Measurements of the Ar^+ energy distribution from an atmospheric surface wave discharge in pure Ar and Ar-O_2 mixture

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In this work, measurements of the Ar^+ energy distribution from an atmospheric argon microwave surface–wave discharge were carried out by means of a mass spectrometer and energy analyser. Measurements were performed in pure Ar and Ar-O_2 plasma as a function of the axial coordinate of the discharge column. The experimental results showed that in both cases the peak of the distribution shifted to higher energies as a function of plasma length. This effect was much more pronounced in the pure argon flow. It was also observed that the distribution width increased with the axial coordinate. We propose some hypothesis to explain these observations based on the kinetics of reactions involving Ar^+ and some fundamental principles of plasma physics.

1. Introduction

Some recent investigations showed that discharges at atmospheric pressure could be used to process biomass [1, 2]. This work is part of a major effort to understand the elementary physical process occuring in a plasma that may be used on new second generation biofuel technologies based on sugarcane bagasse.

By applying mass spectrometry techniques [3], we carried out measurements of the Ar^+ energy distribution of an atmospheric microwave argon discharge produced by a surfatron [4]. From the point of view of the fundamental processes occuring in the plasma, the energy distribution function of heavy particles can supply useful information regarding the elementary chemical processes occurring in the discharge. Since oxygen cointaining discharges is a possible canditate to be used in biomass treatment, due to the presence of reactive oxygen species, knowing the effect of adding O_2 was also important. In this work we compared the Ar^+ energy distribution function in pure Ar and Ar-O_2 plasma.

2. Experimental Setup

In order to yield an argon atmospheric plasma torch, a surfatron surface-wave launcher was connected to a 2.45 GHz Sairem power supply. In the first experiment, the argon gas with purity of 99,999% flowed continuously through a ceramic tube placed inside the surfatron cavity at a flow rate fixed at 2.5 SLM controlled by a MKS flow meter. In the second experiment, a Ar-O_2 mixture 97:3 also flowed at a fixed rate of 2.5 SLM.

Measurements were performed with applied power of 100 W at atmospheric pressure and room temperature. The energy distributions were measured by a Hiden EQP mass/energy analyzer HPR60. The surface-wave launcher was mounted on an optical rail carrier, which provided displacements in parallel and perpendicular directions on the spectrometer probe plane. The plasma column was aligned to the probe orifice by adjusting the surfatron position. The origin of the axial measurements was located at the position where the surfatron was closest to the probe. The measurements were performed in 1 mm step along the plasma and the distribution profiles of the Ar^+ energy distribution were obtained.

3. Results

Figure 1 shows the energy distribution of Ar^+ in both experiments. Figure 2 shows that the mean energy and the full width at half maximum (FWHM) increased with the axial coordinate in both cases. This effect was much more pronounced in the pure argon flow. The effect of increasing mean energy could be explained considering that as the axial coordinate increases both ionization rate and plasma temperature fall but only more energetic ions scape from recombination and collisions with heavy neutrals, which are more likely to occur with lower energy ions. On the other hand, oxygen species may react with more energetic Ar^+ in process such as $O_2 + Ar^+ \rightarrow Ar(^1S_0) + O_2^+$, preventing a sharp rise in the mean energy.

The mean energies were at least one order of magnitude higher than the expected value by taking into account the estimated thermal energy of the neutral species $T_g \approx 0.1$ eV. Since the plasma column was in contact with the metallic surface of the mass spectrometer entrance (0.1 mm orifice) through which species were sampled, a sheath region near the surface could have accelerated the ions towards the orifice. This may explain why higher mean energies were observed. Furthermore, the ratio between the sheath length and the mean free path might have increased as a function of axial coordinate, explaining why the FWHM also increased.

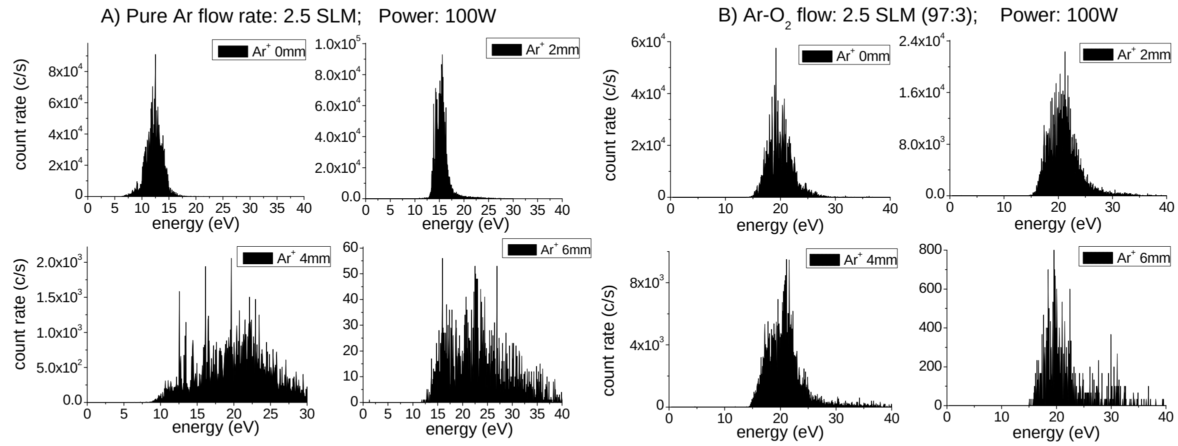

Fig. 1: Axial profiles of the Ar^+ energy distribution from: A) a surface-wave discharge from a pure Ar flow; B) a surface-wave discharge from a Ar-O_2 flow (97:3). In both cases power and flow rate were fixed at 100W and 2,5 SLM.

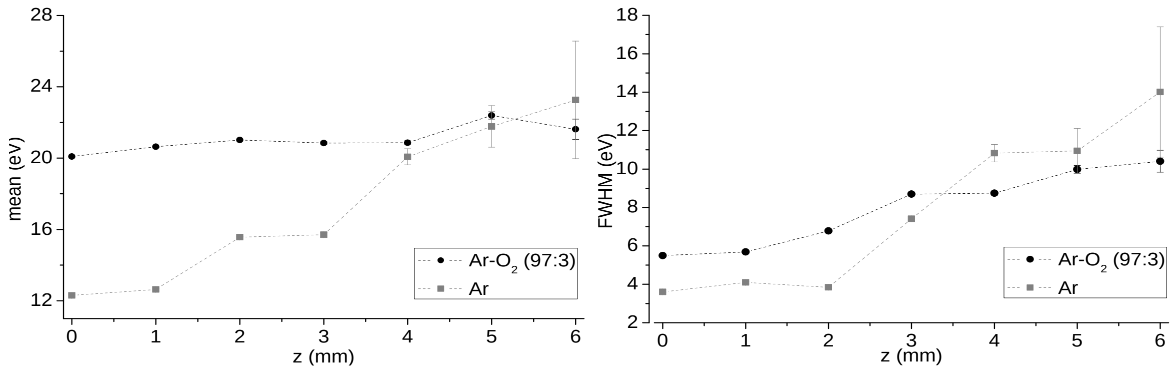

Fig. 2: Mean energy and FWHD of the measured distributions of Ar^+ as a function of the axial coordinate.

Conclusion

The axial profiles of the Ar^+ energy distribution from a surface-wave discharge were measured for a pure Ar flow and a Ar-O_2 flow. The results showed that the distributions mean energy and FWHM increased with the axial coordinate in both cases. Some hypotheses based on the kinetics of reactions involving Ar^+ were proposed. These hypothesis should be checked by other diagnostic measurements and computer modelling.

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