Physical mechanisms of negative corona complicated current pulsation

Chyhin Vasyl

Lviv Academy, Ukraine, Puluya str., 13/61, vchygin@gmail.com

The thesis presents the results of the experimental and theoretical investigations of the complicated current pulsation of the negative corona in electropositive gases of nitrogen and argon with electronegative admixture of oxygen at concentrations of trace values 10^{-3}% - 10^{-1}%. The physical mechanisms of these pulses are discussed. It is ascertained that such secondary structures of the corona current pulse as the precursor and the step at its front are determined by the displacement current. The different character of the main current pulses in N_2 and Ar are explained taking into the consideration the excited metastable molecules.

The thesis presents the results of the experimental and theoretical investigations of the complicated current pulsation of the negative corona in electropositive gases with electronegative admixtures. The pulsing negative corona is the low current gas discharge, that arises between the point with a negative potential and the plane anode at a direct high voltage.

The current pulses are characterized by a strong periodicity and a temporal constancy of parameters. However, the discharge processes in the pulsing corona have been studied insufficiently. The causes are too high concentration of used electronegative gases and the essential simplifications of previous modellings. Using the point radiuses of about ten microns and the oxygen concentration of trace values 10^{-3}% - 10^{-1}% allowed us to register the high-frequency pulsations of the current (HFCP) in nitrogen and argon for the first time. Sizes and shapes of the measured pulses in N_2+O_2 and Ar+O_2 mixtures differ significantly: in N_2+O_2 the current forms two-stages pulse, in Ar+O_2 the HFCP-averaged current decreases monotonically; the peak current increases significantly in N_2+O_2 and falls weakly in Ar+O_2 with an increase of the oxygen concentration (Fig.1).

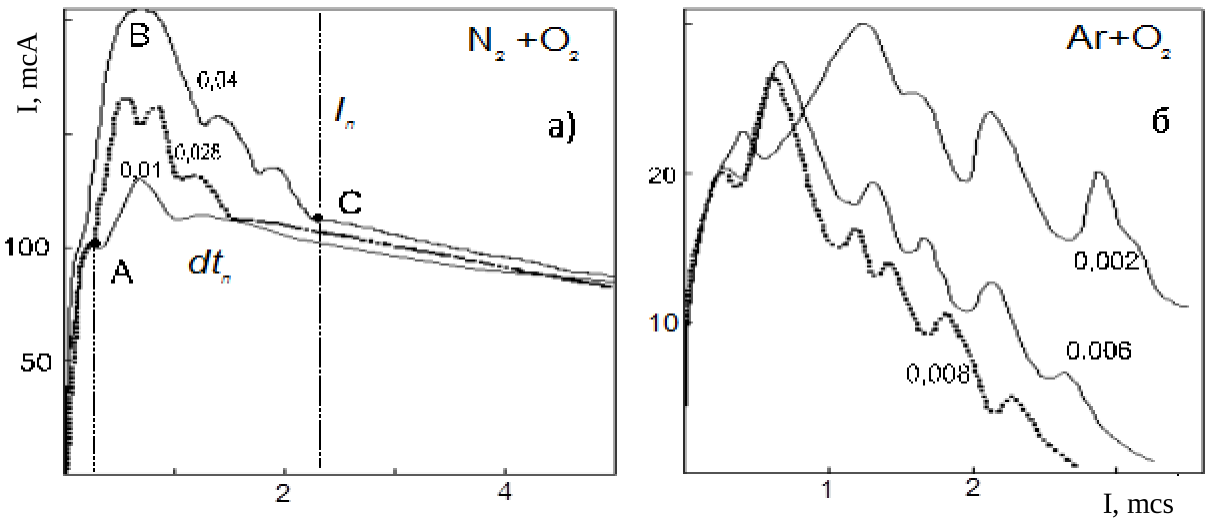

Fig.1. Typical forms of the measured corona current pulses: a) in nitrogen, б) in argon with the admixture of oxygen at concentrations %, marked by numbers

The up-to-date numerical modelling of the negative corona current has been realized, using continuity differential equations for charges fluxes, supplemented by the Poisson's equation for the electrical field in sharply inhomogeneous quasi-two-dimensional space. The used kinetic model includes the ionization and excitation of Ar atoms and N_2 molecules by electron collisions, the ionization by photons, the attachment of electrons to O_2, their detachment from O_2^- due to collisions with N_2 in the ground and excited states, the charge drift and the surface photo- and ion-electron emission. The photoprocesses coefficients have been determined, making use the data for the metastable $N_2(A3\Sigma u+)$, $N_2(B3\Pi g)$, $O_2(a1\Delta g)$ and for high level states. The corona current has been calculated as a sum of the positive charges flow and the displacement current at the cathode.

As a result of the investigations it was ascertained that such secondary structures of the corona current pulse, as the precursor and the step at its front, are determined by the displacement current during an approach of the ionization wave to the cathode. The pulse peak part is formed by the sum of the displacement and positive ions currents on a cathode. The high-frequency pulsations of current are determined by the variable stream of ions on the cathode in the self-screening conditions, at which the feedback between their concentration on the point and the field in tail part of the generation region exists.

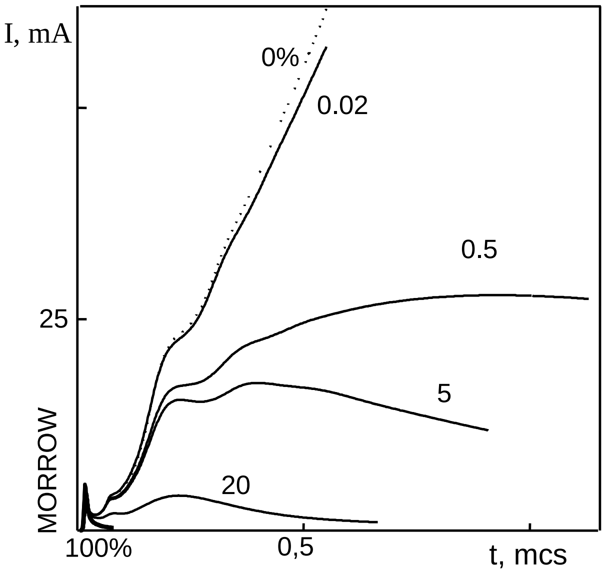

Fig.2. The results of our (0-100%) and Morrow's (100%) numerical modellings of the first corona current pulse

Extending the Morrow's numerical modelling [1] (Fig.2), the graphs reflected a gradual transition from the simple current pulse of the negative corona in 100% O_2 to more complicated pulses with the front steps and the HFCP pronounced at low oxygen concentrations were obtained. It is shown that the single current peak in the first case is in fact the pulse precursor resulted from the ionization processes in the cathode region under a strong influence of the photoelectron emission from the cathode, taken unrealistically large for the corona. But, if the cathode radius has a realistic small value the step duration is very short due to an extremely high speed of the ionization wave in the increasing surface electric field.

The different character of the current pulses in N_2 and Ar has been explained taking into the consideration the excited metastable molecules. It is shown that the peak part shape in N_2-O_2 mixture is formed by the ionization of accumulated oxygen molecules in the cathode region. An influence of the electron detachment from O_2^- by metastables on the current value and the pulse duration is distinctly different in the nitrogen and argon mixtures. In the last case this process is weakened due to the lowered electrons energy.

The knowledge of the negative corona pulsation characteristics in gas mixtures allowed us to develop and investigate the gas analyzer and the gas pressure sensors. Two next applied properties of the negative corona were investigated and tested in the production with a positive effect as well. A replacement of electronegative gas by electropositive one in the generation region results in the current increase in air. A flow of gases with different physical properties through this region leads to an increase of the degree of the spatial and temporal separation of gas and ion components. These effects can be used in the electrical precipitators, gas separators and mass-spectrometers.

References

[1] R. Morrow, *Phys. Rev.* Vol. A32 (1985) 1799 - 1809.