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Development of VUVAS System for Excited Atomic Density Measurement Using Compact Plasma Light Source

小型マイクロ波プラズマ光源を用いた励起窒素原子密度測定用真空紫外域吸収分光システムの開発

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Excited atoms or molecules have important roles in various industrial applications. In our previous work, O_2 and N_2 gas mixture surface-wave plasma (SWP) used for the low-temperature plasma sterilization has a strong relation with O_2 gas mixture ratio. In this study, in order to study the relation between the oxygen atom density and etching effect of spores, a vacuum ultraviolet absorption spectroscopy (VUVAS) system with a compact plasma light source has been developed to measure the atomic density in SWP.

1. Introduction

Low temperature plasma has been widely used in many fields because of its advantages both in physical and chemical processing. Energized atoms or molecules have an important role in industrial application, such as surface modification and chemical vapor deposition (CVD). Different plasma characteristics are required for different application fields, therefore, the diagnosis of the absolute density of active species in the plasma processes is important to control the treatment process and understand the mechanism.

In our previous work, O_2 and N_2 gas mixture surface-wave plasma (SWP) generated in a 30 cm SUS cylindrical chamber was used for the low-temperature plasma sterilization of medical instrument [1-3]. To study the role of the plasma working on the sterilization, the information of neutral radicals generated by plasma discharge is inevitably important. As reported, VUVAS technique can be used to measure the O atomic absolute density in processing plasma [4, 5]. Its advantage is that the measurement will cause little interference to plasma.

In this work, we have developed a coaxial type compact microwave plasma light source for VUVAS method, which can be used in the measurement of excited atomic density in plasma.

2. Experiments

With the VUVAS method, a suitable light source is required. Considering the cost and operability, we developed a compact microwave plasma light source. The new type microwave induced plasma (MIP) light source is based on the coaxial type SWP discharge, which can be driven by 2.45 GHz microwave up to 100W.

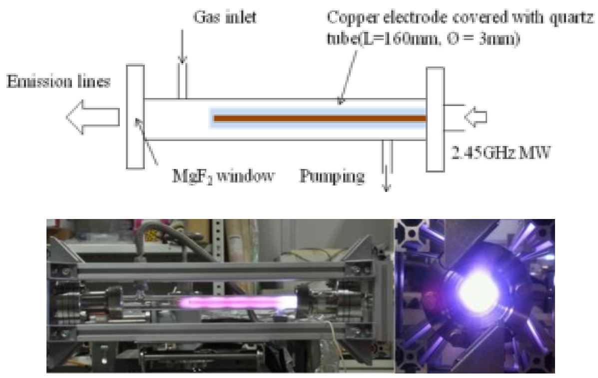

Fig.1. Schematic of the light source and picture of plasma discharge.

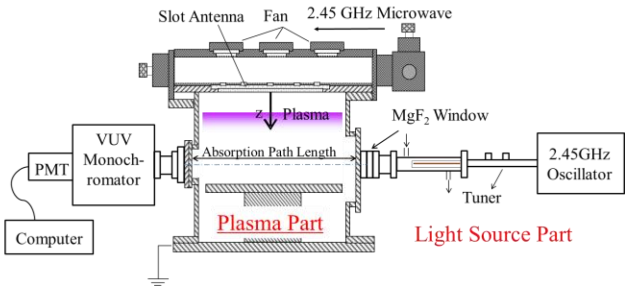

Fig.2. The experiment setup for VUVAS

Fig.1 shows the light source structure and the typical discharge picture. From the discharge pictures, a standing wave pattern of SW discharge is clearly shown. With different working gas filled in the light source, different plasma discharge can be got for different emitting lines. Plasma discharge condition of

Fig.1 is at pressure 7.6 Pa and incident microwave power 80 W

In this study, firstly, this light source will be used to measure the absolute O atomic density in SWP with VUVAS method. As references, resonance emitting lines selected for O atom density measurement are near 130 nm. Because the ground state has three sublevels, thus, there are three resonance lines: 130.22 nm ($3s^3S_0$–$2p^{43}P_2$), 130.49 nm ($3s^3S_0$–$2p^{43}P_1$), 130.60 nm ($3s^3S_0$–$2p^{43}P_0$). The absorption ratio measured from these resonance lines can be used to calculate the O atom density in the plasma [5].

Secondly, with the same VUVAS system, we want to measure the N atomic density in nitrogen plasma. The resonance line of N spectrum should be chosen for VUVAS method. There are also three emission lines for the upper level has three sublevels, they are 119.955 nm, 120.022 nm and 120.710nm. He and N_2 gas mixture has been applied to produce such emitting lines, and the characteristic of emission was checked to find the optimum condition to produce the emission lines.

3. Results

In order to find the best condition of this light source for O atomic density measurement, the O atom emission around 130 nm was measured with different discharge condition, The VUV emission spectrum of the best condition was illustrated fig.3. The intensity ratios of 130.22nm, 130.49nm, 130.60nm in this condition was: 1: 0.88:0.55,

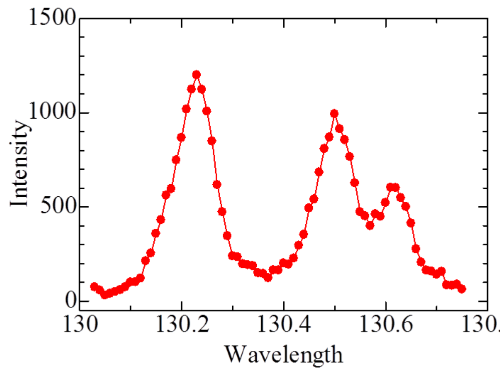

Fig.3. Light source spectra with O_2/Ar discharge.

Light source was operated at pressure 8.2 Pa and gas ratio of O_2: Ar was 1:50 and incident microwave power was 75 W. As references, there are three resonance lines near 130nm: 130.22nm, 130.49nm and 130.60 nm, the ideal ratio among these peaks are 1:0.6:0.2. There are mainly two reasons for the difference between raw data and the ideal profile, which are the broadening and self-absorption. The broadening comes from Doppler broadening and instrument resolution and the shorter wavelength line is easier influenced by the self-absorption [6]. Thus we analyzed the spectrum with software to remove those effects and confirmed it was appropriate for O density measurement in VUVAS method.

To estimate the absolute atomic density in plasma, we need to calculate the theoretical curve which shows the relation between atomic density and the absorption ratio. The absorption ratio I_α can be measured from experiment and describe as the flowing equation,

$$I_\alpha \equiv \frac{I_{LS} - (I_{AB} - I_P)}{I_{LS}}$$

where I_{LS} is the emission intensity come from light source, I_{AB} is the intensity of transmitted emission and I_P is the emission intensity from target SWP. A typical measurement process was shown in Fig.4. The light source was worked at best condition, and the discharge condition of target SWP which was shown in Fig.4 is O_2 50 sccm, N_2 50sccm, pressure 0.1 torr and microwave power 600W. The absorption ratio was calculated at 0.62 and O atom density was 1.86×10^{12} cm^{-3} estimated from the theoretical curve.

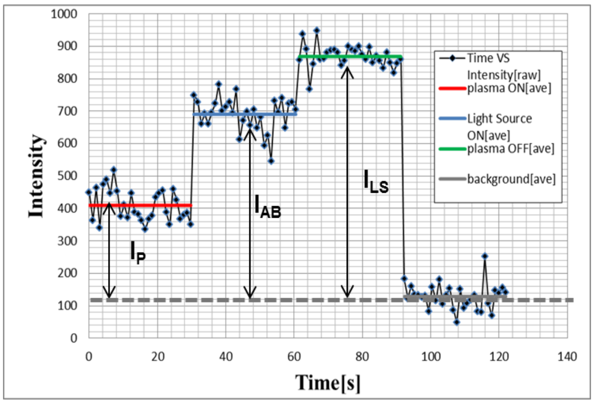

Fig. 4 Temporal variation of signal intensities.

The same approach will be carried out for the N atom density measurement. O atom density in plasma, N spectrum and other results will be explained at the conference.

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