Review
of the Ph. D. thesis of Vladimir Chirkov
entitled "Influence of Charge Formation Mechanism on the Structure of Electrohydrodynamic Flow in Highly Non-Uniform Electric Field"
submitted for the degree of Doctor of Philosophy in Physics
at the St. Petersburg State University

The beginning of the experimental and theoretical research of electrohydrodynamic (EHD) flows in liquid dielectrics dates back to the middle 1950th. To a large extent, the basic physics of EHD flows were originated in the research by G. A. Ostroumov who was a professor of Faculty of Physics of the Leningrad State University. As a matter of fact, he became the founder of the field of electrohydrodynamic phenomena that accompany the electric current passage processes through the low-conducting liquids.

A number of questions concerning electrohydrodynamics left without clear understanding up to nowadays. And one of the key issues is the one about prevailing mechanism of charge formation, which leads to the emergence of EHD flows. The question was left actually undiscussed up to the beginning of the research by Vladimir A. Chirkov. In the opinion of some researchers, the prevailing mechanism is the so-called injection, i.e., the space charge formation at the liquid–metal interface. At the same time, other researchers believe that it is the intensification of dissociation rate under the influence of temperature or the electric field strength (the Wien effect) that leads to the emergence of EHD flow. The issue was to be solved even if for improving the performance of EHD devices.

A number of papers published by Vladimir A. Chirkov and based on the both experimental investigation and computer simulation have answered to a large extent to existed questions even in spite of the unavailability of the analytical solution of the complete set of EHD equations.

The dissertation consists of introduction, main part, references, and included papers. The introduction, in particular, gives the review of previous and related studies, basing on which the author concluded that it was necessary to gain more insight into behaviour of EHD flows in different cases of charge formation. The main part consists of explaining the simulation and experimental techniques, the discussion of the results, and conclusions. The author describes the mathematical background, formulates the necessary requirements for computer model, and discusses the features of the experimental research. Unlike the models presented in the literature, the model developed by Vladimir A. Chirkov takes into account both the surface and the bulk space charge formation. Besides, the author simulates both the migration and convective mechanisms of charge transport. The latter one corresponds to the charge movement together with the liquid, i.e., due to EHD flow (or electroconvection). Both the Wien effect, i.e., the

enhancement of the dissociation rate under the effect of strong electric field, and the dependence of the injection intensity on the electric field strength are taken into consideration. The results of the computer simulation in highly non-uniform electric fields, the method for computing of unsteady integral current characteristics of a cell with low-conducting liquid, and the experimental data are presented in the sections 2.3–2.5 of the main part.

The author has revealed the cause of the contradictions in the literature about the prevailing mechanism of charge formation. Thus, it is the similarities between EHD flow structure in the cases of the Wien effect and the injection charge formation that lead to the ambiguity of the real cause of EHD flow emergence. Besides, the viscous friction is the major force in the central jet and it partially smoothes over the differences between the velocity distributions in the two cases.

Thus, the author managed to bring to a close the issue of the prevailing mechanism of charge formation owing to integrated approach based on the unity of the new computer simulation technique and the experimental study of EHD processes. I believe it is the main result of the research. Moreover, it will stimulate carrying out further investigations on the subject both in Russia and abroad.

During reviewing the Ph. D. thesis, I have raised a number of questions. Firstly, do the ion–molecular reactions matter to the electric current passage processes in liquid dielectrics, taking into account that the conductivity in the low-conducting liquids is provided by the molecular ions? Secondly, why the author supposes the prevalence of the injection current over the dissociation one with the increasing voltage? What can confirm the suggestion? Then, I did not clearly understand whether the author compared the results, obtained using different approximations of the voltage dependence of the relative increase in the dissociation rate on the local electric field strength? And at last, can the author compare current passage processes in a low-conducting liquid with the atmospheric pressure glow discharge?

The mentioned remarks and questions are first of all caused by the scientific interest to the research. The results were published in international journals with high impact factors, discussed on the leading international conferences on the subject, and is known both in Russia and abroad.

The dissertation of Vladimir A. Chirkov fully complies with the international standards for Ph. D. dissertation in Physics, and Vladimir A. Chirkov merits the awarding the Ph. D. degree.

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1st October, 2013