C1-P-019702

CONICAL STRUCTURES ON THE SURFACE OF A LIQUID WITH SURFACE IONIC CONDUCTIVITY: THE SPACE CHARGE EFFECT*

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The free surface of liquids is unstable in a sufficiently strong external electric field. As a result, quasi-stationary conical structures (cone-shaped cusps) can be formed on the surface. Such structures are a source of charged particles (ions or drops), which determines the practical interest in their study. For the case of a perfectly conducting liquid, these structures were described in the classical work of Taylor [1]. It was established that the cone apex half-angle is equal to 49.3^0 and the electric field strength near the apex follows the scaling law $E \sim R^{-1/2}$, where R is the distance from the singular point. This result was generalized to the case of an ideal dielectric liquid in [2]. The influence of the space charge of the droplets emanating from the apex of the conducting liquid cone was considered in [3]. It is remarkable that the electric field in the spray region also obeys Taylor's $R^{-1/2}$ law. Recently, it was shown that this scaling also remains valid if the surface ion current is taken into account [4-6].

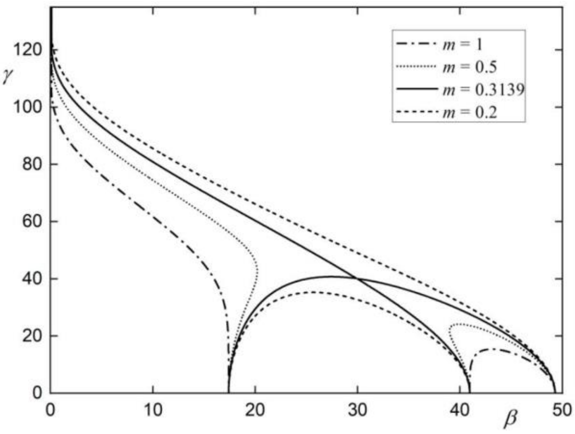

Fig.1. Relations between half-angles β and γ for $\varepsilon = 25$ and different $m = 0.2, 0.31, 0.5, 1.0$.

In the present work, combining approaches developed in [1-6], we consider the conical formation on the surface of a liquid with surface ionic conductivity in an external electric field. Ions move over the cone surface towards the apex, and charged droplets (or ions also) emanating from the cone apex drift through the surrounding gas medium. The exact solution for the electric field distribution near the cone apex is found taking into account the influence of both the space charge of droplets and the surface charge of ions. The obtained solution allows us to determine the relation between the cone and spray half-angles (β and γ) and such parameters as the dielectric constant of the liquid (ε) and the carrier mobility ratio (m). This relation turned out to be quite sophisticated; it contains many different branches: see examples in Fig. 1. Also, the current-angle dependencies for the system were found.

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* The work was supported in part the Russian Foundation for Basic Research under Project 20-08-00172.