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Development of Ellipsometer System for Observation and Analyses of Dusts in Large Plasma Device

大型プラズマ実験装置内ダスト観測・解析用ミー散乱偏光解析装置の開発

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A new system of ellipsometry without an optical fiber was developed for the monitoring of dust generation in LHD. The system consists of two modules. One module composed of a laser-light source, a polarizer, and a rotating-compensator was attached to the view-window of AD01-02 of the 4.5 L port. The other module of analyzer, which is composed of a wire-grid polarizer, a focusing lens, and a light-diffusing plate, was set in the vacuum chamber of LHD. The performance of the developed ellipsometer system was examined by using an RF plasma equipment under the similar arrangement of the system.

1. Introduction

The generation of dusts in nuclear fusion reactors is becoming a serious problem, because they play as sources of core cooling and tritium pollution. *In-situ* measurements and analyses of dust behaviors are important issues to reduce the generation of dusts in a nuclear fusion reactor. Mie-scattering ellipsometry that was developed for monitoring the growth of fine particles in a processing plasma [1-3] can be a useful method for the analysis of dust growth and behavior in a nuclear fusion reactor. We have been developing a Mie-scattering ellipsometry system for the analysis of generation and transport of dusts in the Large Helical Devise (LHD)

Before we had installed modules of laser-light source and detector of an ellipsometry system along with an optical fiber, however, the volume of outgas from the optical fiber exceeded an allowable value under 100 ℃. Hence, the use of optical fiber in the system of ellipsometry was abandoned. We present in this paper a new system of ellipsometry without an optical fiber developed for the monitoring of dust generation in LHD [4].

2. Theory of Mie-Scattering Ellipsometry

The Mie-scattering theory is well known and its equation is shown in a lot of textbooks [5,6]. Meantime, the method of Mie-scattering ellipsometry is developed by us 20 years ago [1-3]. For the analysis of optical structure of thin films in conventional ellipsometry, Ψ and ⊿, which are called ellipsometric parameters, are defined by the ratio of complex reflectance of p (parallel) component and that of s (vertical) component. From the analogy of thin ellipsometric, its parameters are defined (Fig.1) [1] by the amplitude functions of $S_1(\theta)$ and $S_2(\theta)$ [6] used in Mie-scattering theory as

$$\tan\Psi \cdot \exp(i\Delta) = S_1(\theta) / S_2(\theta).$$

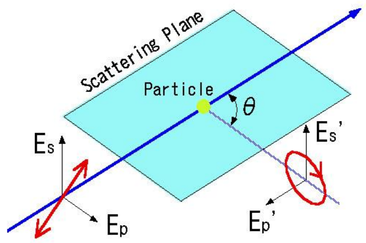

Fig.1. Conceptual diagram of Mie-scattering ellipsometry.

3. Experimental System

Our ellipsometer system consists of two modules. One module composed of a laser-light source (wavelength: 532 nm, maximum output power: 200 mW), a polarizer, and a rotating-compensator was attached to the view-window of AD01-02 of the 4.5 L port. The other module of analyzer, which is composed of a wire-grid polarizer, a focusing lens, and a light-diffusing plate, was set in the vacuum chamber of LHD. The image of distribution of scattered light is projected on the light-diffusing plate through the focusing lens and wire-grid and is observed out of the chamber by using a CCD camera attached to the view-window of AD01-03. Figure 2 shows the schematic diagram of the ellipsometer system attached to LHD.

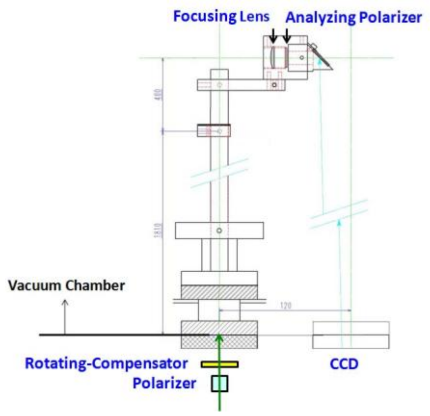

Fig. 2. Schematic diagram of the ellipsometer system attached to LHD. Light source module and CCD camera are attached to view-windows of AD01-02 and AD01-03 of 4.5 L port, respectively. Analyzer module is set in vacuum chamber.

Figure 3 shows a photo taken from the AD01-02 view-window out of the chamber. The left arrow indicates the position of measured dusts where a scattering object was put instead of dusts. The projected image of the scattered light is observed at the position indicated by the right arrow.

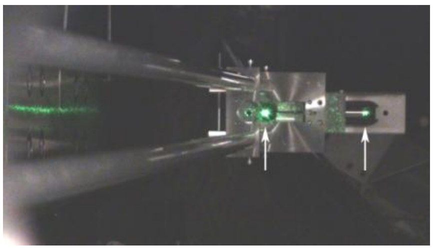

Fig. 3. Photo taken from AD01-02 view-window out of vacuum chamber. Left and right arrows indicate the positions of dust measurement and projected image of scattered light from substitution object, respectively.

The performance of the developed ellipsometer system was examined by using an RF plasma equipment under the same arrangement of ellipsometric system as in the LHD except for elimination of a focusing lens and substitution of a light-diffusing plate with a mirror (Fig.4). Polarize and analyzer azimuth were set at 90° and 45°, respectively. Spherical divinylbenzene fine particles of 2.25 μm in diameter were suspended on an RF electrode.

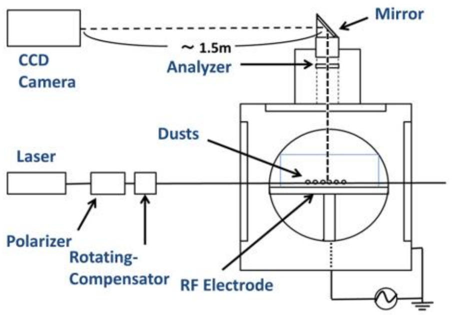

Fig.4. RF plasma equipment for Mie-scattering ellipsometry measurement.

4. Results and Discussion

The intensity of light on CCD as a function of rotating-compensator azimuth C, i. e., I(C), was obtained as shown in Fig.5. Fourier coefficients of I(C) were calculated, then ellipsometric parameters were determined to be Ψ=75.8°, Δ=38.3°, which are valid values for the measurement.

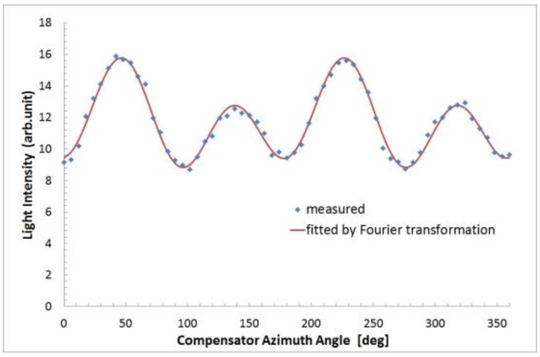

Fig.5. Light intensity variation with compensator azimuth angle of measurement (upper) and calculation after Fourier transformation (lower).

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