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Measurement of Hydrogen Ion Reflection from Tungsten Surface based upon Phase Sensitive Detection
位相検出法によるタングステン表面水素イオン反射特性計測

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We have been developing a new technique to measure the angular and energy distributions of low energy hydrogen ions reflected from tungsten surface based upon phase sensitive detection of Hα (656.28 nm) line. In order to avoid any excitation of plasma oscillation, a tungsten target immersed in hydrogen plasma is biased from -50 V to -250 V with 73 Hz modulation frequency. The corresponding shift and broadening represents the change in velocity distribution of hydrogen atoms reflected at the surface. The system still has a poor S/N ratio problem and the new system free from drift wave-type noise is being constructed.

1. Introduction

The investigation of plasma wall interaction (PWI) is an important matter toward further progress of both fusion and plasma processing for semiconductor industry. In a fusion device, PWI, such as strong particle radiation from the plasma, causes the wear of plasma facing walls [1-5] and the sputtered impurities from the wall exacerbate the discharge condition [6-7]. In case of plasma processing, on the other hand, PWI is utilized for practical applications [8-11] such as thin film deposition, surface residue removal, plasma etching, *etc*. The experimental study, however, has not been performed enough, especially in low energy range due to technical difficulties on the direct detection of particles governing PWI.

In this study, we have been developing a technique to measure the angular and energy distributions of low energy hydrogen ions reflected from tungsten surface based upon phase sensitive detection of Balmer-alpha (Hα) Doppler-broadening.

2. Experiment

A linear magnetic field type plasma irradiation device forms a 10 cm wide 1 cm thickness sheet-shaped plasma of electron density $n_e=2\times10^{11}$ cm^{-3}/A against discharge current in the magnetic field of 900 G. This device irradiates plasma onto a flat tungsten target (Fig. 1). To detect the precise Doppler-broadened signal of Hα arising from the ion reflection, the electrical bias voltage applied to the target is modulated and Hα line from the immediate vicinity of the target surface is phase-sensitively detected by a Czerny-Turner mount type spectrometer of 0.01 nm resolution. The optical axis to the spectrometer is set parallel to the target surface.

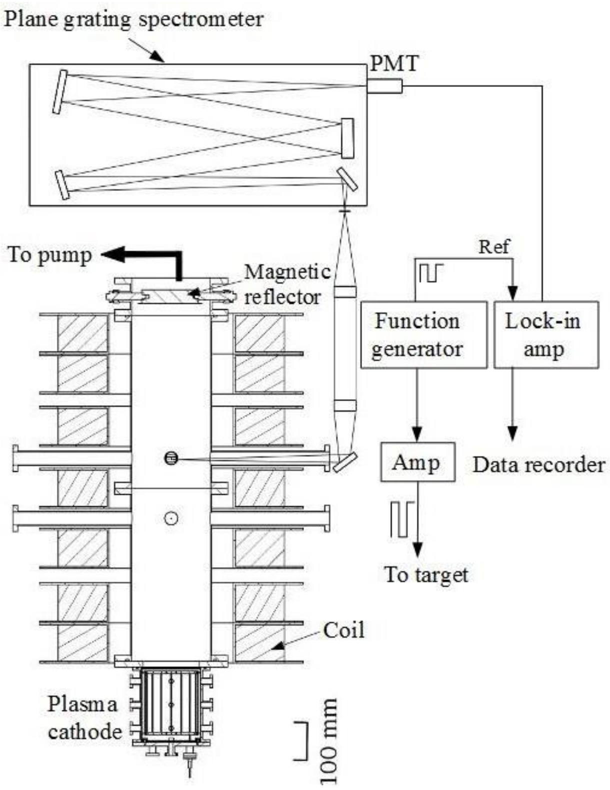

Fig. 1. Experimental apparatus to investigate the reflection of low energy hydrogen ion on tungsten surface. The electrical bias onto the target is modulated and the Hα line spectrum is phase-sensitively detected.

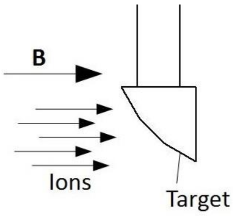

Fig. 2. Schematic diagram of the relation among the magnetic field, the direction of ions and the target.

3. Results of non-phase-sensitive measurement

To examine the overall S/N ratio of the experimental system, a non-phase-sensitive measurement of Hα line spectrum has been attempted. A result in case of -50 V to control hydrogen incident energy is shown in Fig. 3.

The accumulation of signal was carried out at 27 times because the Hα spectrum of one measurement could not be seen apparently due to poor S/N ratio. After the accumulation of the measured data, the spectrum profile was smoothed to eliminate the high frequency noise. The comparison of FWHM among several ion energy is given in Fig. 4.

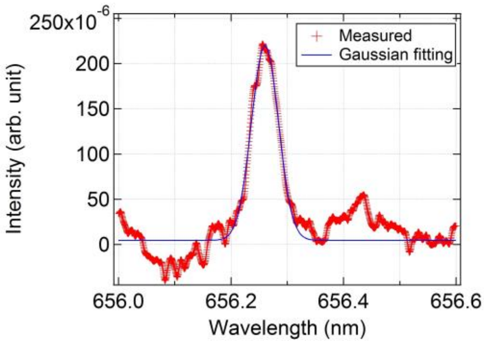

Fig. 3. A result of Hα line spectrum measurement in the vicinity of the tungsten surface in case of -50 V to control hydrogen incident energy. The accumulation of signal was carried out at 27 times.

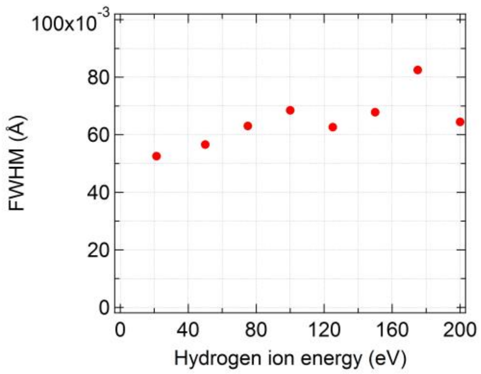

Fig. 4. FWHM of Hα line spectrum vs. hydrogen ion energy.

4. Development of magnetic field free system

The present system intrinsically possesses problem associated with drift wave due to the confinement magnetic field. Thus, a multicusp plasma container will contain hydrogen plasma with which the target is irradiated by plasma ion bombardment in a field free region. In this region, a tungsten target is irradiated with hydrogen ion beam in a vacuum chamber surrounded by a multicusp surface magnetic field (Fig. 5). The optical axis of a high resolution spectrometer is set parallel to the tungsten surface. At this time, a 0.01 nm resolution spectrometer, SS-100C (JASCO) is utilized to obtain Hα line spectrum during the irradiation. The modulation of ion beam makes a phase sensitive detection of the signal from Hα possible, and the minute signal from Doppler-broadening of Hα due to the reflection can be observed with relatively high S/N ratio.

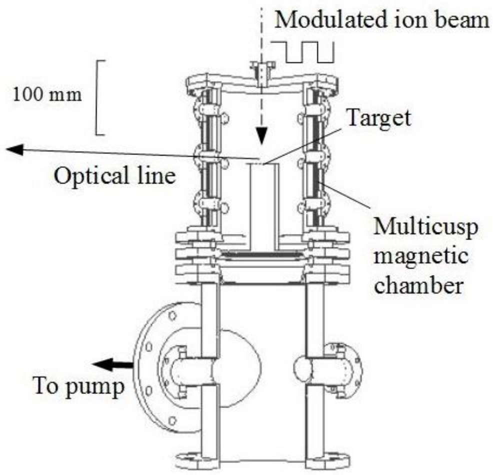

Fig. 5. Modulated hydrogen ion irradiation device.

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