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THE ELECTRON NUMBER DENSITY MEASUREMENT FROM PULSED NEEDLE-TO-CYLINDER GAS DISCHARGE SOURCE AT ATMOSPHERIC PRESSURE IN HELIUM

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Abstract. The novel atmospheric pressure gas discharge source is constructed. The source is driven by pulsed power generator in pure helium. The electron number density N_e=(0.55±0.11) × 10^{15} cm^{-3} is measured by means of He I 447.2 nm line fitting procedure. The similar N_e results are obtained from He I 492.2 nm line using the same diagnostics procedure. However, the N_e measured from the hydrogen Balmer H_β line is three times lower, probably due to the H I emission from the outer discharge region. In case of plasma-water drop interaction, analyzing the H_β line, N_e=0.55 × 10^{15} cm^{-3} is obtained at the beginning of treatment. During the water drop treatment, the spectrum of Fe I lines as a consequence of oxides formation on the cathode surface, is recorded as well.

1. INTRODUCTION

The He I spectral lines originating from a matrix gas are previously used for N_e diagnostics purposes (Jovović and Šišović 2015, Jovović and Konjević 2014). Due to the presence of an electric field induced by quasistatic ions, the He I 447.1 nm and He I 492.2 nm lines are asymmetrically broadened in atmospheric pressure glow discharge source (Jovović and Šišović 2015). Near the cathode wall, the He I red wing asymmetry is even more pronounced, which is the consequence of a strong DC electric field. The diagnostics procedure based on fitting the He I lines (see Jovović and Šišović 2015), is applied here as well for the characterization of novel atmospheric pressure gas discharge source. Additionally, the fitting of the H_β line is performed and the N_e results discussed.

The novel gas discharge source operating in helium (99.999 %) comprises stainless steel cathode (C) and graphite anode (A), see Figure 1. The source is driven by homemade pulsed voltage generator (2-999 μs pulse width, 0.1 % - 100 % duty cycle). The discharge gap and gas flow were 2 mm and 0.45 l/min, respectively. The optical emission spectroscopy (OES) is performed using Ebert type spectrometer (focal length 2 m, reflection grating 651 grooves/mm, dispersion

0.74 nm/mm) and TE cooled CCD camera (2048 × 506 pixels, pixel size 12 × 12 μm).

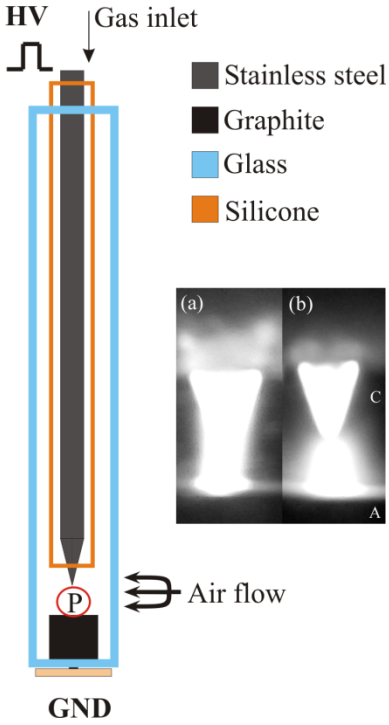

Figure 1: The cross-section of atmospheric pressure gas discharge source. The photos of discharge burning in pulsed (a) and DC regime (b) are given in the inset (C – cathode, A – anode).

2. RESULTS AND DISCUSSION

The 2D contour plots showing the spatial distribution of the H_β line and He I 447.2 nm line recorded by means of the CCD camera area scanning mode are shown in Figure 2. One may notice that in the pulsed regime, both near cathode region and plasma column exist. In the region near cathode, the broadening of both studied lines are evident, see the upper part of Figure 2. The best fit of the H_β line and He I 447.2 nm line, emitted from the plasma column, are presented in Figure 3. The experimental conditions are given in figure captions. The N_e values obtained as a result of the fitting procedure are the following: $(0.16\pm0.03) \times 10^{15}$ cm^{-3} (H_β), $(0.55\pm0.11) \times 10^{15}$ cm^{-3} (He I 447.2 nm) and $(0.48\pm0.1) \times 10^{15}$ cm^{-3} (He I 492.2 nm). The 3 times lower N_e is measured from the H_β line probably due to the H I emission from the outer discharge region.

In the frame of this study, we tested the possibility of using needle-to-cylinder plasma source for decomposition of small volume liquid samples. Hence, the distillated water drop (volume of 0.013 – 0.02 ml) placed on the top of anode was used. Interestingly, $N_e = (0.55\pm0.11) \times 10^{15}$ cm^{-3} is measured from the H_β but

exclusively at the beginning of plasma-water treatment (0-35 s). It is a time period when the water vapor partial pressure is significant in the discharge gap P and H I lines emitted from the central plasma region. In the same time period, Fe I lines originating from the cathode material are present in the spectrum, see e.g Figure 4. At the end of plasma-water treatment, $N_e \sim (0.16 \pm 0.03) \times 10^{15}$ cm^{-3} is measured and Fe I lines vanish from the spectrum. Concerning the N_e determined after the analysis of He I lines, no significant change is detected.

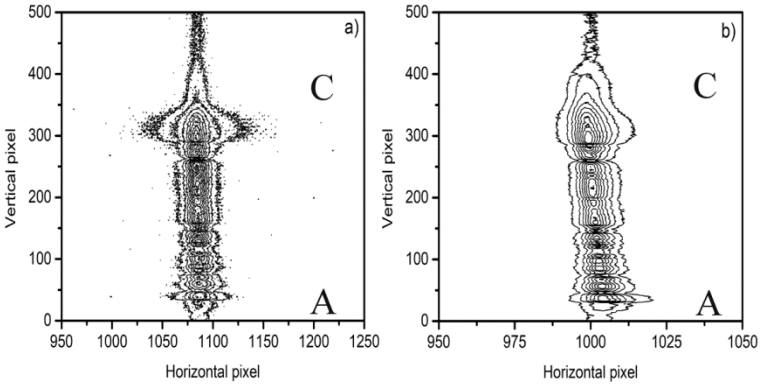

Figure 2: The H_β line (a) and He I 447.2 nm line (b) recorded in the pulsed regime using the imaging mode of CCD camera. Experimental conditions: pulse width 800 μs, duty cycle of 5 %, *I*=20 mA, *U*=435 V.

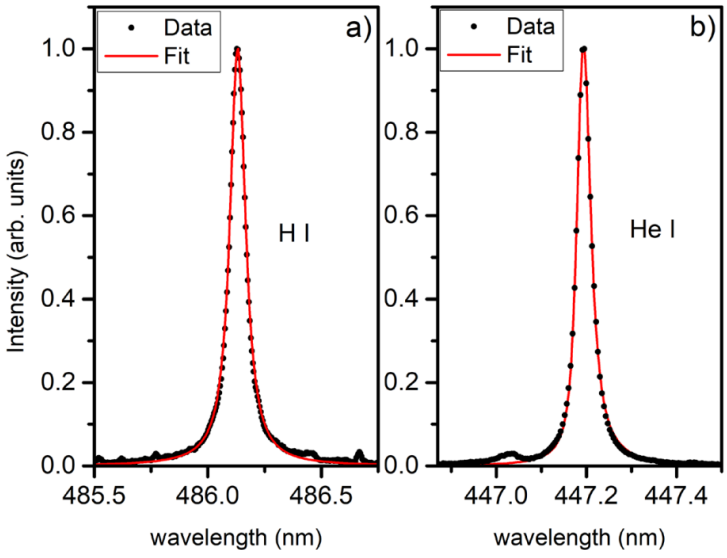

Figure 3: The best fit of the H_β line (a) and He I 447.2 nm line (b), both recorded in the second order of diffraction grating. Experimental conditions: pulse width 800 μs, duty cycle of 5 %, gap 2 mm, *I*=20 mA, *U*=434 V.

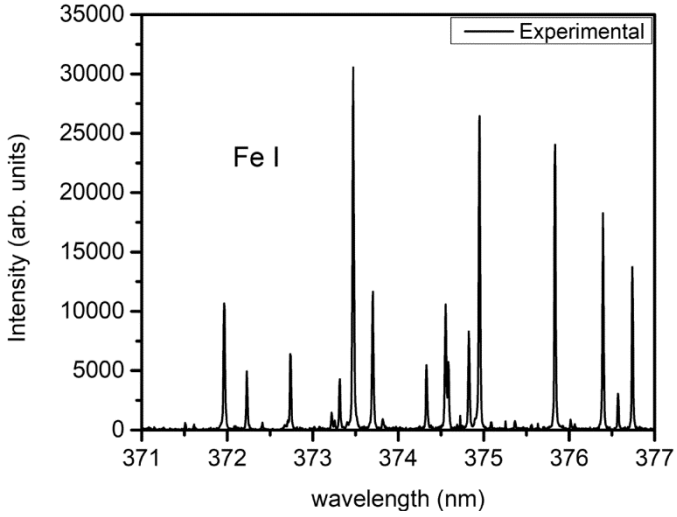

Figure 4: The spectrum of Fe I lines in the range 371-377 nm (*I*=20 mA, pulse width 800 μs). The diffraction grating operated in the second diffraction order.

The tentative explanation for the presence of Fe atoms in plasma is related to the formation of iron-oxide layers on the cathode surface during the plasma–water interaction. The potential application of the presented needle-to cylinder atmospheric pressure gas discharge source operating in pulsed regime is foreseen for the analytical study of conductive liquid samples. In addition, the spectra of cathode material may be used for plasma diagnostics purposes as well. The knowledge of plasma science, fluid dynamics, heat and mass transfer, photolysis, multiphase chemistry, etc., is required for the full understanding of plasma-liquid interaction (Vanraes and Bogaerts 2018).

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