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論　文　内　容　要　旨

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学位論文題目	CT-TDLAS measurements of gas concentration and temperature distributions in a semiconductor chamber (CT-TDLASによる半導体チャンバ内のガス濃度・温度分布測定)		

内容要旨

In recent years, semiconductor devices have been highly integrated, and transistors with complicated structures like the three-dimensional NOT-AND flash memories or the fin field effect transistors are being manufactured in mass production phase. One of main processes for fabricating these devices is the dry etching, in which microscopic trench structures with high aspect ratios in vertical directions can be realized. With increasing the integration densities, even atomic size fabrications have been expected for the dry etchings. However, the process includes some serious difficulties, one of which is that the critical dimensions (CDs) of the fabricated devices are not uniform across a wafer processed with non-uniform spatial distributions of etchant gas concentration, temperature, and plasma sheath intensity. The CD uniformity has been improved to some extent by precisely controlling the temperature distribution on a multi-zone electrostatic chuck. On the other hand, the technology of the atomic layer etching has been actually developed, in which the CD uniformity is considered to be less sensitive to the spatial distributions compared to conventional dry etchings. Although the quality of the dry etching has been gradually refined with these technologies, the improvement of CD uniformity has not yet achieved to get sufficient yields in mass productions, and controlling the spatial distributions still continues to be a high priority. To achieve it, the technology to measure the spatial distributions in a semiconductor process chamber is strongly desired.

Tunable diode laser absorption spectroscopy (TDLAS) is a useful method for the chamber in-situ monitoring in non-contact manner. In the TDLAS, absorption spectra of trace gas are measured using near-infrared or mid-infrared laser light sources, and the gas concentration and temperature can be determined. Various applications of the TDLAS for plasma diagnostics in chambers were reported. In-situ monitoring which focused on the dry etching were also performed, where trends of concentration of gas species or plasma radicals were measured. However, as a conventional TDLAS utilizes a single laser path in the measured area and collects just one absorption spectrum integrated over the laser path, it cannot measure the spatial distributions of gas concentration or temperature. To measure the spatial distributions in a chamber, computed tomography-tunable diode laser absorption spectroscopy (CT-TDLAS) can be a promising candidates. In this method, infrared absorption spectra for multiple laser paths passing through a measured area are collected. Based on the spectra, the spatial distributions of gas concentration and temperature are reconstructed by using the computed tomography (CT) calculations. In the past, this method has been adopted for diagnosis of an aero-propulsion engine, and analysis of vehicle engine exhausts or combustion fields. However, an application for measurement in a semiconductor process chamber has not been reported. The inner space of the semiconductor process chamber is a closed system, and the

behaviors of temperature and pressure are considered to be different from those of engine or combustion fields.

In this work, the CT-TDLAS was applied to measure CH_4 concentration and temperature distributions simultaneously in our designed experimental semiconductor process chamber. To focus on the basic investigation of the CT-TDLAS feasibility to the semiconductor process chamber, the gas species (CH_4) and the chamber pressure (760 Torr) employed in the examinations were limited. Chapter 1 is devoted to the introduction, where the motivation of the CT-TDLAS measurement in the semiconductor industry is mentioned. In chapter 2, theoretical background of the CT-TDLAS is reviewed. In chapter 3, construction of CH_4 spectrum database required for the CT-TDLAS measurements is described. In chapter 4, the CT-TDLAS measurement system and structure of the semiconductor process chamber for experiments in which the CT-TDLAS system is installed are shown. In chapter 5, the validity of the CT-TDLAS measurements and the algorithm was checked using a simple experiment with a five-fold concentric cylinder and simulations of the computer fluid dynamics. In chapter 6, CH_4 was actually fed into the chamber to measure the concentration and temperature distributions with the CT-TDLAS, then the meaning of the measured results were discussed.