OPTICAL RESEARCH OF THE INFLUENCE OF GAS FLOW FEATURES ON THE TRANSVERSE ARC AIR PLASMA

I. Prysiazhnevych, V. Chernyak, V. Yukhymenko

Laboratory of the Plasmachemistry, Radiopphysics Faculty of Kyiv National Taras Shevchenko University, Glushkova Pr. 2/5, 03022 Kyiv, Ukraine
chernyak_v@ukr.net

There are a lot of plasmachemical applications for today which need nonequilibrium plasma sources of atmospheric pressure. One of the way to make such plasma generators is to provide an effective heat- and mass- transferring between plasma and environmental. It can be realized by using transversal gas flow, which is perpendicular to the current lines of the discharge. Such transversal discharges as gliding arc /1/, gliding arc in tornado /2/, transverse arc /3/ and glow discharge /4/ can generate nonthermal plasmas at atmospheric pressure. Results presented in this work will show that even transverse gas flows can result in nonthermal and thermal plasma generation both. The level of the plasma non-equilibrity partially depends on the gas flow rate G and the discharge current I_d .

The electroarc discharge in the transverse blowing air flow (transverse arc – TA) was investigated. Two copper horizontal electrodes with diameter *d*=6 mm placed opposite each other were used. A nominal gap between them was δ=1.5 mm. The axially symmetric steel nozzle, with inner diameter ∅=1 mm, was maintained vertically perpendicular to the electrode axis at the distance *L* =20 mm and was centred strictly between the electrodes. A standard dry air system supplied with the flow meters was used. There was enough high gas-dynamic pressure in the flow to blow out the electric arc downstream. TA discharge was powered by the DC source at the ballast resistance R = 2 kΩ in the circuit. Electric current-voltage parameters were measured with the standard electronics. Volt-ampere characteristics (VACH) of TA for air flow rates G=0÷110 cm^3/s are represented on the figure 1. Its decreasing character is typical for the arc discharge. Dependence of the discharge voltage U on the different air flow rates G is shown on figure 2. Such non-linear character of $U_d(G)$ dependence can't be explained only by the fact that energy carries out from the discharge region with G increasing and to support the fixed discharge current it is necessary to increase the voltage on the discharge.

Non-linear $U_d(G)$ dependence on the figure 2 can be connected with the specularities of the gas flow: i) a monotonic voltage increasing with the gas flow rate G increasing (laminar gas flow); ii) voltage on the discharge increases (for $I_d \leq 700$ mA) or remains almost constant (for $I_d > 700$ mA) with further increasing of G (this region corresponds to the transient gas flow regime: from laminar to the turbulent); iii) when the gas velosity becomes bigger than the drift velosity of ions in the electric field, further voltage increasing starts, which is escorted by the appearance of the filament plasma structures directed along the flow.

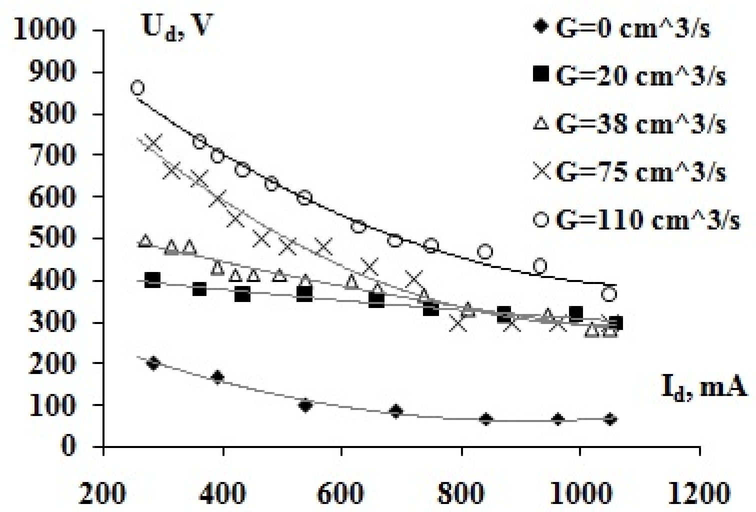

Fig. 1 Volt-ampere characteristics of the TA for different air flow rates G.

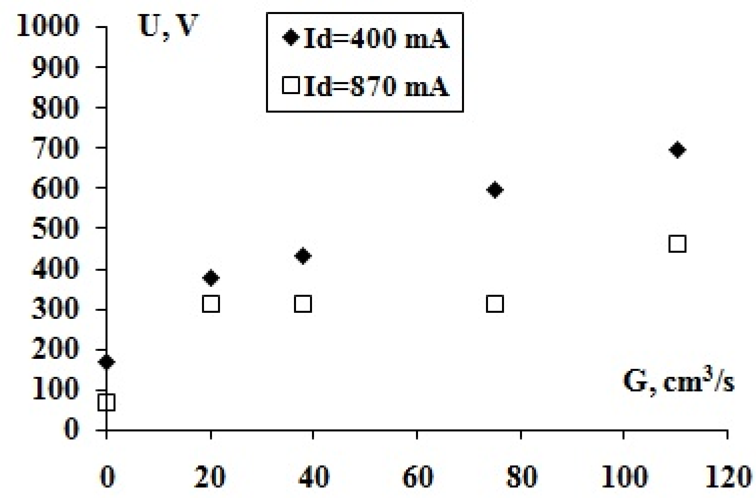

Fig. 2 Dependence of the discharge voltage U on air flow rates G for two different discharge currents I_d.

Plasma parameters of TA was investigated by optical emission spectroscopy for different discharge currents $I_d=10^2\div10^3$ mA and air flow rates G=0÷200 cm^3/s. Emission spectra of TA plasma was detected in the range of 200-1100 nm with spectral resolution nearly 0.7 nm by spectrometer SL 40 based on CCD elements.

Excitation temperatures of the electronic states of atoms (electronic temperature T_e^*) in TA plasma were determined by the relative intensity of the cooper (material of electodes), oxygen, hydrogen spectral lines by Boltzmann plots. Vibration T_v^* and rotation T_r^* temperatures of $N_2(C^3\Pi_u)$ molecule were evaluated by relative intensities of the emission bands of 2^+ system of nitrogen by using SPECAIR /5/ simulation. The following ratio of the excitation temperatures $T_e^*>T_v^*>T_r^*$ were obtained in TA plasma. It was shown that T_e^* slightly decreases along the gas flow in the afterglow zone, while T_v^* remains constant. Founded difference of the temperatures T_e^*(Cu)>T_e^*(O, H) can be explained by the additional mechanism of the population of the excited electronic states of cooper atoms due to the ion-ion recombination, which is almost absent for the blowing gas atoms.

The main recombination mechanisms were considered and the recombination time τ_r at N_e~10^{13}÷10^{14} cm^{-3} $T_g \approx T_r(N_2) \approx 2000$ K, T_e~1 eV, p=1 atm was estimated for plasma of the TA in air. It was concluded that ion-ion recombination ($A^+ + B^- + M \rightarrow A^* + B + M$) is the main recombination process in the plasma of the arc discharge with copper electrodes in the transverse blowing air flow. It was shown that characteristic ion-ion recombination time τ_r ~ 6 ·(10^{-5} ÷ 10^{-6}) s /6/ is comparable with the time of optical transitions in copper atom. It leads to the essential contribution into the population of the electronic states of Cu atom by the ion-ion recombination of the corresponding positive ion. In /7/ was shown that main positive ions in electroarc discharges with copper electrodes are copper atomic ions. T_e^*(Cu)>T_e^*(O, H) since the population of Cu atoms occurs on the levels with excitation energy closed to the difference between atomic ionization energy and electron affinity energy of negative ions of air plasma (ε~ 2 eV) /6/.

Dependence of the excitation temperatures of molecule N_2 in the TA plasma on the gas flow rate G was studied (fig. 3). Vibration and rotation temperatures were determined from the calibration curves /8/ built as functions of the corresponding excitation temperatures with taking into account instrument function of used spectrometer.

Non-monotonic character of the T_r^* temperature dependence on the G can be connected with transition from laminar to the turbulent gas flow with G increasing at fixed discharge current. Changing of the form and structure of the TA plasma column correlates with it good.

Dependences of the excitation temperatures in TA plasma on the discharge current were studied for different air flow rates. It was shown that there is a convergence of T_v^* and T_r^* temperatures, which starts from the discharge current I_d ~ 500 mA, thus plasma of TA becomes isothermal at G=0 cm^3/s. Similar behaviour of the temperature dependence was observed at big flows (G>150 cm^3/s). At large gas flows (where turbulent starts) plasma of TA becomes more isothermal. At the same time at low gas flows difference between excitation temperatures almost doesn't depend on the discharge current. Thus there are optimal regimes of gas flow rates that can provide the certain non-thermality level of the generated TA plasma for the investigated range of the discharge currents.

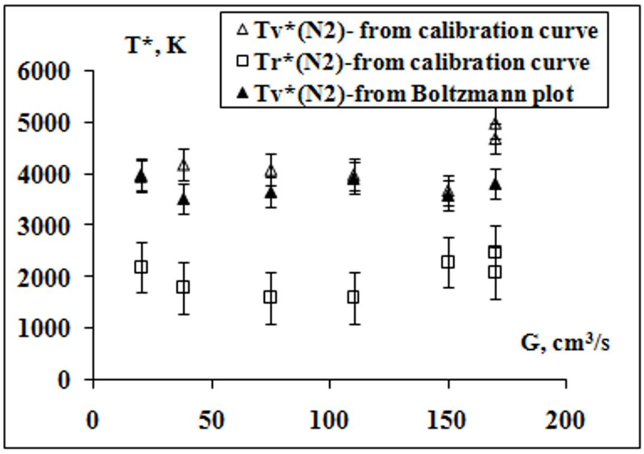

Fig. 3 Dependence of the vibration and rotation temperatures of N_2 molecule in TA plasma on the gas flow rate G.

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