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Plasma torch optical and spectral diagnostic of arc plasma generators of alternating current

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Now the significant attention is given to development of devices for generation of nonequilibrium air plasma of atmospheric pressure with electron concentration more than 10^{13} cm^{-3} and gas temperature less than 2000 K [1-3]. There are a lot of applications of this type of plasma, and every year their amount increases. For example there are systems of sterilization [4], air-plasma hardening of materials and modification of polymer surface[5]. Besides organic waste processing technologies are actively developed in the last decade[6]. It is known that calorific value of many kinds of solid organic containing waste is enough for the organization of processes of their combustion with the purpose of destruction with the subsequent recuperation of part of energy. A great amount of combustion plants is created all over the world. However it rather more efficient to subject organic waste to gasification because in this case the organic component of waste will be transformed to combustible gas having a wide spectrum of opportunities on further application, the main of which is energy generation. According to the preliminary estimations and calculations the low temperature plasma application in these processes will allow essentially increasing in their efficiency, and use of plasma generators of the examined type looks very promising.

In this report the results of the optical diagnostic of the single-phase (fig. 1) and multi-

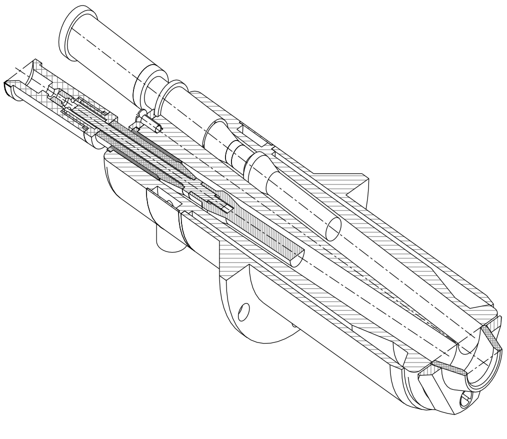

Figure 1. Principal scheme of single-phase alternating current plasma generator

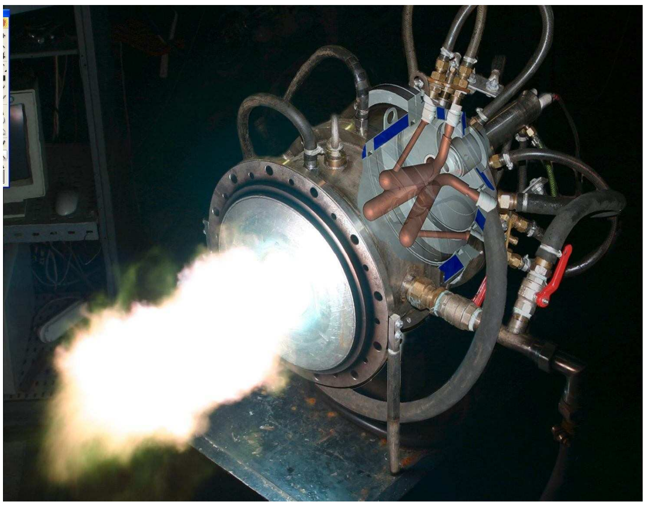

Figure 2. Photo and principal scheme of multi-phase powerful alternating current plasma generator.

phase (fig. 2) alternating current air plasma generators are presented. The plasma generator can be used as an independent device in modern plasmachemical installations. In our case the single-phase plasma generator is used as current carrier injector [6] to insure reliable ignition of arcs of powerful plasma generators (up to 500 kW). So the investigations of this device are relevant.

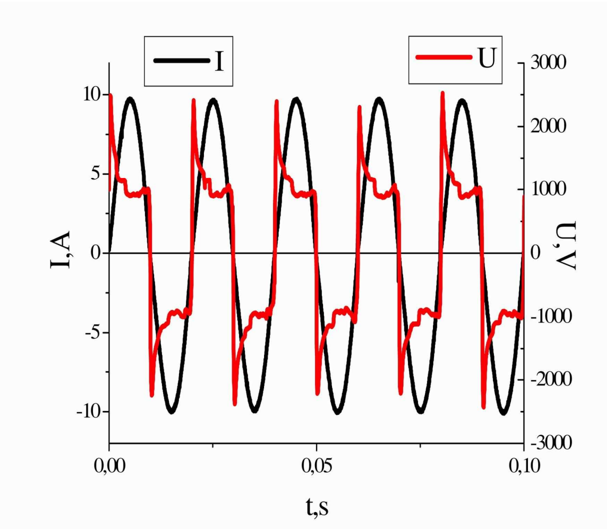

Figure 3. Time dependences of current I and arc- voltage drop U.

One of the important characteristics of the plasma generator is the temperature of different components of the plasma torch. In this work the electron and gas temperatures are investigated. The electron temperature was determined as copper atoms excitation temperature that can be compared to electron temperature due to high pressure that is usual for examined plasma type [7]. Gas temperature was determined using estimation of rotational temperatures of the first negative system of nitrogen N^+ and (0-0) band of violet system of cyanogens CN. Two methods were used: comparing of experimental and modeling cyanogens molecular spectrums and using empirical equation connecting rotational temperature and parameters of particularly resolved (0-0) band of first negative system of nitrogen [8]. The using of these two methods allows the control of the obtained results.

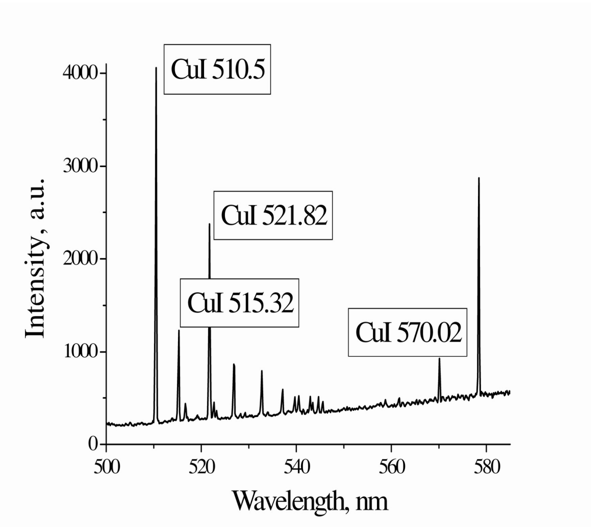

Figure 4. Emission spectrum of copper atoms.

The single-phase alternating current plasma generator is a double jet plasma generator with vortex stabilization of the arc (fig. 1) [7]. During the experiments gas flow Q has been varied between 0.9 and 4.4 g/s. Time dependences of current and arc-drop voltage are shown in fig.3. The system of spectral measurement comprises the spectrograph Andor Shamrock RS-303i with 2400 l/mm grating and the focusing system. The spectrum was recorded on CCD-camera Andor DU-420. During the experiments the width of the spectrometer slit was 50 mkm, exposure time – 100 ms. For the described conditions the spectrograph resolution was 0.03 nm.

The emissions spectrums of copper (fig. 4) were used to determinate electron temperature with the method of relative intensity of lines. Two methods of determination the temperature of gas component of the plasma generator were used. The first one consists in comparing of the modeling spectrum to experimental spectrum of (0-0) band "violet" system of cyanogens, the second consists of using of the empirical dependence between the rotational temperature and parameters of particularly resolved spectrum of (0-0) band of the first negative system of nitrogen [8]. And these two methods show good agreement between themselves.

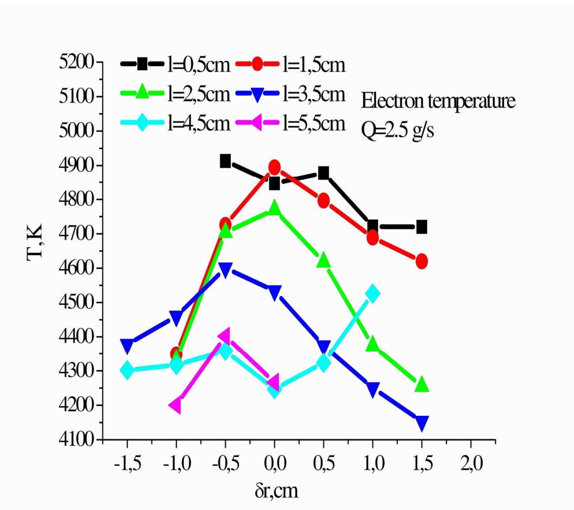

Figure 5. Cross-profile of electron temperature at gas flow Q=2.5 g/s on different distance l from nozzle section

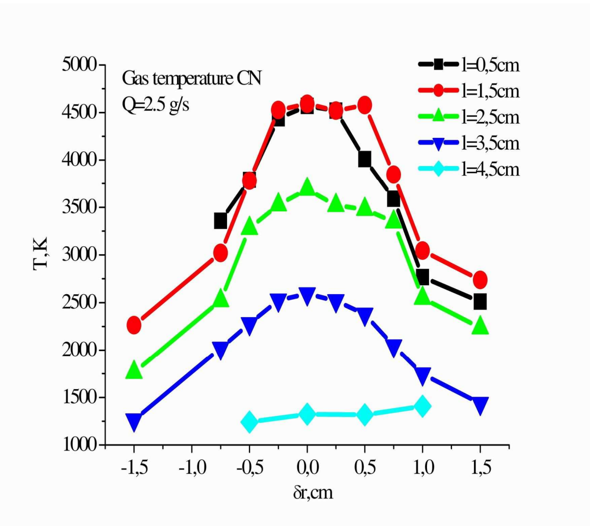

Figure 6. Cross-profile of gas temperature at gas flow Q=2.5 g/s on different distance l from nozzle section obtained with comparison modeling with experimental spectrums.

The example of the plasma torch's cross profile of electron temperature is presented on fig. 5. How it can be noticed, the transverse gradient of electron temperature is small. During the moving off from nozzle section electron temperature changes little too. Moreover it was found that longitudinal gradient and value of electron temperature change little during gas flow rate increase. This fact can be explained in such way. It was noticed [7] that arc-drop voltage does not vary virtually in verifying gas flow. But in the same time applied electric field is the single source of plasma heating. And other reasons that are able to influence on plasma heating change little in changing gas flow.

The cross profiles of gas temperature is presented in fig. 6. Gas temperature has lager cross and longitudinal gradients than electron temperature because the gas component is more sensitive to heat exchange than electrons.

The method of the relative intensity of coopers lines were used to determinate temperature of the torch of multi-phase plasma generator. On the fig. 7 inline profiles for different regimes are presented.

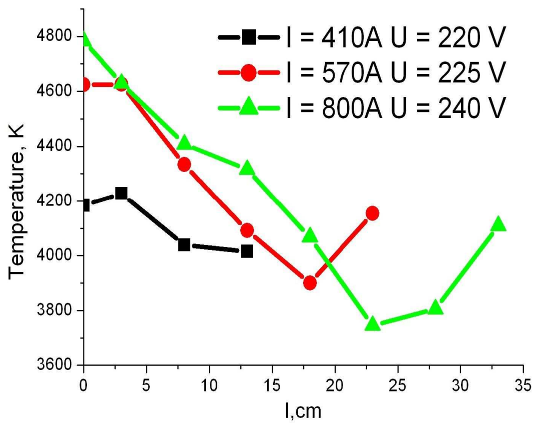

Figure 6. Inline-profile of temperature in the centre of the multi-phase plasma generator'ss torch at gas flow Q=30 g/s on different distance l from nozzle section. I, U - active value of the arc's current and voltage correspondingly.

The presented results can be applied in development of plasmachemical reactors and help to understand more completely the processes taking place at use when single-phase alternating plasma generator is used as a current carrier injector to insure reliable ignition of arcs of powerful plasma generators.

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