，適合應用於量測連續曲面或是所有反射之拋光材料之表面形貌。

在量測實驗中，不同平整度之平面鏡、碳化矽晶圓試片皆使用本研究所開發之量測技術成功量測出表面形貌分布，並改變晶圓相應位置與傾斜晶圓角度來驗證此技術能量測到晶圓形貌。本量測技術之系統解析度可達 11.12 nm，最大檢測範圍可達直徑 60 mm。

關鍵字：表面形貌、相位展開、Fizeau 干涉術、偏振干涉解相法、偏振相機。

Abstract

This study presents a "Single-shot Polarization Interferometric Surface Profilometry Technique" that enables precise measurement of the surface topography of a test object. It addresses the limitations encountered in existing semiconductor surface profilometry, such as complex system architecture and restricted measurement range. The proposed technique leverages the polarization interference phenomenon between the reflected light from the test object and a reference surface to perform surface profilometry, eliminating the need for additional electro-optic modulators. When polarization interference occurs, the polarization states of the two reflected beams become orthogonal, and the phase variation in the interference image encodes the topographical information. Through the introduced polarization interference phase-unwrapping algorithm, the phase distribution of the test object can be determined, and by utilizing the surface profilometry equation, the corresponding surface topography can be calculated.

The measurement system developed in this study combines "polarization interference" with a "polarization camera," creating a non-common-path measurement system. This design not only enables the test object to generate interference images but also effectively reduces the complexity of the setup. Simultaneously, it captures the intensity signals from four different polarization directions. In this measurement system, the optical characteristics of the reflecting mirror and the polymer phase retarder are exploited to project the reflected beams onto the imaging system, forming four orthogonal polarization interference images. Compared to phase-shifting interferometry techniques, the proposed system performs surface profilometry without the need for phase modulators or devices that alter the phase difference of the interference images. It only requires the acquisition of a single interference image to calculate the surface topography of the test object, making it suitable for measuring the surface topography of continuously curved surfaces and polished materials with various reflective properties.

In the measurement experiments, the developed measurement technique successfully captured the surface topography distribution of different flat mirrors and silicon carbide wafer samples. The technique's capability to measure wafer topography was verified by altering the

wafer's position and tilting angle. The system's resolution was found to reach 11.12 nm, with a maximum detection range of a 60 mm diameter.

Keywords: Surface profile, Phase unwrapping, Fizeau interferometry, Polarization Interferometry, Polarization Camera.