INTRODUCTION

The structure of the electrohydrodynamic (EHD) flows in highly nonuniform electric fields for electrodes of the type of a needle over a plane has been studied earlier [1–4] with the help of experimental research and numerical simulation, and the process of the EHD flow’s establishment has been investigated as well [5]. It is shown that the flows have a typical zone structure as described previously for the electrodes of the type of a wire over a plane. The flow force’s structure is determined by a thin jet of the charged liquid extending from the needle electrode to the plane one. The typical mechanisms of the charge formation in liquid dielectrics are described, in particular, in [6]. The injection from the needle electrode’s surface is the dominant way of the charge’s formation in the case of highly nonuniform electric fields. Immediately under the needle’s point, there forms a zone of some reduced pressure with the pressure decrease being rather considerable up to 0.1 atm with a voltage of 30 kV. The results of the investigation of EHD flows in a superstrong nonuniform electric field are presented in this work. The growth of the field’s nonuniformity degree is achieved due to the light needle electrode point radius of up to 3 μm.

The needle electrode outlines obtained according to the experimental photos taken with the help of an optical microscope with a digital video camera are depicted in Fig. 1. Needle no. 1 was used in the set of experiments described earlier in [3–5], while needle no. 2 was obtained through grinding and was used in the present work.

Some authors think that the usage of micropoints ensuring super high local electric fields should provide effective charge formation and effective EHD flows even at relatively low voltages. Thus, this work is dedicated to the investigation of the problem of charge formation stimulation in a liquid and the study of the corresponding structure of the EHD flows in superhigh electric fields. The novelty of this research consists in the decrease of the needle electrode’s point radius to a size of about several micrometers, as well as in the
combination of the usage of a micropoint electrode with the introduction into the stringently purified dielectric liquid of some electron-accepting additives.

The characteristic values of the local electric field strength in the majority of works (in particular, in [3–5]) is not more than $10^8$ V/m within the working range of voltages. In this work, we have been able to ensure local strengths of the electric field at least an order higher due to the small radius of the electrode. In order to estimate them, the electrostatic problem has been simulated without considering the spatial charge. The distributions of the electric field strength along the surface of the needle electrodes (from the needle’s point up to a distance of 1 mm) are presented in Fig. 2a (on a logarithmic scale along the axis of the ordinates). It is seen from the diagrams that, on the surface of needle no. 2, the electric field strength is about an order of magnitude higher than in the case of needle no. 1.

The axial diagrams of the electric field strength distributions are presented in Fig. 2b. It is seen from them that, within the close vicinity of the needle electrode with a characteristic dimension of 10 μm, the electric field strength in the system with a sharp needle is higher than in the system with a blunt needle. Within the main part of the interelectrode gap (IEG)—from 1 mm to 10 mm—the strengths of the electric field are close and the differences between them are not more than 10%.

With the interelectrode potential difference on the needle (no. 2) electrode point being 15 kV, the electric field strength attains values of about $10^9$ V/m corresponding to the level of the intraatomic field. One might expect that, in such superstrong electric fields, some new effects can appear. Firstly, the autoelectronic emission into the liquid with the following localization of electrons in so-called electron bubbles becomes possible. The respective effect has been previously studied in a number of works and used, in particular, to increase the spatial density of the charge in EHD atomizers [7]. Secondly, Wien’s effect should manifest itself in these strong fields, which, in turn, should change the structure of the EHD flows arising in the liquid. In addition, there is quite possible the beginning of cavitation under the needle electrode point in the region of reduced pressure.

**EHD FLOWS IN PURE VASELINE OIL**

Vaseline oil with low voltage conduction ($\sigma = (2.6 \pm 0.2) \times 10^{-14}$ Ohm$^{-1}$ m$^{-1}$) was used as a stringently purified dielectric. The corresponding time of the Maxwellian relaxation

$$\tau = \varepsilon \varepsilon_0 / \sigma$$

is about 700 s.

The experimental cell is a cylindrical vessel of some transparent plastic of diameter 6 cm and height 7 cm; the steel needle electrode is placed along the cell’s axis at a distance of 1 cm from the plane. Some high voltage is applied to the needle electrode.

The current-voltage characteristics (CVC) of the system under study have been obtained both under stationary and dynamic conditions (Fig. 3), i.e., with the voltage modulation by a saw-tooth signal at different rates of modulation. Owing to the automatic performance of the process of receiving and processing the CVC, the measurements have been carried out many times, thus permitting one to make sure of the precision of the corresponding results. The measured dynamic CVC have been compared with the CVC obtained in an ordinary way when the current values are measured at fixed voltages after all the transient phenomena have finished. The current is measured with the help of a Keithley 6485 picoammeter, which allows one to determine currents of a picoampere order beginning with voltages of some hundreds of volts.

The examination of the dynamic CVC shows that, under certain conditions, namely, when the voltage is