PECULIARITIES OF DISCHARGE PLASMA IN TRANSVERSAL GAS AND
GETEROPHASE STREAMS

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Abstract

The results of experimental researches of discharges plasma in transversal gas and
geterophase (gas - solution) streams with use optical and probe techniques will be
represented in this work. The influence of various energy transports from a plasma column
and near electrode processes on a level of nonequilibrium of plasma is considered.

1. Introduction

Was shown earlier [1], that in under anode area of the secondary discharge, which is
supported by a plasma stream under low level (0.1 torr) pressure, exists under anode a jump of a
potential. The threshold character of dependence of growth rate of diamond layers from voltage
of secondary discharge specifies also on the existence under anode of a jump in the secondary
discharge of atmospheric pressure [2]. The magnitude of a jump of a potential depends from
voltage of the secondary discharge and was and orders of this voltage [1]. Under of fulfilment of
a condition \( \lambda > \lambda_D \), where \( \lambda \) - length of free run of an electron, and \( \lambda_D \) - radius Debaja, it can
enable to form electron beams with energies of tens and hundreds electronvolt, influencing on the
anode and to be used for selective effect on a material of the anode. The research of distribution
of a potential of an electrical field along an axe of a stream of an air bloating an electrical fixed in
space arc of atmospheric pressure is conducted in the given work. Exactly the given discharge is
used auxiliary from creating a plasma stream for secondary discharge [3].

2. Experiments

The measuring were conducted with the help of installation, which was placed in hermetic
volume with air clearance system. It represents the device Fig. 1 with a system of cooling. The
device consists of the independent auxiliary and secondary discharge. The auxiliary discharge was
lighted up between two cooled electrodes 1 and was inflated by an air, to electrodes could be
applied the constant or variable voltage. The secondary discharge is generated between a cooled
electrode 2 and plasma of auxiliary discharge 3 (being the second electrode), by which was
applied the constant voltage. For deriving distribution of floating potential in plasma, along axis
of a stream of air, used a mobile probe 4 (by diameter \( d =200 \))
μm and height h = 0.5 mm). Through a voltage divisor he was connected to the oscilloscope. The oscillogram at the constant nourishment of the independent auxiliary discharge is represented in a fig. 2, herewith $U_-$ constant, and $U_-$ variable component (duration of variable component $t_v$ of $\sim 2$ msec, and duration of peak $t_p$ of $\sim 0.1$ msec). The spectrometric complex on the basis of KSVU-23 together with a quartz lens 5, was used for the analysis of a plasma radiation (Fig. 1b).

The temperature of a population of electronic levels of copper atoms was determined by a method of relative intensities on two lines 510.5 nm and 515.3 nm, with use of the equation:

$$T_e = \frac{E^\lambda - E}{\ln(\lambda^3 g_{12} f_{12}) - \ln(\lambda^3 g_{12} f_{12})},$$

where $E^\lambda$, $E$ and $f$, $J$ are an energy of top levels and an intensity of taken lines, $\lambda^3$ and $\lambda$ are a waves lengths of taken lines, $g$ and $g$ are a statistical weights of levels, $f_{12}$ and $f_{12}$ are an oscillators force.

The temperature of a population of vibrationally levels of nitrogen molecules $T^*$, was determined on $2^*$ system of nitrogen, transition $\square^2 \square \rightarrow \square^3 \square$ with use of the equation:
\[ T_{r'k} = \frac{\Delta E_{r'k}}{\ln \left( \frac{J_{r'k',r'k} \cdot J_{r'k',r'k'}}{J_{r'k',r'k} \cdot g_{r'k',r'k'}} \cdot \left( \frac{\lambda_{r'k',r'k'}}{\lambda_{r'k',r'k''}} \right)^4 \right)} \]  \hspace{1cm} (2)

where \( \lambda_{r'k',r'k} \) and \( \lambda_{r'k',r'k''} \) are lengths of transitions.

3. Experimental Results and Discussion

The volt-ampere characteristics of an arc discharge \( u_s (i_s) \) are presented at fig. 3 for various streams of an air \( g_{air} \): 0.1 (1), 0.125 (2), 0.15 (3), 0.175 (4), 0.2 l/s (5) in the absence of an electrode 2 (fig. 1a). The curves 1 - 3 correspond to condition with continuous plasma column, 5 and 4 - for condition with teared plasma column. The dashed curve 6 corresponds to a regime of an arc burning in a mixture of an air \( g_{air} = 0.175 \) l/s and water solution \( g_{aq} = 0.12 \) ml/s. Length of a plasma column varied in a research range of an air streams from 10 up to 50 mm.

The data show that increasing of arc ventilation, i.e. energy loss from plasma, caused not only essential increase of arc plasma column length, but also the increase of a power, put in discharge. Especially it is observed in a condition with a teared plasma column.

The practical coincidence of curves 4 and 6 indicates that addition of water aerosol to the air stream does not cause the increase of energy loss from plasma in experiment conditions. It can be connected with the essential decrease of an axial velocity of the air stream on a pulverizer exit at mixing additive of water. The decreasing of a plasma column length also indicates that the
velocity of an air stream at mixing additive of water in an air is decreased.

The importation of an electrode 2 in a plasma column of an arc under a floating potential causes both the additional cooling of gas on a cold surface, and to the appearance of an additional wall recombination of plasma charges. It is resulted in a more strongly marked dependence of power, put in a discharge, from gas flow rate, as the data presented on a Fig. 4 indicate (parameters of curves on Fig. 4 coincide parameters of curve 1 - 5 on a Fig. 3).

The influence of water film covering of electrode 2 (Fig. 1a) on volt-ampere characteristics of arc was studied to determine the relative contribution of wall recombination and cooling on surface to energy loss from plasma. The water was moved continuously through the axial channel of electrode 2 for formation of a film on electrode. The results of these measurements have shown that when the electrode introduced in a plasma column was covered by water film the power discharge was practically equal to the discharge power in the absence of electrode. The data obtained shows the prevailing role of wall recombination in energy loss from plasma when the electrode 2 is introduced in the arc plasma column.

The volt-ampere characteristics U_d(I_d) of a secondary discharge supported by an auxiliary arc discharge are represented in a Fig. 5 for G_air = 0.1 (1), 0.125 (2), 0.15 (3), 0.175 (4) and 0.2 l/s (5) at a constant current of an arc I_a = 0.55 A and voltage drop on an arc discharge U_a = 550 (1), 600 (2), 650 (3), 700 (4) and 750 V (5). The curves 1, 2 correspond to conditions, when the brightly flashing plasma column of an arc did not achieve the anode of a secondary discharge. At large streams of an air The extraction of an arc column along an axes of an air stream exceeded the distance between the anode of a secondary discharge (2, Fig. 1) and electrodes of an arc discharge (1, Fig. 1).

The following results were obtained in an outcome of researches. The distributions of a floating potential of plasma along an axes of a stream of an air are represented on Fig. 6, 7. The curves correspond to a different expense of an air: curve 1 - expense 0,16 l/sec; 2 - expense 0,12 l/sec; 3 - expense 0,1 l/sec; 4 - expense 0,08 l/sec;

The case of nourishment of the independent auxiliary discharge by constant voltage was used (fig. 6 and fig. 7). The behaviour of a constant component of a floating potential represents on fig. 6, and the variable component – on fig. 7.

![Fig.](image)

It is shown in the given work, that the distribution of a floating potential has an unmonotone distribution. Possibly, the unmonotonicity appears from the essential modification

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of impulse only of plasma heavy particles by interaction of a gas stream with plasma. As the thermal velocity of positively charged particles is comparative with a flow velocity and much less thermal velocity of electrons.

the dependence of a temperature of a population of electronic levels of copper atoms $^*$ and a temperature of a population of vibrationaly levels of electronic level of nitrogen molecules $T_v$, in the plasma of secondary discharge from a distance $z$ are represented for two air streams 0,125 and 0,075 l/sec on fig. 8, 9 accordingly. Also the are indicated distributions of intensities along $z$ for a copper line $I_{Cu}$ (510,5 nm) and nitrogen band $I_{N2}$ (357,3 nm) present on fig. 8 and fig. 9.

As it is visible from dates reduced on Fig. 8, 9 the plasmas are essential nonequilibrium in the field of a maximum of concentration - the essential separation of temperature of a population of electronic levels of copper atoms from temperature of a population of vibrationaly levels of nitrogen molecules is observed. The magnification of an air stream of blowing an arc poorly influences on a modification of an absolute value of temperature of a population of electronic levels of copper atoms.

4. Conclusions

The influence on the energetic arc discharge characteristics such factors as ventilation of arc by cold gas or mixture and contact of plasma column with a cold surface is researched. It's shown that the most effective removal of energy from plasma is provided with air-flow-cooling and contacting of plasma with a cold surface of metal. Power waste due to a wall recombination is predominant when plasma column touch with a cold metal surface. The plasmas of secondary discharge are essential nonequilibrium in the field of a maximum of concentration - the essential separation of temperature of a population of electronic levels of copper atoms from temperature of a population of vibrationaly levels of nitrogen molecules is observed. The magnification of an air stream of blowing an arc poorly influence on a modification of an absolute value of temperature of a population of electronic levels of copper atoms. The distribution of a floating potential in plasma column of a discharge in a transversal stream of gas has an unmonotone
distribution. Possibly, the unmonotonicity appears from the essential modification of impulse only of plasma heavy particles by interaction of a gas stream with plasma.

References