31st EPS Conference on Plasma Phys. London, 28 June - 2 July 2004 ECA Vol.**28G**, P-4.058 (2004)

Comparison between the IEDs of positive ions Ar^{+}, Ar^{++} and Ar_2^{+} in an asymmetric capacitive argon discharge and argon-oxygen discharge

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1. Introduction

The mass-resolved ion energy distribution (IED) has been investigated at the grounded electrode of a capacitively coupled rf (13.56 MHz) discharge in argon and argon-oxygen mixture. The IED was determined for Ar^{+}, Ar^{++} and Ar_2^{+} for a large range of pressures and powers. With increasing of pressure the mean ion energy decreases. The reason for the shift to lower energies is the decreasing of the ion-neutral mean free path with the increasing of the pressure. With increasing pressure, the frequency of ion-neutral collision become higher and ions lose energy.

Mass spectrometry yields first the nature of ions created in the plasma and second, the corresponding ion energy distribution function. The IEDs for investigated ions exhibit a double hump shape. These features result from both the creation of thermal ions in the sheath, by charge exchange processes and from rf modulation of the sheath potential. Two types of ions can be considered: those created in the sheath, respectively the ions that enter the sheath from the plasma and reach the anode surface without collision. Both groups are related to the periodic extinction of the electric field leading to a periodic penetration of electrons into the sheath [1]. Only low energetic ions came to the surface of the grounded electrode because of low sheath voltage between plasma potential and ground and because of the asymmetry of the device [2].

2. Experimental setup

The investigated rf plasma was confined in a plasma chamber of an asymmetrical industrial OTP Plasmalab 100 capacitively coupled system. The mass-resolved IED was measured at the grounded electrode (included the chamber walls) (fig.1) which was much larger than the driven electrode. The top electrode diameter was 295 mm, inter-electrode spacing 50 mm and the driven electrode diameter was 205 mm. The quartz plate shown in fig 1 was 12 mm thick and covered the cathode with the exception of a ring approximately 5 mm wide at the cathode's edge. The pressure range was 20 - 80 mTorr and the range of powers was 10 – 150 W. Ion and neutrals kinetic energy distributions were measured with a Hiden EQP Plasma probe which uses an electrostatic ion-energy analyser (ESA) followed by a triple section quadrupole mass spectrometer (QMS) for mass analysis.

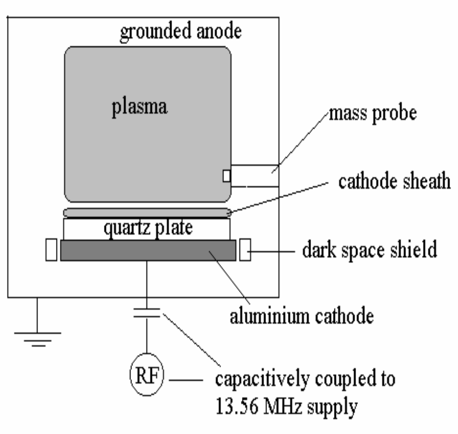

Fig. 1: A schematic diagram of the capacitively coupled discharge

3. Results and discussion

In Figure 2 the IEDs for argon ions are presented. The left column corresponds to ions resulting from pure argon and the right column corresponds to the ions resulted from the argon-oxygen mixture. The IEDs obtained from pure argon discharge are peaked at higher energies than the ones obtained in argon-oxygen mixture. Oxygen is an electronegative gas and in addition with argon induces a decrease of the plasma potential compared with pure argon discharge [3]. The ions energy corresponds to the average potential difference between the plasma glow and the potential of the surface of grounded electrode [2]. The potential difference across the sheath formed in front of the anode wall is diminished compared to the discharge in pure argon, and the energies of ions in argon-oxygen mixture are lower.

Ar^+, Ar^{++} and Ar_2^+ are all present in our positive-ion mass spectra, whatever the pressure and rf power values are. The highest proportion of all positive ions is obtained at low pressure and high power, but Ar^+ is always the dominant ion (the parent of the feed gas), in pure argon and in argon-oxygen discharges as well (figures 2 and 3). Ar^+, Ar^{++} and Ar_2^+ ion integrated intensities increase with increasing power at fixed pressure (figure 3).

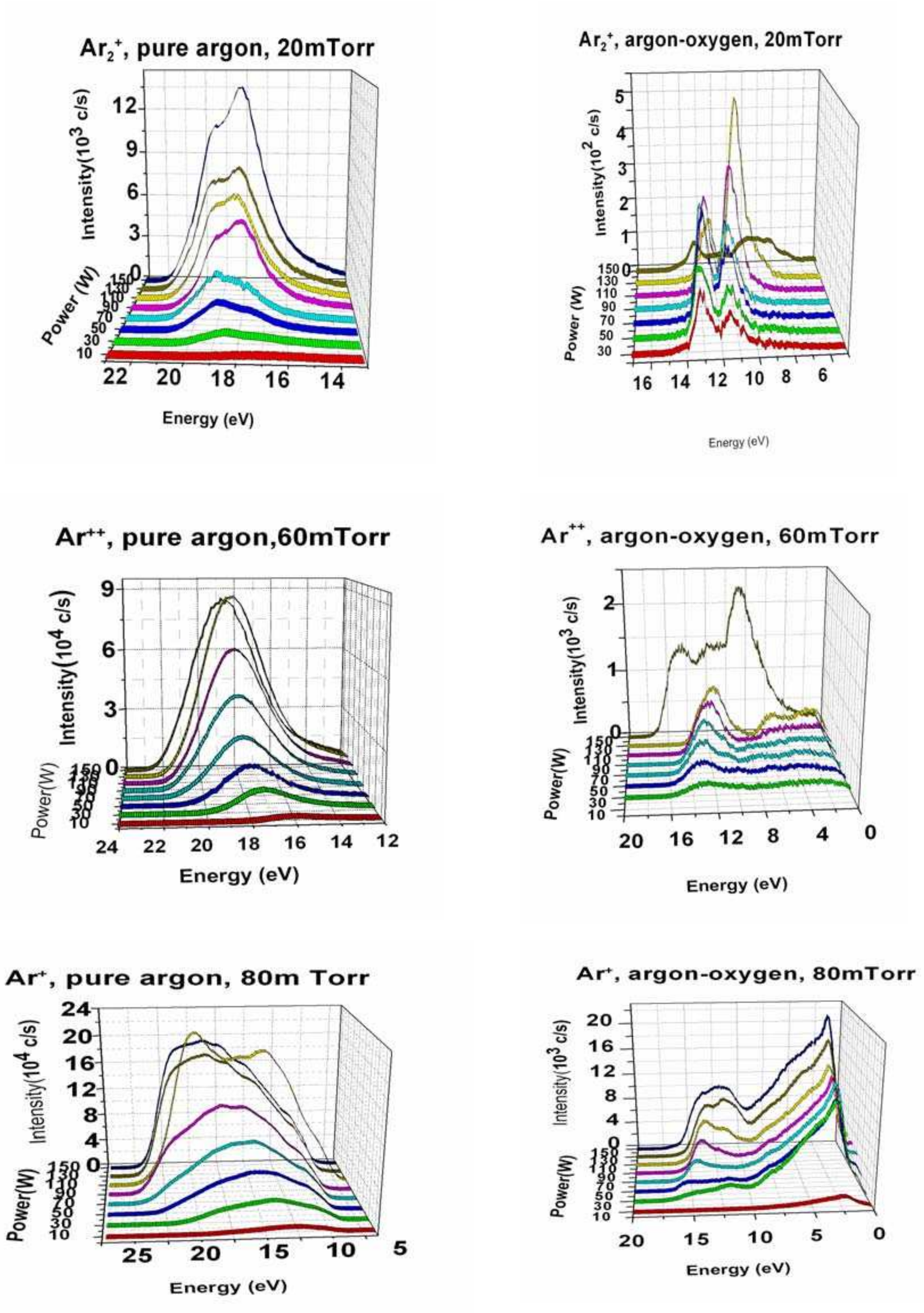

Fig. 2: IEDs for studied ions at different powers and pressures

For pure argon discharge, the Ar^+ flux is 3.5 times higher than the argon-oxygen discharge; for Ar^{++} 10 times and for Ar_2^+ 100 times (fig. 3).

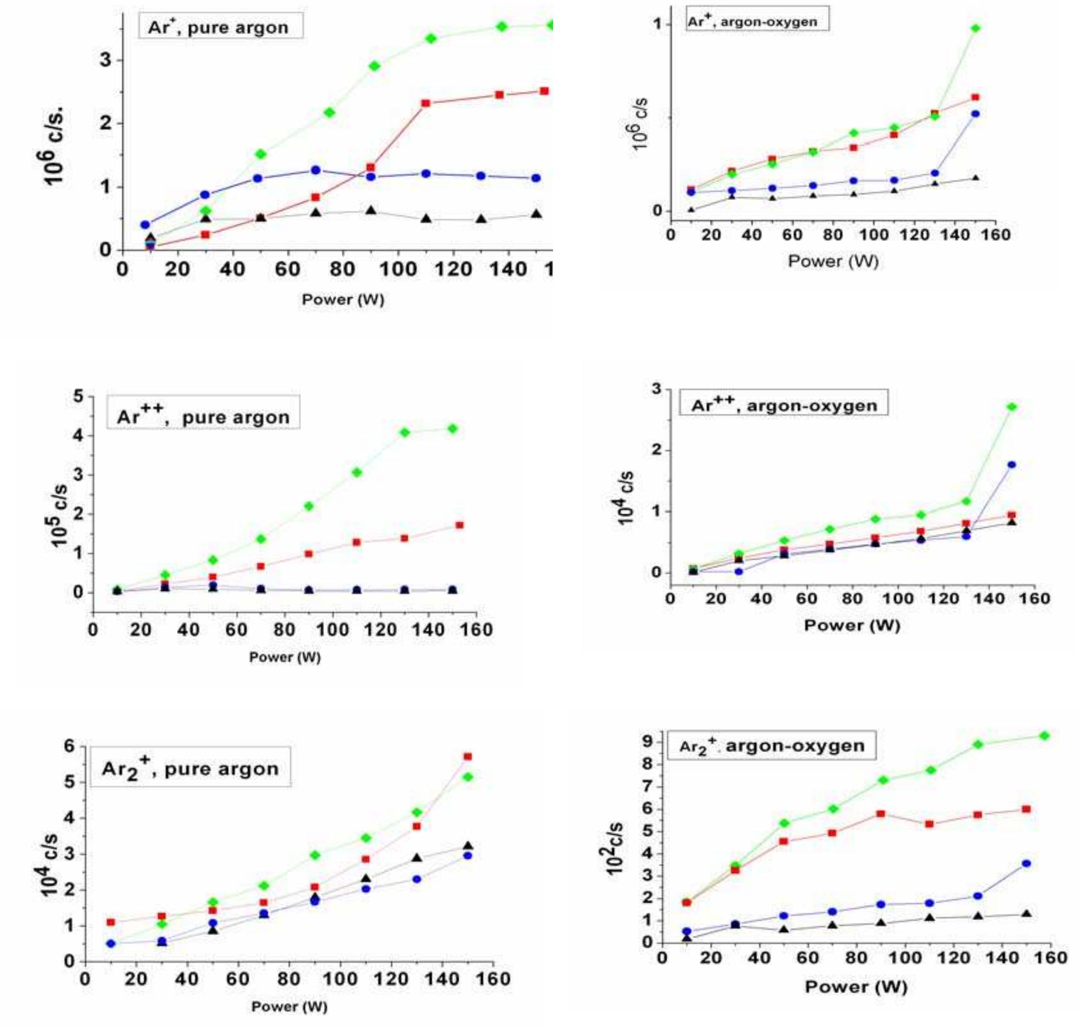

Fig. 3: Integrated intensities (fluxes of species) at different pressures: red for 20 mTorr, green for 40 mTorr, blue for 60 mTorr, black for 80 mTorr and different powers.

3. Conclusions

In this article were experimentally investigated the energy and fluxes of argon ions from rf argon and argon-oxygen plasmas at the grounded electrode of an asymmetrical capacitively-coupled device.

4. References

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