Optical emission spectroscopy of a plasma jet for biomedical applications

E. Martines[1], L. Zampieri[1], R. Barni[1] and C. Riccardi[1]

[1] *Department of Physics "G. Occhialini", University of Milano–Bicocca, Milano, Italy*

This contribution describes analyses performed on optical emission spectra obtained from an atmospheric pressure plasma jet for biomedical applications, and shows how different plasma parameters, such as electron temperature and density, and vibrational and rotational temperatures, can be estimated through a careful analysis of the spectral data.

1 Introduction

Atmospheric pressure plasma jets operating at low power levels, typically with helium or argon as main gas, have become a major tool for the studies of biomedical plasma applications ("plasma medicine"). Biological effects are primarily induced by active chemical species produced within the plasma thanks to the dissociation of air molecules mixing with the plasma plume. A proper modelling of the complex chemistry taking place within the plasma requires a knowledge of the plasma parameters. While advanced diagnostic techniques can be used to deduce many of these properties, it is also of interest to have simple methods to make the same kind of estimation. One of the simplest diagnostic techniques which can be used is Optical Emission Spectroscopy (OES). This is also relatively cheap if a compact spectrometer is used. The present contribution describes some of the advancements that our group has made in developing reliable methods to interpret emission spectra obtained on plasma jets.

2 Experimental setup

The spectra analysed in this contribution have been obtained with an Avantes AvaSpec-ULS4096CL-EVO compact spectrometer, capable of measuring spectra from 200 to 1100 nm with a resolution of 0.3 nm. The optical system consisted in a 6-mm diameter lens with 8.7 mm focal length, focused within the plasma jet, so that light from a spot with 0.5 mm diameter could be collected and sent to the spectrometer through an optical fibre. The spectrometer was calibrated using a calibration lamp.

3 Analysis of the helium and argon lines

The population of helium and argon excited states derives from a balance between excitation, which we consider solely due to electron impact, and decay, due to either spontaneous emission, electron impact or impact with heavy species (neutrals, ions, excimers).

Electron impact excitation rate coefficients starting from the ground state and from metastable states have been evaluated from cross sections [1], assuming a Maxwellian distribution function (in the future it is planned to evaluate the distribution function using a Boltzmann equation solver).

Decay process rate coefficients have been evaluated using the detailed balance principle for electron impact and using expressions found in the literature for heavy species impact [2,3]. A comparison of the different processes led to the understanding that electron impact decay is not sufficient to model the system, and that in particular collisions with ground state neutrals are a major player in the overall balance. Electron density and temperature at different positions in the plasma jet and for different power supply options were evaluated from line ratios, using the expressions described above. The photon escape factor was not considered and will be the object of future studies.

4 Analysis of the molecular nitrogen lines

The spectral lines related to the second positive system of the neutral nitrogen molecule were fitted using an expression which includes the rotational and vibrational excited states, assuming a Maxwellian distribution of these states. The rotational and vibrational temperatures were thus estimated. The values were also compared to similar estimates made in two other atmospheric pressure plasma, namely a surface DBD and a low power arc. As expected, the rotational temperatures found in the biomedical plasma jet were lower than in the other plasmas.

5 Conclusions

OES is potentially a powerful tool for the analysis of atmospheric pressure plasma jets for biomedical applications. Here we have described a first step towards a full use of its potential, and some experimental results which have been obtained.

References

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