Topic number: 10

Cold atmospheric pressure plasma jet discharge with bare electrodes operated in argon

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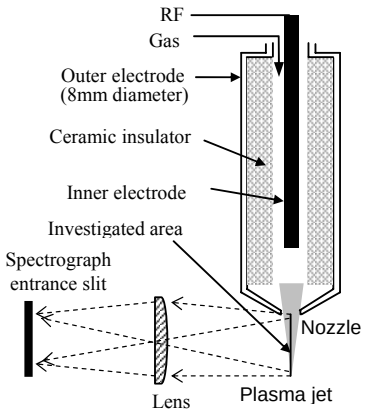


Fig.1: The plasma source schematic.

Introduction

In a previous paper [1] we have described a small size cold plasma jet source, based on a radiofrequency discharge with bare electrodes (without barriers), operated at atmospheric pressure, and we have demonstrated its applicability for polymer surface modification. In this contribution we focus on the characterization of the jet expanding from the source, focusing on the emitting species and gas temperature distribution, as obtained from optical emission spectroscopy measurements.

Experimental set-up

The scheme of the plasma jet source is presented in Fig. 1. The operation details of the source were presented in [2]. The feeding gas (Argon 99.999 % purity) flows between the inner electrode and a ceramic insulator. The discharge is generated at 13.56MHz in the space limited by the inner electrode and the nozzle and the ionized gas expands as a jet of 1 mm diameter and up to 5 mm length (visually evaluated), depending on the working parameters (gas mass flow rate and RF power between 500–8000 sccm, and 7-16 W, respectively). The electrodes are cooled by the working gas itself and ambient atmosphere. The plasma jet was investigated using a 500is/sm Bruker spectrograph equipped with a 1024 x 255 pixels Andor Idus CCD camera. The axial part of the plasma jet was focused on the spectrograph entrance slit by means of an 80mm positive lens and was investigated along the flow direction with a spatial resolution of 23μm.

Results and discussions

Fig. 2 shows an emission spectrum recorded near the discharge, at 0.58 mm from the nozzle, for an RF applied power of 14 W and 4500sccm Ar mass flow rate. There can be observed the strong emission of the excited feeding gas (ArI) and the weaker emission of radical impurities (OH, N_2, OI). Fig. 3 presents the axial distribution of the lines or band heads intensities, each normalized at its maximum, corresponding to the following transitions: OH ($A^2\Sigma^+ \rightarrow X^2\ \Pi$ v'-v" 0-0, λ =306.4 nm); N_2 (SPS $C^3\Pi_u \rightarrow B^3\Pi_g$, v'-v", λ =380.5nm), ArI (λ= 772.22 nm) and OI (λ= 776.95 nm). The excited OI and ArI species dominate the emission in the nozzle vicinity (up to 1.5mm) while the molecular excited species dominate downstream at larger distances. The gas temperature (considered equal with OH rotational temperature) along the jet axis was determined by simulation of the OH recorded spectra [3].

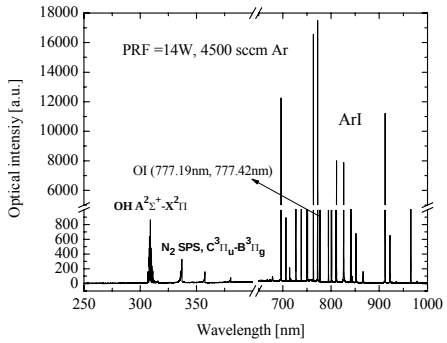


Fig.2: A spectrum recorded at 0.58mm from the nozzle.

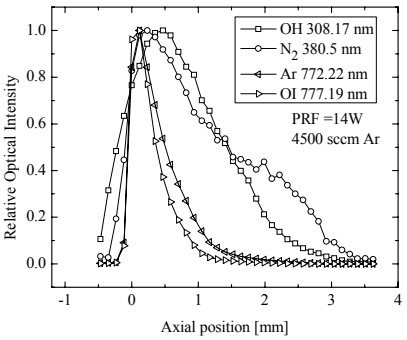
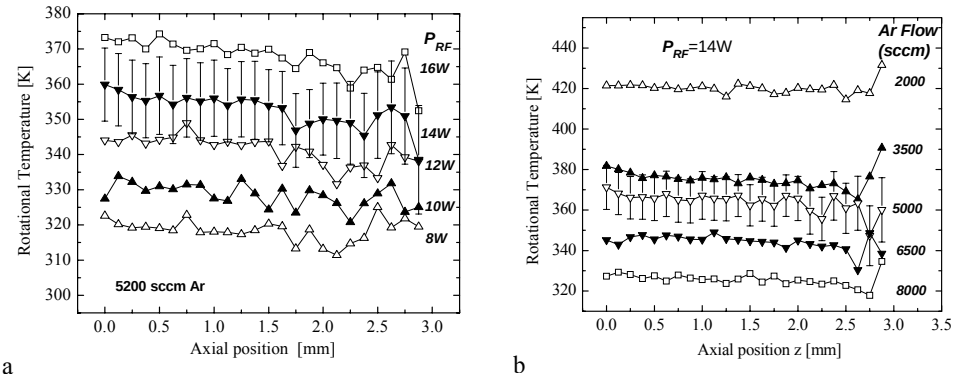


Fig.3: Distribution of the normalized spectral intensities along the plasma jet axis.

Fig.4 a) and b) presents the temperature distributions along the plasma jet for different working parameters (power values in the range 8-16W, and Ar mass flow rates between 3500-8000 sccm). The temperature lies in the range 310K-380K and for a given set of working parameters it decreases only slightly along the plasma jet. At low Ar mass flow rates (2000 sccm) the plasma source is not efficiently cooled by the flowing gas, which leads to a higher jet temperature (420K at 14 W).



a b

Fig.4: Axial distribution of plasma jet temperature: a) 5200 sccm Ar and diverse RF applyed powers; b) 14W RF applyed power and diverse Ar mass flow rates. The error bars were presented for only one curve to avoid raveling them.

Conclusions

The low temperature of the plasma source may assure nondestructive treatment of temperature sensible materials (polymers, textiles, etc.). Also, according to the reported measurements, which show that the radical emission dominates at large distances, the wettability improvement of polymers observed after treatment in [1] is mainly due to plasma O and OH radicals reaction with the polymer surface. Such as, O etching can be responsible for the surface roughening while attachment of OH groups modifies the surface chemistry. That does not exclude the possible contribution of other species or of UV radiation coming from the discharge, which was not possible to evaluate at present.

Acknowledgments

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Reference

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