PLASMA SYSTEM WITH ROTATIONAL GLIDING ARC BETWEEN SOLID ELECTRODES

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Rotational gliding arc with solid electrodes has been studied at different flow of working gas (air). Plasma torch studies by emission spectroscopy method. Measurements have been made at various levels from the electrode surface along the entire flare height. Electronic temperature levels of plasma component population have been determined. Current-voltage characteristics under different operating conditions were investigated.

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INTRODUCTION

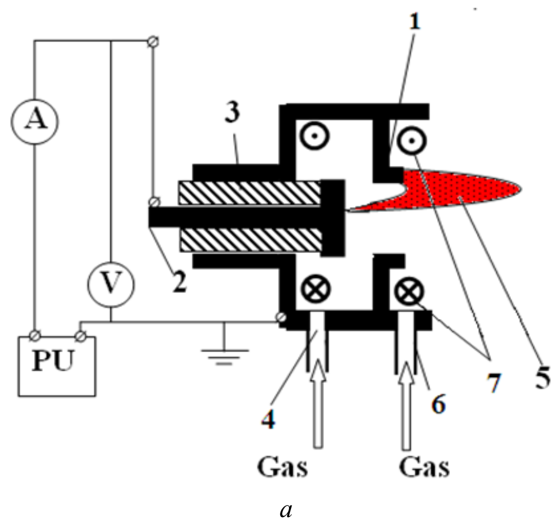
Manufacturing and study of plasma systems that would work under high pressure, generate non-equilibrium plasma and have long operation life is an important task for plasma technologies [1]. Today, plasma generators with rotating sliding arcs best meet these conditions. These generators are available in two versions: RGArc with [2 - 4] and without [5 - 8] the longitudinal motion plasma column.

Dynamic plasma system with RGArc without the longitudinal motion plasma column with solid electrodes is studied in this research. Electrodes are made of copper and stainless steel. This system can be used as a source of active particles, which are injected into the reaction chamber. Since the arc slides over the metal electrode under the influence of the gas flow, the operation life of such system should be much longer than in the case when sliding and rotation are absent.

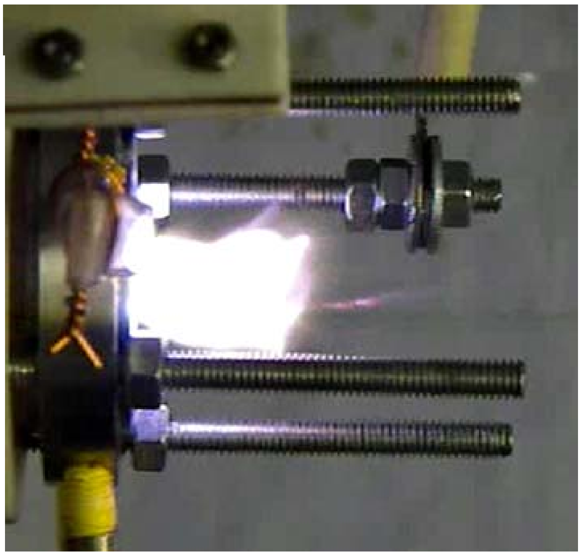
1. EXPERIMENTAL SETUP

Schematic view and photo of the experimental setup are shown in Fig. 1. Discharge burns between two solid electrodes, which are made of stainless steel (1) and copper (2), and insulator (3) is between them. The working gas flow is introduced tangentially to the lateral wall of the cylindic chamber through the channel (4). The plasma torch (5) is rotating under the influence of the gas flow and gliding along the surface of the upper electrode. The working gas was air. Set up construction provided an additional channel for gas flow (6), but it was not used in this work.

The current-voltage characteristics of the discharge depending on the rate of airflow and mode (different polarity of electrodes). The behaviour of rotating gliding arc was investigated in dependence on the size of the gas flow and discharge current with high-speed cameras.



a



b

Fig. 1. Schematic view (a) and photo (b) of the experimental setup

2. RESULTS AND DISCUSSION

The current-voltage characteristics of the discharge are shown in Fig. 2 for two modes: stainless steel cathode (see Fig. 2,a) and copper cathode (Fig. 3,b) at different air flows. Airflow rate was varied in the range from 42 to 417 cm^3/s.

It can be said, on the current-voltage characteristics base, that increasing of the air flow rate leads to the breakdown voltage increasing, when the cathode is stainless steel one. But this voltage, within the error, is only slightly modified, if air flow rate is more than 250 cm^3/s. The increasing the air flow rate slightly up the lower limit of the of currents range, when system has a copper cathode (120…400 mA for the case of air flow rate 42 cm^3/s; 220…400 mA for the case of air flow rate 417 cm^3/s). Breakdown voltage, within the error, changes slightly.

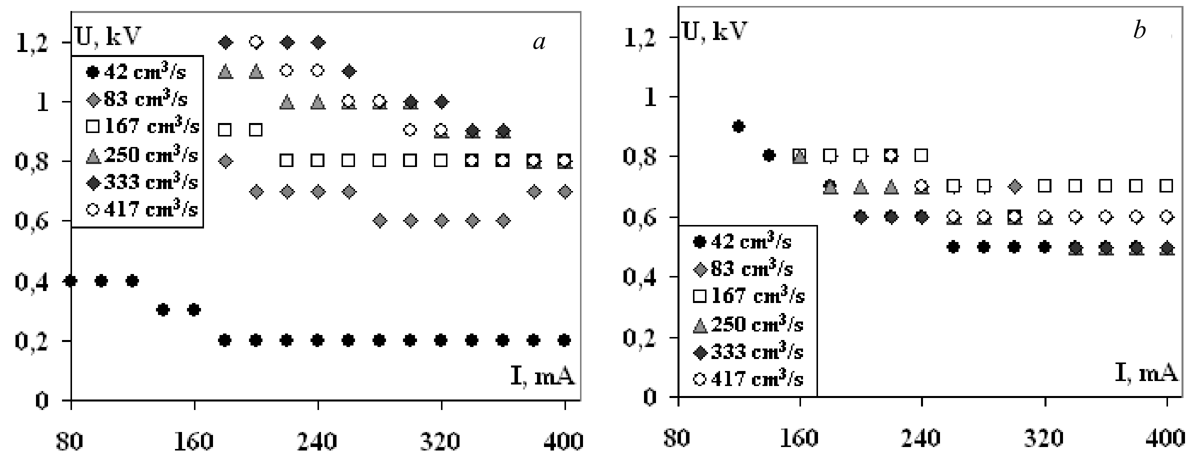


Fig. 2. Current-voltage characteristics of discharge: stainless steel cathode (a), copper cathode (b) at various air flow rates (from 42 cm^3/s to 417 cm^3/s)

The emission spectroscopy was used for plasma diagnostics. Emission spectra were registered by usage of spectral device – spectrometer S-150-2-3648 USB. This spectrometer allows registering the emission spectra in the wavelength range 200…1000 nm. Temperatures of excited electron levels population for various chemical elements and their distribution along the plasma torch were defined in dependence on the air flow rate value and discharge current. This method is described in details in [9].

Typical emission spectra of plasma in rotational gliding arc discharge are shown in Fig. 3: stainless steel cathode (see Fig. 3,a); copper cathode (see Fig. 3,b).

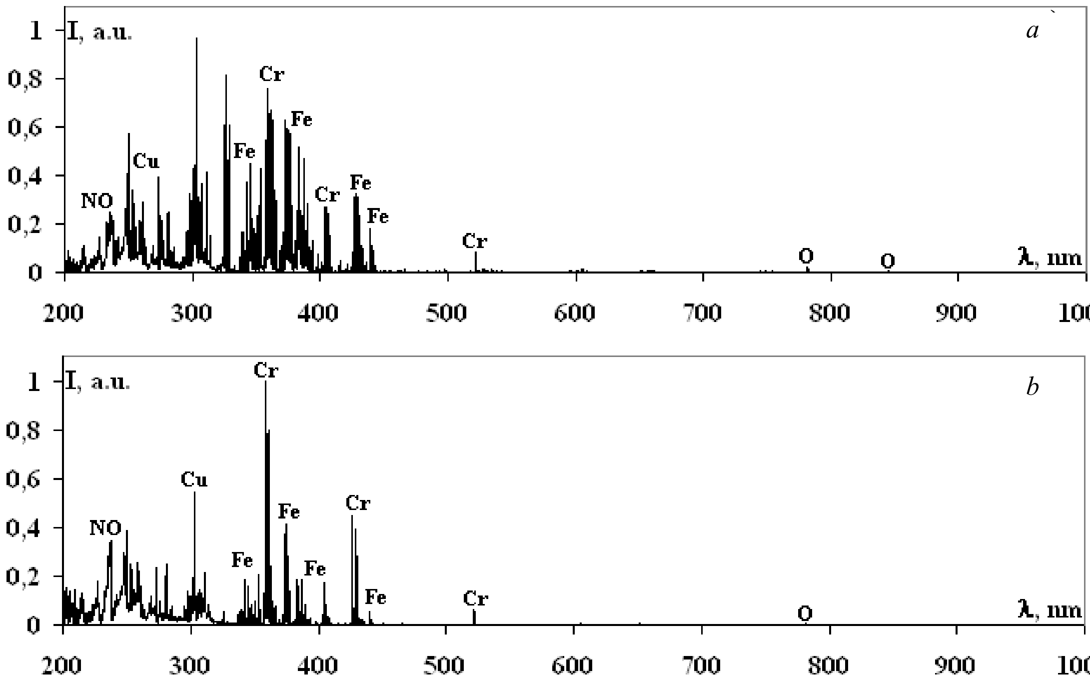


Fig. 3. Typical emission spectra of plasma in rotational gliding arc discharge with solid electrodes for stainless steel (a) and copper (b) cathode. G = 167 cm^3/s; h = 0 mm; I = 340 mA; U = 0,8 kV

Spectra in both cases are mixtures, they contain atomic lines, electrode materials Cr, Fe, and Cu multiplets, oxygen atoms O multiplets, and NO molecular bands. The temperatures of excited electron levels population (T_e^*) plasma components such as Cr and O were determined from these spectra. Determination of temperatures of excited electron levels population (T_e^*) for oxygen atoms was carried by the Boltzmann diagram method using three most intense multiplets (777.2 nm, 844 nm, 926 nm) and data from [3]. T^*_e of Cr atoms has been determined by the ratio of the intensity of two intense multiplets (357.9 nm and 425.4 nm) by using comparison of calculated and experimental spectra. Determination of other components temperatures has been significantly more complex. It was caused by overlapping of their spectra.

The plasma discharge was diagnosed at different discharge currents and along the plasma torch height (h). The range of air flow rate is 167…417 cm^3/s. The temperature (T_e^*) dependences on the current level were specified for Cr and O atoms at different air flow rates and stainless steel cathode. They are shown at Fig. 4. The error of T_e^* definition is near 500 K, so we can say that the components temperature depends weakly from current.

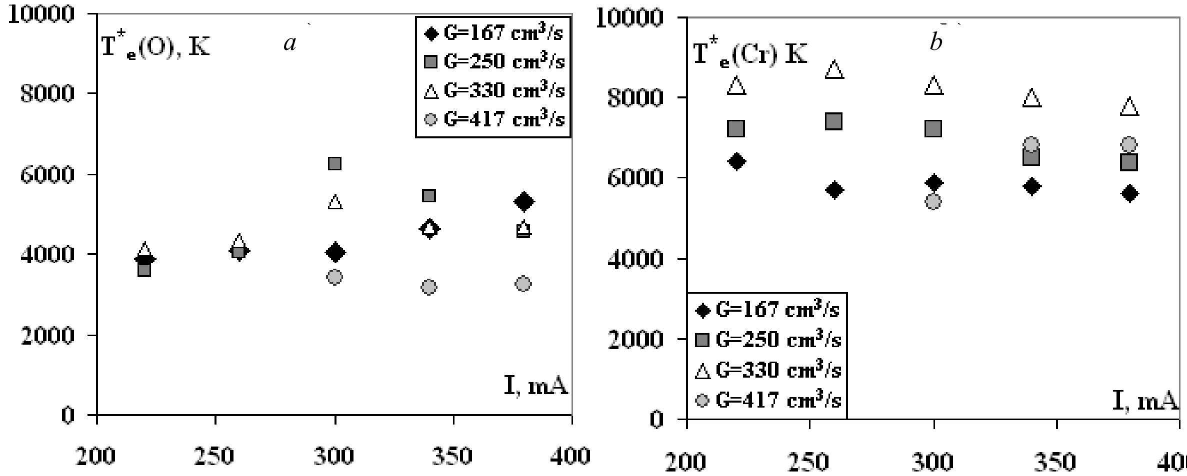


Fig. 4. The temperature (T^*_e) distribution for oxygen and chrome atoms under different air flows for oxygen (a) and chrome atoms (b) as a function of discharge current

The temperature (T_e^*) of Cr atoms increases with the air flow in the range of air flow rate 167…333 cm^3/s. The temperature (T_e^*) of O atoms, within the error, does not change. It may be noted that the temperature of excited electron levels population at Cr atoms in 1.5…2 times higher than same temperature of oxygen atoms. This can be explained by the peculiarities of these chemical elements excitation.

Axial temperature (T_e^*) distribution for oxygen and chrome atoms under different air flows (167…417 cm^3/s) and stainless steel cathode is presented at Fig. 5.

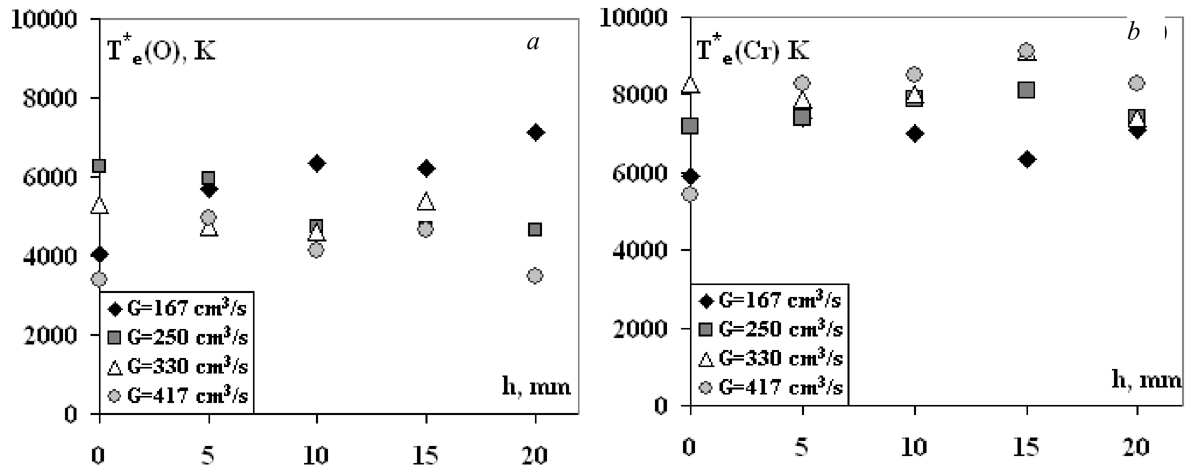


Fig. 5. The temperature (T^*_e) distribution for oxygen (a) and chrome (b) atoms under different air flows along the plasma torch height. Discharge current - 300 мА

The relationships mentioned above, show that temperature (T_e^*) of oxygen atoms is increased with height of the plasma torch for low air flow rate (167 cm^3/s). Such dependence wasn't observed for larger airflows. An essential increasing in T_e^* was observed at the maximum flow (417 cm^3/s) for Cr atoms along plasma torch. Such trend wasn't observed for smaller flows.

The maximum plasma torch height was lower and fixation of emission spectra plasma was more difficult in case of copper cathode. The temperature T_e^*(O) is 3500 ± 500 K, within the error, does not change with height of the plasma torch and the air flow rate (167 and 417 cm^3/s). T_e^*(Cr) is 7000 ± 500 K in a range of heights (h = 0…5 mm) at low air flow (167 cm^3/s). The temperature T_e^*(Cr) = 9000 ± 500 K at the beginning of the torch (h = 0mm) and 8000 ± 500 K on height h = 5 mm at the maximum airflow (417 cm^3/s).

CONCLUSIONS

Elements of both electrodes (Cu and Fe, Cr) present in the torch plasma. Also the spectra in small amounts are multiplets of oxygen atoms and bands of NO molecules.

When the cathode is stainless steel, temperature Cr and O weakly changed from current. However, T_e^* of these components has strong dependence on air flow.

Observed strong increase T_e^* for O in the case of small air flow (167 cm^3/s) height the plasma torch. Along with being temperature throughout the plasma torch height within the error limits does not change at high airflow.

Axial distribution of T_e^*(Cr) for small air flow does not change within the error limits, but at high air flow (417 cm^3/s) it was detected change of T_e^*(Cr) in height the plasma torch.

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ПЛАЗМЕННАЯ СИСТЕМА С ВРАЩАТЕЛЬНОЙ СКОЛЬЗЯЩЕЙ ДУГОЙ С ТВЕРДЫМИ ЭЛЕКТРОДАМИ

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Исследовалась вращательная скользящая дуга с твердыми электродами при различных потоках рабочего газа (воздуха). Проводились исследования плазменного факела методом эмиссионной спектроскопии. Измерения проводились на разных уровнях от поверхности электрода вдоль всей высоты факела. Определены температуры заселения возбужденных электронных уровней компонент плазмы. Исследованы вольт-амперные характеристики при различных режимах работы.

ПЛАЗМОВА СИСТЕМА З ОБЕРТОВОЮ КОВЗНОЮ ДУГОЮ З ТВЕРДИМИ ЕЛЕКТРОДАМИ

О.В. Соломенко, О.А. Недибалюк, В.Я. Черняк, Є.В. Мартиш, І.І. Федірчик, І.В. Присяжневич

Досліджувалась обертова ковзна дуга з твердими електродами за різних потоків робочого газу (повітря). Проводилися дослідження плазмового факела методом емісійної спектроскопії. Виміри проводились на різних рівнях від поверхні електроду вздовж усієї висоти факела. Визначені температури заселення збуджених електронних рівнів компонент плазми. Досліджені вольт-амперні характеристики при різних режимах роботи.