数理物質科学研究科　博士論文の要約

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博士論文題目
Development of an optical height sensor and key optical components for wafer inspection systems
（ウエハ検査装置のための光学式高さセンサと主要光学部品の開発）

Key optical technologies for semiconductor wafer inspection systems have been studied and developed to improve their performance and their cost of ownership.

Wafer inspection systems are necessary for development and production of LSI devices to improve their yield in development phase and maintain it in production phase. The production yield is the most important factor in mass production of LSIs, since final cost of the LSI chips largely depends on it. To obtain high yield in development phase and maintain it in production, problems in production systems and process parameters need to be detected and corrected as soon as possible. Various wafer inspection systems are applied in many production steps to detect such problems and find their root causes. In addition, higher throughput and sensitivity has been required for the wafer inspection systems as LSIs become widely used and its process rule continues to shrink quickly.

Wafer inspection systems are divided into two categories, electron-beam inspection systems and optical inspection systems. The inspection systems based on electron microscope are used to measure dimensions of patterns formed on wafer surface or identify types of defects detected by defect inspection systems. Optical inspection systems are used to detect defects on bare wafers and patterned wafers such as particles, scratches and pattern defects.

Optical technologies are necessary in both types of the wafer inspection systems. Optical height sensor is commonly used in both inspection systems for focus adjustment in observation of the wafer surface. High-power deep-ultraviolet (DUV) laser and high-resolution optics are necessary for optical inspection systems to realize high sensitivity in the inspections.

We have developed simple and accurate optical height sensor for the inspection systems. We have analyzed root causes of pattern dependent measurement error in conventional methods and developed new coordinate averaging technique. We have applied this to multiple-slit-projection method and achieved accuracy better than 0.35um on a patterned wafer with large reflectivity variation. Quick and accurate auto-focusing has been achieved by applying this method to an electron-bean inspection system.

We also have developed a DUV laser and high-resolution imaging optics for optical wafer inspections. In the development of the laser, the fifth harmonics laser is designed and built for future inspection systems. We have reviewed a method for designing a frequency conversion optics carefully and designed the optics considering manufacturability. Then, we have constructed the laser and confirmed output power over 100mW with the spectral bandwidth less than 20pm and good beam quality. We have shown that the narrow spectral-linewidth quasi-continuous-wave DUV laser suitable for realizing low cost DUV optics is feasible with frequency conversion of a mode-locked laser. In the development of the imaging optics, microscopic oblique detection imaging optics for DUV light is designed and evaluation tool for the lens is constructed. Then the lens is manufactured and tested on the tool. Evaluating the performance of the lens with point images and considering inspection pixel sizes, appropriate balance between cost and imaging performance is expected. The performance suitable for DF wafer inspection systems is demonstrated.

Improvement of the performance of wafer inspection systems have been achieved and will be expected by the developments shown above. The optical height sensor is applied to electron-beam inspection system and throughput of the system is improved. This technique can be applied to optical inspection systems to improve their sensitivity by reducing focusing error during inspections. The DUV laser, DUV optics and optics evaluation technique has been applied for the development of next-generation inspection systems to improve their sensitivity.