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SPATIAL DISTRIBUTION OF Ar I 750.4 nm AND Ar II 427.8 nm LINES EMISSION IN RF DISCHARGE

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1. INTRODUCTION

Radio frequency (rf) discharges produced in argon plasma are useful for many applications in material processing such as etching, sputtering, thin film deposition, treatment of surfaces etc. (Powell, 1984; Einspruch, 1984; Morgan, 1985; Miyake, 1992; Tokonami, 1992). Knowledge about basic principles of radio frequency discharges even of simple system such as argon discharges is still far from satisfactory. For improving rf plasma applications it is necessary develop diagnostic techniques in order to understand discharge structure and processes inside of discharge.

This paper reports result of spatially resolved optical emission measurements from pure argon rf discharge. The radiation of neutral and ionic argon spectral lines is emitted from well defined 13.56 Mhz rf reactor in pressure range from 6.67 to 66.67 Pa and 200 V applied rf voltage. The time averaged spectroscopic measurements showed that different spectral lines have different positions of the peaks of the emission distribution.

2. EXPERIMENTAL

In the experiments presented here, the plasma source was the Gaseous Electronic Conference (GEC) Radio Frequency Reference Cell. The details of the design of the Cell are given in Ref. Hargis et al. (1994). Briefly, the GEC RF Reference Cell is a parallel plate discharge chamber with 102 mm diameter electrodes separated by 25 mm. The electrodes are cylindrically symmetric and their surfaces are horizontal. The top electrode contains 169 holes 380 μm in diameter to provide a showerhead gas inlet. The cylindrical vacuum chamber is constructed of stainless steel and has 8 cooper gasket side ports symmetrically positioned to the chamber midplane. Two 203 mm diameter ports are fitted with 136 mm diameter quartz windows for spectroscopic observations. Two additional ports, orthogonal to these, are 152 mm diameter flanges, one of which accommodates a turbo molecular pump for establishing a base pressure of $< 10^{-5}$

Pa. Four 70 mm ports at 45^0 with respect to the four larger ports are also mounted at the Cell midplane. The bottom of the vacuum chamber is constructed so the pumpout of the gas is accomplished by four symmetrically placed 70 mm diameter ports piped into a single exhaust line to a mechanical vacuum pump. The top electrode is grounded to the chamber on the outside of the vacuum interface. The bottom electrode is powered by a 13.56 Mhz rf power supply isolated by a filter box in external circuit. The flow rates were 10 standard cubic centimeters per minute. Gas pressures were 6.67, 13.33 33.33 and 66.67 Pa and the peak-to-peak applied rf voltage was 200 V.

The experimental setup for spectroscopic measurements is described elsewhere (Djurović *et al.*, 1993).

The monochromator is equipped with a cooled 5cm diameter end-on photomultiplier for detection of the optical signal. The photomultiplier tube is connected to a picoameter and signal from the picoameter is fed to a personal computer through IEEE-488 interface.

3. RESULTS

The Ar I 750.4 nm and Ar II 427.8 nm lines were observed in the pressure range of 6.67 to 66.67 Pa. The time averaged intensity distributions along the discharge axis for Ar I 750.4 nm line for different pressures are shown in FiG 1. To obtain good signal-to-noise ratio every experimental point in Fig. 1 represents the average value of 40 readings from the picoameter.

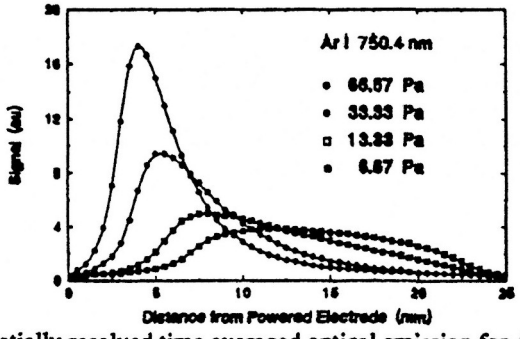

Fig. 1 Spatially resolved time averaged optical emission for Ar I 750.4 nm line.

The measurements of the optical intensity distributions of Ar II 427.8 nm line for different pressure are shown in Fig. 2. These measurements are taken under same conditions as the measurements of Ar I line and show similar behaviour.

The intensities of both Ar I and Ar II lines are highly dependent on the discharge pressure. As the pressure is increased the most intense regions of

emission shift toward the powered electrode and the well defined sheats (dark zone near the electrode surface) are formed.

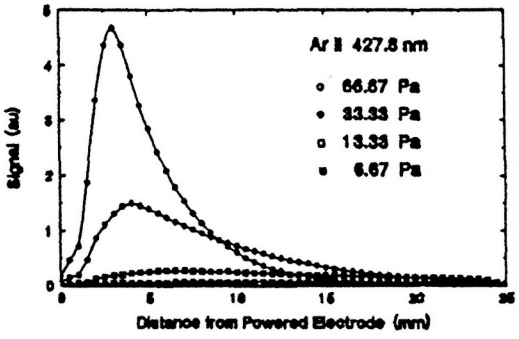

Fig. 2 Spatially resolved time averaged optical emission for Ar II 427.8 nm line.

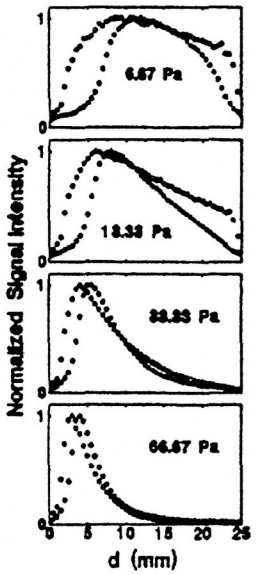

Fig. 3 Normalised time averaged emission spatial profiles for Ar I 750.4 nm line and Ar II 427.8 nm line.

Analysis of the spatial variation in the optical signal intensity indicates that the bright band of emission peaks for a given pressure is closer to the powered electrode in the Ar II emission than for the Ar I emission. This is more evident in Fig. 4 where the normalized time averaged intensity distributions of the Ar I and

Ar II lines are shown. This figure also indicates that for all plasma conditions the Ar II emission profile is spatially broader than Ar I profile.

From these measurements one ca conclude:

- Emission intensity at the electrodes (positions 0 and 25 mm in Figs. 1 and 2) is not zero (after noise subtraction), which implies that the plasma extends outside the electrode region.
- Spatially resolved profiles of both Ar I and Ar II lines show considerable pressure dependence.
- The maximum intensity position of the Ar II line is closer to the powered electrode than maximum intensity positions of the Ar I line.

The last conclusion is the most important one. This in contradiction with the intuitive picture that can be produced for secondary electron sustained discharge. In that picture electrons get accelerated from zero energy and thus should excite transitions with lower thresholds first. An explanation of this apparent inverted distribution of the emission is offered in Ref. Petrović *et al.* (1995).

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