PHOTOEMISSIVE CHARGING OF MONODISPERSED AEROSOL PARTICLES UNDER ATMOSPHERIC PRESSURE

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The photoemissive charging of liquid aerosol particles that settle at atmospheric pressure has been studied theoretically and experimentally. Results have been compared, and satisfactory agreement has been achieved.

The determination of the magnitude and sign of the charge of an aerosol particle interacting with ultraviolet radiation is a timely problem because these parameters determine the course of important processes, such as the development of a thunderstorm in the atmosphere and the form of the trajectories of motion of charged particles in electromagnetic fields.

The present studies are devoted to theoretical and experimental consideration of processes of photoemissive charging of monodispersed aerosol particles.

We determine the applicability of a quasistationary approximation for the photoemissive charging of spherical particles that are settling under atmospheric pressure. In [1], it was shown that the charge carriers in the given situation are represented by free electrons and ions.

We estimate the relaxation time for the concentration field of the charge carriers around a particle.

The process of charging the particles in the presence of their own electrostatic field contains two components of charge transfer: diffusion and drift [2-5]; therefore, the maximum value of the relaxation time can be estimated as the sum of the relaxation time of the diffusion process and the drift time.

To determine these times, one should know the characteristic distance covered by the charge carriers. We define the characteristic distance as the thickness of a diffusion boundary layer, which for molecular diffusion near a spherical surface located in the flow is of the form [6]

\[ d = BrRe^{-\frac{1}{3}}. \]  

Here \( B = 0.3 \) is a coefficient, \( Re = 2\nu Gr/v \).

We estimate the relaxation time assuming that the charge is carried by \( O^- \) ions. The electron mobility is considerably higher; therefore, the electron relaxation time is less. We determine the diffusion relaxation time [7]:

\[ \tau_{\text{dif}} = \frac{d^2}{4D_0}, \]  

the value of \( D_0 \) is adopted from [8]:

\[ D_0 = \frac{u_0 kT}{e}, \]  

\( U_0 \) is defined in [8] as

\[ u_0 = 0.815 \frac{e I}{m_o v_0}. \]  

We define the second component of the relaxation time, the drift time of the \( O^- \) ions:

\[ \tau_{\text{dr}} = \frac{d}{v_{\text{dr}}}, \]  


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where \[8\]

\[v_{dr} = \nu_0 F_{sur} \]  

We determine the total relaxation time additively:

\[\tau = \tau_{\text{diff}} + \tau_{dr} \]  

The time during which a particle stays in the flare zone is equal to

\[t_f = \frac{L}{v_S} \]  

Numerical estimates according to Eqs. (2), (5), (7), and (8) show that for the characteristic parameters of the process \(\tau \sim 10^{-5}\) sec, \(t_f \sim 10^{-2}\) sec.

Therefore, the inequality \(t_f \gg \tau\) holds. This allows one to use a quasistationary approximation when solving the problem on photoelectronic charging of settling particles. Thus, for cases \(Q < 0\) and \(Q > 0\), in \([1]\) it has been obtained that

\[I = 4\pi R^2 E_{une} - 4\pi R^2 D_f (Re, Sc) \frac{dn}{dR} e, Q < 0; \]  

\[I = -4\pi R^2 E_{une} - 4\pi R^2 D_f (Re, Sc) \frac{dn}{dR} e, Q > 0. \]

Integration of Eqs. (9) and (10) with boundary conditions \(R \to \infty\) and \(n \to 0\) and with the binding condition of flows at the surface of the particle \(I = I_s - 4\pi^2 v_{ensur}\) gives an expression, for the photocurrent from the surface of spherical particles depending on the magnitude of their charges, which in the region of the negative and positive charges is of the form

\[I = \frac{Qul_s}{4\pi^2 e_0} \left(1 - \exp \frac{-Qu}{4\pi D_f (Re, Sc) e_0} \right) + Qu, \quad Q < 0; \]  

\[I = \frac{Qul_s}{4\pi^2 e_0} \left(\exp \frac{Qu}{4\pi D_f (Re, Sc) e_0} - 1 \right) + Qu, \quad Q > 0. \]

When studying photoionization processes in dispersed systems, it is important to know the explicit dependence of the particle charge on time. To do this, we represent the current intensity from the surface of a negatively charged particle as the rate of change of its charge \(I = -\frac{dQ}{dt}\). With regard to the accepted notation, Eq. (11) assumes the form

\[\frac{dQ}{dt} = -\frac{Qul_s}{4\pi^2 e_0} \left(1 - \exp \frac{-Qu}{4\pi D_f (Re, Sc) e_0} \right) + Qu. \]

The minus sign in Eq. (13) indicates that photoemission results in the loss of the negative charge by the particle.

A numerical estimation of values on the right-hand side of Eq. (13) shows that for the absolute values \(Q\) the exponent approaches rapidly zero and can be neglected. Integration of (13) with regard to this fact for the initial condition \(t = 0, Q = Q_{in}\) gives the result

\[\frac{4\pi^2 e_0}{ul_s} \ln \frac{Q_{in}}{Q} + \frac{Q_{in} - Q}{I_s} = t. \]

We can conclude from Eq. (14) that for the magnitudes of charges \(Q\) the kinetics of the process does not depend on diffusion, i.e., in this case the primary charge transfer from the surface of the particle is determined by the drift of electrons in the electrostatic field.

We consider the region of negative charges, the absolute value of which satisfies the inequality \(0 < Q < \frac{4\pi D_f (Re, Sc) e_0}{ul_s}. \)