Influence of the discharge current and gas flow rate on the non-equilibrium level of plasma of the transverse arc in air at atmospheric pressure

I. Prysiazhnevych, V. Chernyak*, V. Yukhymenko

Laboratory of the Plasmachemistry, Radiopphysics Faculty of Kyiv National Taras Shevchenko University, 03022 Prospect Glushkova 2/5, Kyiv, Ukraine

*chernyak_v@ukr.net

Plasma parameters of transverse arc dischage in air at atmospheric pressure was investigated by optical emission spectroscopy. Exitation temperatures of atoms and molecules in generated plasma were measured and its distributions along the gas flow were studied. Non-monotonic character of rotational temperature dependence on the gas flow rate was found. It can be resulted from the transitional regime of gas flow (from laminar to turbulent). It was concluded that one can get the biggest level of plasma nonthermality by chosing the gas flow rate and the discharge current.

There are a lot of plasmachemical applications for today which need nonequilibrium plasma sources of atmospheric pressure. It is known that transversal atmospheric pressure discharges such as Chernihowskiy gliding arc [1], gliding arc in tornado [2] and transverse glow discharge [3] can generate nonthermal plasmas due to the effective heat- and mass- transferring between plasma and environmental.

The electroarc discharge in the transverse blowing air flow (transverse arc – TA) [4] was used to generate non-equilibrium atmospheric plasma.

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 $\varnothing$=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. 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÷220 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 electrodes), 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-electron recombination, which is almost absent for the blowing gas atoms.

Dependence of the excitation temperatures of molecules in TA plasma on the gas flow rate G was studied (fig. 1). Vibration and rotation temperatures were determined from the calibration curves [6] built as functions of the corresponding excitation temperatures with taking into account instrument function of used spectrometer.

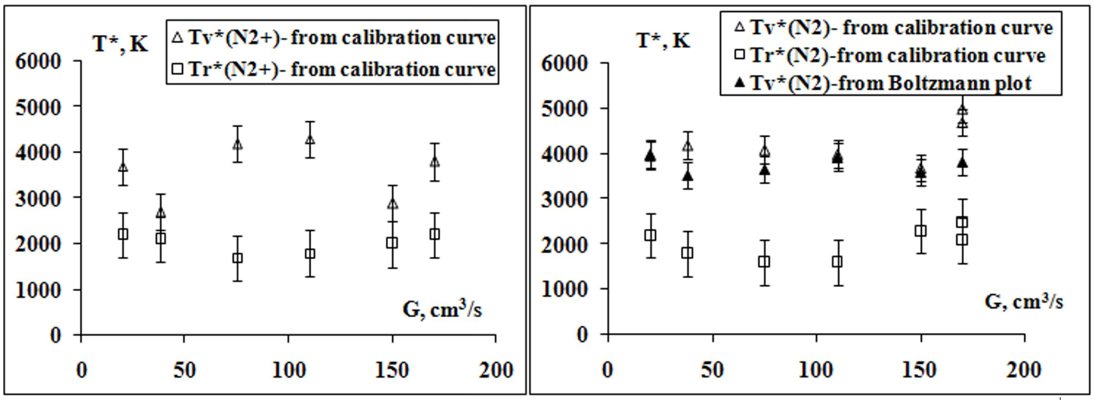

Fig. 1 Dependence of the vibration and rotation temperatures of N_2 molecule and of molecular ion N_2^+ in TA plasma on the gas flow rate G.

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 $I_d \sim 500$ mA, thus plasma of TA becomes isothermal at G=0 cm^3/s. Similar behavior of the temperature dependence was observed at big flows (G>150 cm^3/s). 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.

References

[1] Czernichowski A., Czernichowski M. *Proc. Int. Symp. on Plasma Chemistry – ISPC17,* Toronto, (2005). CD.
[2] C. Karla, I. Matveev et al. *Elec. Proc. of Technical Meeting, Central States Section,* Texas, 21-23 March, (2004), A34.
[3] Z. Machala, Ch. Laux, Ch. Kruger, *IEEE Trans. Plasma Sci.* Vol. 33, No 2, (2005) 320-321.
[4] I. Prysiazhnevych, V. Chernyak et al. *Ukr. J. Phys.* Vol. 52, No 11, (2007) 1061-1067.
[5] www.specair-radiation.net
[6] Prysiazhnevych I.V., Chernyak V.Ya., Olzewskii S.V., Solomenko Ok.V., *Ukr. J. Phys* Vol. 55, No 10, (2010) 1094-1102.