THE TIME DEPENDENCE OF THE NEGATIVE CORONA CURRENT IN AIR AND IN OXYGEN

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The time dependence of the negative corona current has been measured in air and in oxygen. The experiments were carried out at laboratory temperature and in the range of pressures of 60 to 100 kPa. The difference in the electron attachment processes in the outer zone of the negative corona in air and in oxygen could be used for an explanation of experimentally observed differences in the time dependences of the corona current.

ВРЕМЕННАЯ ЗАВИСИМОСТЬ ОТРИЦАТЕЛЬНОГО ТОКА КОРОННОГО РАЗРЯДА В ВОЗДУХЕ И КИСЛОРОДЕ

В работе приводятся результаты измерений временной зависимости отрицательного тока коронного разряда в воздухе и кислороде. Эксперименты выполнены при комнатной температуре в области давлений от 60 до 100 кПа. Различие в сводстве к электрону процессов, происходящих во внешней зоне отрицательного коронного разряда в воздухе и кислороде, можно использовать для объяснения экспериментально наблюдаемого расхождения во временной зависимости тока коронного разряда.

I. INTRODUCTION

The experimental results of measurements of the dependence of the negative corona current on the air temperature [1, 2] and its dependence on the velocity of the air stream in the low velocities ragde [3, 4] suggested the theoretical formulation of models of the outer zone of the negative corona discharge in electronegative gases [5, 6]. Qualitative explanations of the referred to experimental results have been given using the assumption that the product of ion-molecular reactions in the ionizing and in the outer zone of the discharge have an influence on the conductivity of the outer zone of the corona discharge. Measurements of the time dependence of the corona current in air and in oxygen allowed us to continue in our theoretical calculations.

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II. THEORETICAL ESTIMATIONS

The generation of ozone in the negative corona discharge in air, oxygen and their mixtures with other gases is a typical phenomenon. The other products (nitrogen oxides) have usually lower values of concentration in comparison with the ozone concentration. The role of the ozone action in the negative corona discharge has been estimated in our model of the outer zone of the negative corona [6]. As the probability of the electron attachment in the mixtures of ozone with molecular oxygen and nitrogen is higher for ozone than for oxygen [7], the decrease of the electron current can be explained as a result of the rise of the ozone concentration. This explanation can be used as long as the electron current is not negligible at the anode in comparison with ionic currents.

For the values of E/N below 15 Td the electron attachment is via the three-body process [8]

$$e + O_2 + O_2 \rightarrow O_2^- + O_2. \tag{1}$$

The second possible process is the direct monomolecular reaction

$$e + O_2 \rightarrow O_2^- + h\nu. \tag{2}$$

For higher values of E/N than 15 Td the dissociative attachment ossurs followed by ion-molecular reactions of the charge exchange

$$O_2 + O^- \rightarrow O_2^- + O \tag{3}$$

$$O^- + O_2 + O_2 \rightarrow O_3^- + O_2. \tag{4}$$

The dissociative attachment has a role in the ionizing zone, while reactions (1) and (2) are important in the outer zone of the discharge. More effective is reaction (1). It can be realized particularly in the ionizing zone of the corona discharge in oxygen. At atmospherical pressures the transition of the molecule O_2 from the $3\Sigma g$ state to the metastable $1\Sigma g^+$ state is probable. Electrons loosing their kinetic energy in these processes can be attached after collision via the three-body process. In air the probability of this process owing to the lower oxygen concentration is lower in comparison with the probability in oxygen. It could explain why the electron attachment cross section in oxygen is higher than in air [9]. We have calculated the rate of the electron currents by formula [10] for the coaxial cylindrical electrode

$$\frac{j}{j_0} = \exp\left[-[n_2] Q \sqrt{\frac{2\varepsilon}{m_e}} \frac{r}{v}\right], \tag{5}$$

j is the electron current density in the zone with the radius r, j_0 is the electron current density on the boundary of the ionizing zone (we have presupposed that all electrons are emitted from the ionizing zone as free electrons), $[n_2]$ is the concentration of the neutral molecular oxygen, Q is the total cross section for the electron attachment including all the possible processes of the electron attachment. ε is the mean energy of electrons with a mass m_e drifted from the ionizing zone to the outer electrode with a velocity v.

We have employed approximations of the dependences of the cross attachment sections [11] in Figs. 1 and 2. The values of the mean electron energy ε, the drift velocity v and E/N for our discharge tube have been estimated by the asumption that the space charge has no influence on the electric field in the discharge tube. The used values are drawn as a function of the radius r in Figs. 3 and 4.

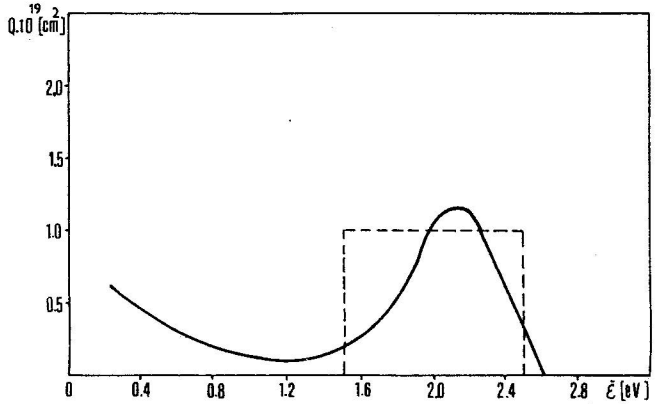

Fig. 1. Dependence of the electron attachment cross section on the electron mean energy for oxygen [11].

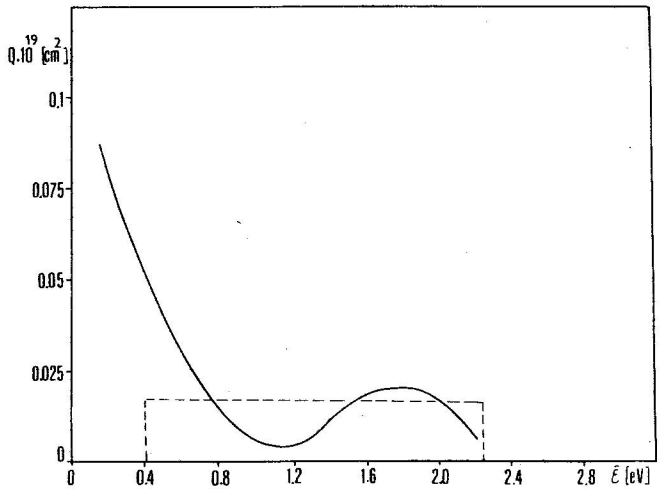

Fig. 2. Dependence of the electron attachment cross section on the electron mean energy for air [11].

For $r=0.3$ mm in oxygen there $j/j_0=e^{-30}$, while for air at $r=0.65$ mm there $j/j_0=0.5$. In spite of the fact that the used approximation is very rough, we can claim that the electron component of the total current is negligible in oxygen and has a role in air.

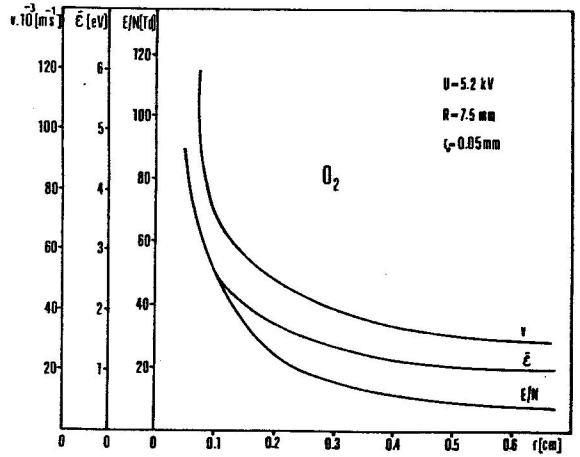

Fig. 3. Dependence of the electron drift velocity mean energy and E/N ratio on the radius for oxygen.

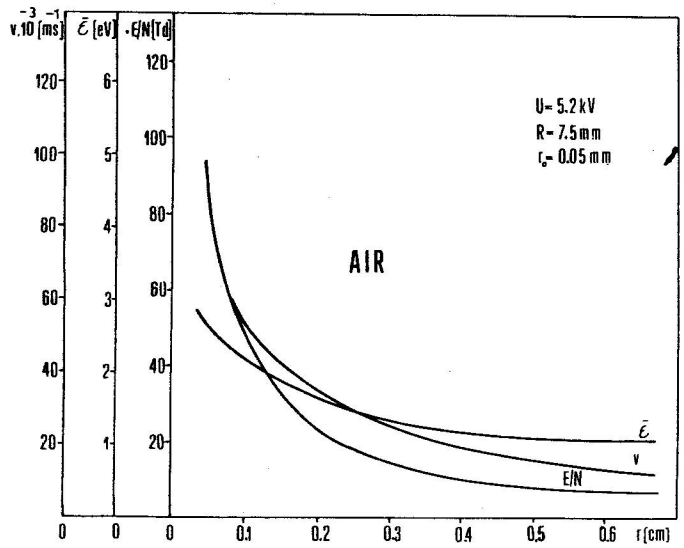

Fig. 4. Dependences of the drift velocity, mean energy and E/N ratio on the radius for air.

Owing to this fact we can assume in oxygen only two kinds of ions in the total discharge current O_2^- and O_3^-. For concentrations of ions n_2 and n_3 at the anode there is valid the formula

$$\frac{d}{dt}(n_2+n_3)=0, \tag{6}$$

or

$$n_2+n_3=n_{2_0}. \tag{7}$$

n_{2_0} is the concentration of O_2^- ions at the beginning of the discharge. The current density on 1 cm^2 of the outer electrode at the time t is

$$j(t)=Ee(\mu_2 n_2+\mu_2 n_3), \tag{8}$$

where μ_2, μ_3 are mobilities of O_2^- and O_3^- ions.

Using the formula (7) in (8) we can express the current density $j(t)$

$$j(t)=j_0+Een_3(\mu_3-\mu_2), \tag{9}$$

where $j_0=eE\mu_2 n_{2_0}$ is the initial current density at the moment $t=0$ sec. The concentration of neutral ozone molecules $[n_3]$ can be expressed by Eremin [12]

$$[n_3]=\frac{[n_2]_0 k_0}{k_0+k_1}\left\{1-\exp\left[-(k_0+k_1)\frac{P_0 t}{V}\right]\right\}, \tag{10}$$

where k_0 is the coefficient of the creation, k_1 the coefficient of the decomposition of ozone molecules, $[n_2]_0$ is the initial oxygen concentration, P_0 is the power of discharge, V is the volume of discharge, t is the duration of discharge. This formula (10) in connection with (9) allows to express the total current per 1 cm length of the outer electrode with a radius R in the form

$$J_t=J_0-2\pi REe\,\frac{n_3}{[n_3]}\,\frac{[n_2]_0 k_0}{k_0+k_1}\left\{1-\exp\left[-(k_0+k_1)\frac{Pt}{V}\right]\right\}(\mu_3-\mu_2). \tag{11}$$

Since $\mu_3>\mu_2$, the negative corona current will have to rise during the time of discharge to an equilibrium value.

III. EXPERIMENTAL APPARATUS

In the experiments coaxial cylindrical electrodes were used, the outer cylinder made of brass and nickel coated had a radius of 7.5 mm and the length of 50 mm. Both ends were rounded. The inner electrode was a molybdenum wire with a diameter of 0.1 mm. The electrode system was fixed on teflon holders and inserted into a glass vessel with the total volume of 4700 cm^3. The measurements of the time dependence of the current $I(t)$ at constant voltage between electrodes

V. CONCLUSIONS

The different mechanism of the electron attachment in oxygen and in air is the reason of a different character of the experimental current time dependences for the negative corona discharge. The role of the electron component of the total discharge current in oxygen is negligible in comparison with that in air.

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Received March 22nd, 1978