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RADIAL DISTRIBUTION OF PLASMA ELECTRON DENSITY AND TEMPERATURE IN ATMOSPHERIC PLASMA JET

Z. MIJATOVIĆ, S. DJUROVIĆ, I. SAVIĆ, L. GAVANSKI and T. GAJO

University of Novi Sad, Department of Physics, Faculty of Sciences,
Trg Dositeja Obradovića 4, Novi Sad, Serbia
E-mail mijat@uns.ac.rs

Abstract. Radial distribution of plasma electron density and temperature of atmospheric argon plasma jet were measured by applying spectroscopic method.

1. INTRODUCTION

Various methods can be applied for plasma jets formation. One of them is based on electrical arc, see for example Snyder et al.1994. Such kinds of jets are used for welding, cutting and coating. They usually work in DC regime with high electrical current (up to 1000 A) and high gas flow (several tens of l/min). At the exit of such sources the plasma temperature can reach 20000 K while the electron density can be around 10^{23} m^{-3}. In this work a DC wall stabilized electrical arc is used. High current pulses were added to the DC current that caused the formation of plasma jet at the exit of the arc column. In this paper results of measurements of plasma electron temperature and electron density along the plasma jet radius are presented.

2. EXPERIMENTAL

Wall stabilized arc working in DC regime is used in this experiment. Argon under atmospheric pressure was the working gas. The Ar gas flow was around 20 l/min. The operating DC current through the arc was 32 A. High current pulses were added to the DC current, so the maximal total current in pulses was 180 A and lasted 4 ms. The pulses were obtained by using civil network and a proper electronic circuit. The frequency of the pulses was 1 Hz. The detailed description of this arrangement can be found in Djurovic et al. 2012 and Gajo et al. 2013.

During high current pulses the plasma jet appeared at the exit of the arc column on the side of the anode. The jet spread into free air through the hole in the anode. The jet was observed side-on close to the exit (about 1 mm from the anode). Radiation from the jet was focused on the entrance slit of 1m-monochromator with 1200 g/mm diffraction grating. At the exit of the monchromator ICCD camera was placed for spectral line recordings. Image of the plasma jet taken with ICCD is presented in Figure 1. Approximate dimension of the plasma jet is 20 mm in length and 5 mm in diameter close to the arc exit. Spectral recordings were made at the maximum of current pulses about 1 mm far from the arc anode. This is also illustrated in Figure 1.

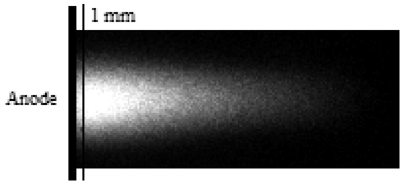

Figure 1: Plasma jet and position of recordings.

The determination of plasma electron densities and temperatures along the radius of the plasma jet was done by applying spectroscopic methods. For plasma electron temperature the Boltzmann plot method was applied using Ar I 415.8, 425.9, 427.2. 430.0, 470.2, 696.5 and 706.7 nm spectral lines. Plasma electron densities were determined from Stark widths of Ar I 430.0 nm spectral line based on theory Griem 1974 with application of correction given in Nikolić 1998. All spectral lines were recorded at 36 positions along the jet diameter. This enabled the application of the Abel inversion procedure. After this procedure these lines were used for plasma diagnostics. Boltzmann plot used for plasma electron temperature determination at the axis of the jet is presented in Figure 2. Example of the recorded profile of Ar I 430.0 nm line, after the Abel inversion procedure, is presented in Figure 3. Estimated errors for temperatures are below 20 %, while for plasma electron densities are below 15 %.

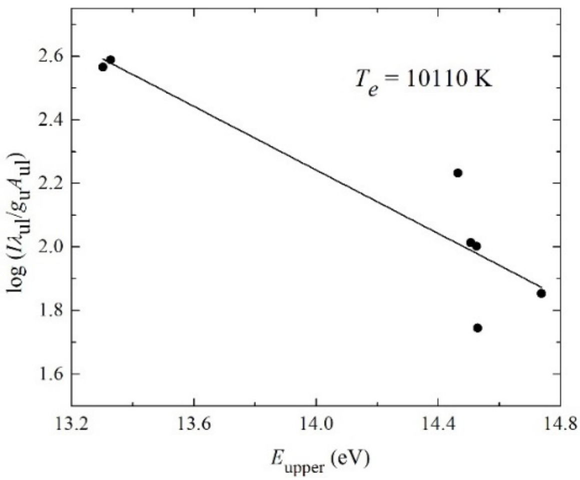

Figure 2: Boltzmann plot using seven Ar I spectral lines.

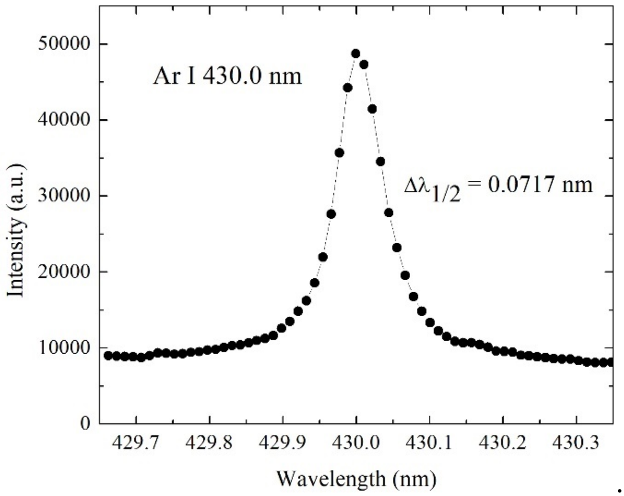

Figure 3: Example of Ar 430.0nm line.

3. RESULTS

Figures 4 and 5 show the distribution of plasma electron temperature and plasma electron density along the radius of the plasma jet at axial position 1 mm far from the exit of the anode.

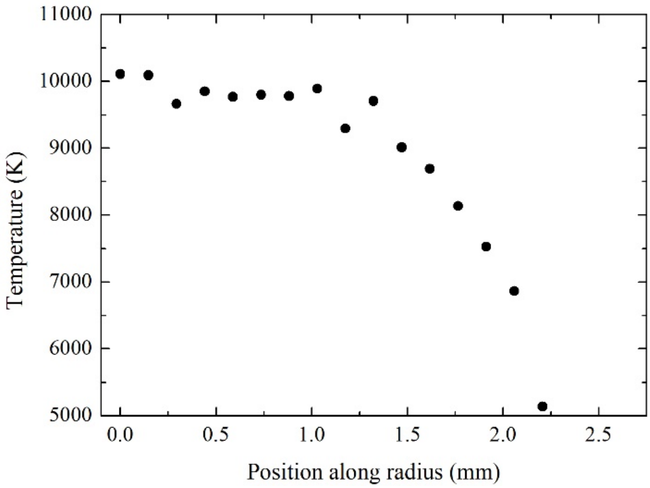

Figure 4: Radial distribution of plasma temperature.

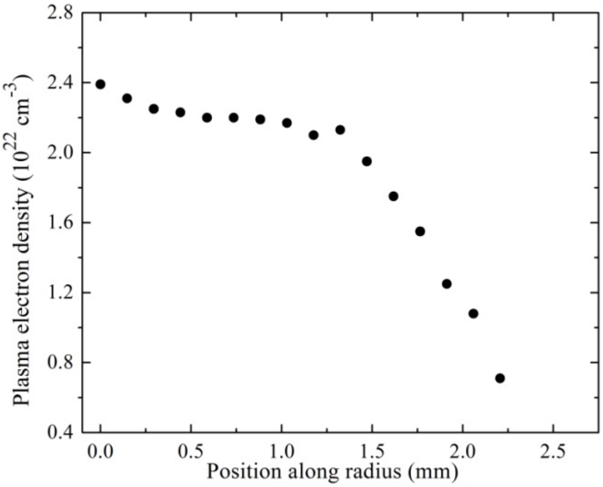

Figure 5: Radial distribution of plasma electron density.

As it can be expected, maximum values of plasma temperature and electron density are around the axis. The temperature profile at around 2 mm from the axis is close to 10000 K. This fact shows that this plasma region, with high plasma temperature, can be used for various plasma applications, like melting materials, powders for coating, plasma reactions, etc. From the comparisons with the values of plasma electron densities and temperatures obtained in Snyder et al. 1994 it can be concluded that they are in reasonable accordance.

Acknowledgement

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