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FEATURES OF HIGH-FREQUENCY CAPACITOR DISCHARGE COMBUSTION PROCESS IN MEDIA WITH DISPERSE PHASE

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Measurements of current, voltage and amplitude of electric field of dusty high-frequency capacitor discharge have been carried out. Increase in the current proceeding in discharge at its dustiness by substances with potential ionization less than 7 V was established. Electromagnetic wave parameters extending in dusty high-frequency capacitor discharge were calculated. The absence of characteristics change in discharge electromagnetic field at degrees of its dustiness $\nu<10^{-2}$ was shown.

Gas discharges in plasma technology are usually used only as a source of plasma jet. However, substance processing in gas discharge directly has a number of advantages in comparison with substance processing in plasma jet. First of all, higher temperature of plasma and lower axial temperature gradient are typical for gas discharge. Presence of electric fields and higher concentration of electrons in discharge area make plasma catalytic properties more defined.

It is more optimal to use high-frequency discharges of capacitive type to carry out processes in discharge area. Discharges of this type have large volume of discharge plasma at low level of power supplied to discharge. Walls of plasma-chemical reactor and intensification of processes occurring in plasma may be refined by amplitude modulation.

In this work electro-physical characteristics of high-frequency capacitive discharge dusty by dielectric and conducting materials were measured. The diagram of experimental set-ap is given in Fig. 1. High-frequency capacitive discharge with a ring electrode with the diameter of 48 mm was used. Presence of the second grounded electrode, as experience has shown, does not substantially influence [1] the characteristics and modes of capacitive discharge combustion. The discharge was excited in quartz tube with the diameter of 36 mm. Discharge combustion was carried out in the air at atmospheric pressure. Discharge power varied from 1 to 3 kW. Electromagnetic field frequency amounted to 40 MHz. Dispersion of materials which were used for discharge dust amounted to 20...60 mkm. Powder was supplied to central discharge area by pneumatic feeder. Consumption of plasma forming gas amounted to 0,6 m^3/h.

Voltage-current characteristics of discharge in free consumption mode and in the case of discharge plasma dustiness by dielectric and conducting particles were measured. The degree of discharge plasma dustiness determined as a ratio of spray substance volume to total volume of discharge chamber changed from 0 to 10^{-4}. Discharge dustiness degree was measured by determining the change of sprayed powder weight for a certain period of operation of experimental device. Voltage was measured by voltmeter V3-52/1 furnished with additional capacitance divider. Current was measured by Rogowski loop.

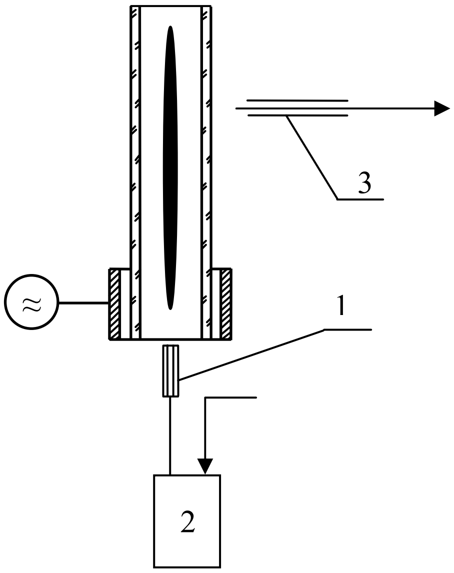

Fig. 1. *Diagram of experimental set-ap: 1) tube for powder supply; 2) feeder; 3) capacitive probe*

As a result of measuring the increase of high-frequency current in discharge at its dustiness with such substances as Al_2O_3, Na_2SO_3, $Ca(CH_3COO)_2$ was stated. At discharge dustiness with substances having ionization potentials higher than ionization potential [2] of calcium, discharge characteristic change is not observed. In particular, at discharge dustiness with Ni, Fe current change in discharge is in the range of measurement errors. The results of current change measurements in discharge at its dustiness with substances with different ionization potentials are given in Fig. 2. The value of ionization potential is put on X-axis and the ratio of current in dusty discharge to the current in free discharge is put on Y-axis.

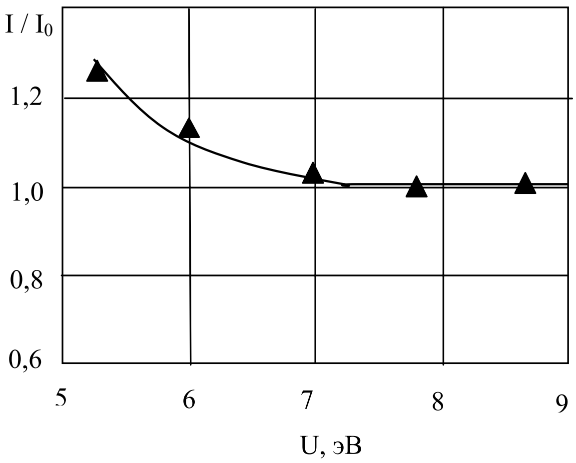

Fig. 2. *Dependence of current in a discharge on a value of ionization potential*

Let us note that current increase in a discharge is accompanied by proper decrease of voltage at high-voltage electrode. So, at discharge dustiness with aluminum oxide current increases by 15 %, voltage decreases simultaneously by 15 %. Therefore, discharge power at its dustiness does not change. The degree of dustiness and dispersion of dusting material influence insignificantly on discharge plasma resistance.

The results of experiments showed high resistance of high-frequency capacitive discharge to dustiness both by dielectric and conducting material. Let us note that discharge resistance to dustiness is mainly determined by change at dustiness of its electrodynamic characteristics.

In this connection radial component of electric field of high-frequency capacitive discharge was measured as well. Measurements were carried out by capacitive probe; a signal from it was delivered to oscillograph input. Capacitive probe represented copper finger with the diameter of 1 mm and length of 3...5 mm. The results of measurements are given in Fig. 3. It follows from the results of measurements that the changes in axial distribution of radial component of electric field of capacitive discharge at its dustiness are insignificant. Only slight increase of electric field amplitude along discharge axis in the case of its dustiness by conducting material is observed.

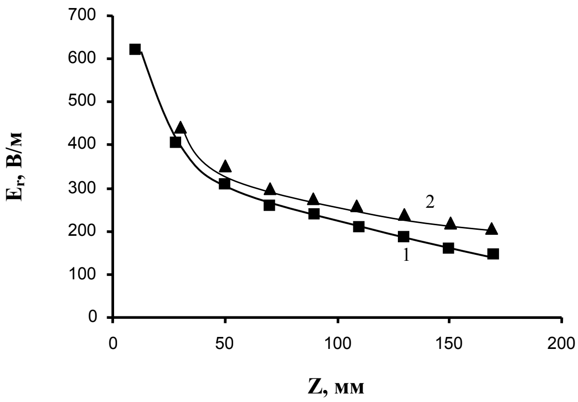

Fig. 3. *Electric field distribution along the axis of high-frequency capacitive discharge: 1) freely combusting discharge; 2) discharge dusted with nickel ($\nu=10^{-4}$)*

Let us examine the process of electromagnetic wave propagation along the channel of high-frequency capacitive discharge. As it is shown in paper [1] the character of electromagnetic field of high-frequency capacitive discharge is similar to the character of electromagnetic field of high-frequency torch discharge except the region abutting directly on high-frequency electrode. Therefore it might be supposed that combustion of high-frequency capacitive discharge is realized due to dissipation of energy of «direct» and «reflected» cross-magnetic waves as in the case of high-frequency torch discharge. Electromagnetic field decay in discharge plasma and correspondingly, a part of energy consumed for maintenance of discharge combustion process is determined by the value of decay constant of electromagnetic wave. The decay constant in its turn may be determined from the expression for wave number. Wave number of cross-magnetic wave propagating along the channel of discharge [3] has the following form:

$$h^2 = (\alpha + j\beta)^2 \approx -\frac{2}{5a^2\varepsilon'},$$

where a is the radius of discharge channel; $\varepsilon' = \varepsilon/\varepsilon_0$ is the relative value of complex permittivity of discharge plasma; α is the decay constant; β is the phase coefficient.

Complex permittivity ε of discharge dusted plasma may be determined [4] by the formula of Lorentz-Lorentz:

$$\varepsilon = \varepsilon_2 \left[1 + \frac{v(\varepsilon_1 - \varepsilon_2)}{\varepsilon_2 + \frac{1-v}{3}(\varepsilon_1 - \varepsilon_2)} \right].$$

Here: ε_1, ε_2 are the complex permittivity of dusting material and plasma respectively; v is the ratio of dusting material to general volume of dusted plasma. The results of calculation of decay constant of electromagnetic wave propagating in plasma of high-frequency capacitive discharge with power of 1 kW depending on degree of its dustiness are given in Fig. 4.

As it is seen from Fig. 4 the change of decay constant of electromagnetic field of capacitive discharge is observed only at degrees of dustiness $v > 10^{-2}$. Similar degrees of dustiness can not be implemented in practice. Real degrees of discharge dustiness, in particular using pneumatic feeder amount to $v < 10^{-4}$.

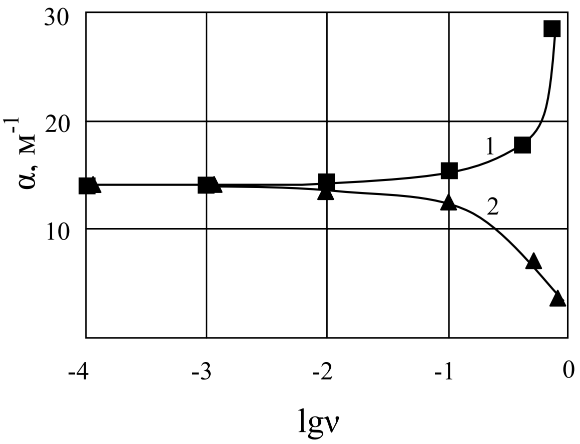

Fig. 4. *Dependence of decay constant of electromagnetic wave in discharge plasma on degree of its dustiness: 1) Al_2O_3 (dielectric); 2) Ni (metal)*

Thus, the results of calculations allow stating that combustion of high-frequency capacitive discharge is stable at its dustiness by dielectric and conducting materials at $v < 10^{-2}$ that is confirmed by the results of experimental measurements.

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