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Spectral analysis of an argon plasma jet expanding from a dielectric barrier discharge in the ambient atmosphere

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1. Introduction

In this contribution we present the spectral properties of a DBD plasma jet, with emphasis on species distribution along the expanding direction and the gas temperature distribution, as obtained from the comparison of OH radical recorded spectra with computer simulated spectra. In a previous paper [1] we have proved that the argon plasma expanding in the ambient atmosphere from a dielectric barrier discharge have direct applications for surface modification of polymers.

2. Experimental set-up

The DBD expanding plasma source [1] is based on a plan-parallel discharge (gap width 1mm) with a single dielectric barrier, which defines together with the grounded electrode and the lateral

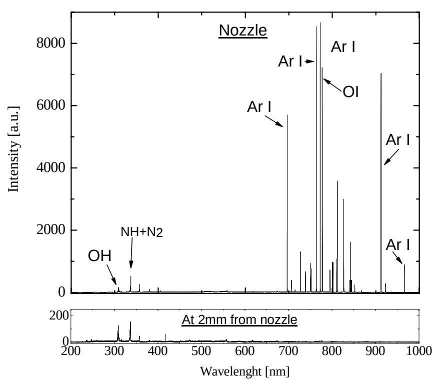

Figure 1. Spectra of the DBD plasma jet (up: in the nozzle; down: at 2 mm from the nozzle)

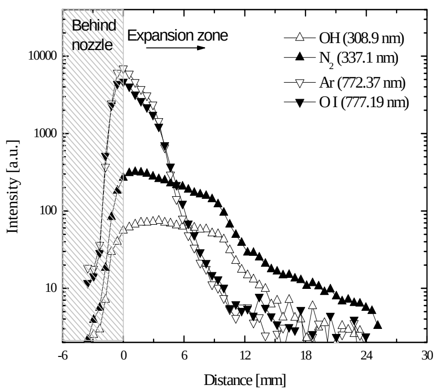

Figure 2. Intensity distribution of the investigated species related to the distance

spacers a trapezoidal discharge volume, larger at the gas insertion point and smaller at the plasma exit (nozzle dimension of 1 mm x 5mm). The trapezoidal shape has role in focusing the plasma outside the interelectrodic space. The gas used for the experiments was argon (99.999%) flowing inside the discharge space at mass flow rates ranging from 2000 to 8000 sccm. The powered electrode was connected to a 13.56 MHz radiofrequency generator; the power values used were in the range of 4 to 16W. The measurements were conducted using 0.5m Bruker Spectrograph with CCD camera and an optical system for collecting the light. The imaging mode was utilized: the spectra along the flowing direction (z-axis) of the jet were recorded (in the spectral range 200-1100 nm) on the CCD all at once, by projecting the central part of the jet (extended along the z direction) on the spectrograph slit height.

3. Results and discussion

In Figure 1 are presented spectra recorded at the nozzle exit (0 mm) and at 2 mm distance from it, respectively. The most important radiative species identified were Ar I, OI, N_2, and OH. By

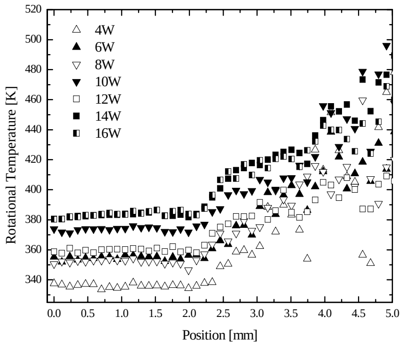

Figure 3. Temperature dependence upon distance (flow is 4500 sccm)

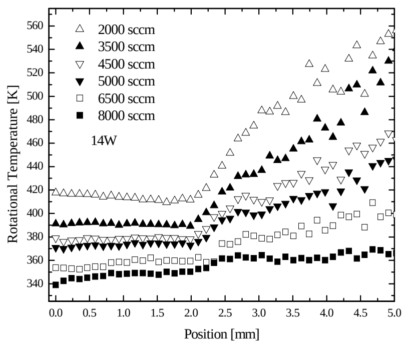

Figure 4. Temperature dependence upon distance (power is 14W)

comparing the two spectra it can be noticed that the atomic species dominate the emission in the early expansion (at the nozzle exit), while at 2 mm the atomic lines are almost completely washed out and the spectrum is dominated by the molecular species emission. This behavior is confirmed by the dependence of the emitted lines and bands intensity upon position (Figure 2). As concerning the dependence of the gas temperature upon position for various powers, as an observed rule, the higher the power the higher is the obtained temperature (Figure 3). Two regions are seen in Figure 3: the temperature is almost constant up to around 2 mm, from which point starts to increase rapidly (error bars not shown in order to keep the figure clear, but are higher at large distances). Figure 4 presents the dependence of the gas temperature upon position for mass flow rates from 2000-8000 sccm, at constant power of 14 W. The higher is the mass flow rate, the lower is the temperature, according to the cooling of the discharge by the flowing gas. The same behavior as in Figure 3, is noticed also in Figure 4, namely the plasma jet exhibits an almost constant temperature in the first region of the expansion followed by an increase in the second portion of the expansion.

4. Conclusions

The emission of atomic plasma species (Ar I and O I) is prominent in the nozzle proximity (up to 2mm), while at larger distances the OH and N_2 molecules dominate the overall spectrum. Possible, in the frame of an excitation mechanism based on electronic collisions, the electrons near the nozzle have energies high enough to excite the atomic levels, while at larger distances their energy decreases to values that allow only the excitation of low lying levels of molecular species. The increase of the gas temperature observed in the late expansion could be related to enhancements of internal energy dissipation and of electron-ion recombination at the jet margins, processes sustained by the entrainment of the ambient gas. Such effects were also noticed and discussed by other authors [2].

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