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Short Communication

Influence of Electroconvection on Nano- and on Microstructural Relief of the Electrodes Surface

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Experimental results on degradation of nano-structural plane electrode surface at electroconvection in working liquid ПМС-50 with iodine are presented. It is shown there are various surface iodine structure courses by electrochemical processes on electrode surface.

Keywords: Electric current, Electrode, Liquid, Electroconvection.

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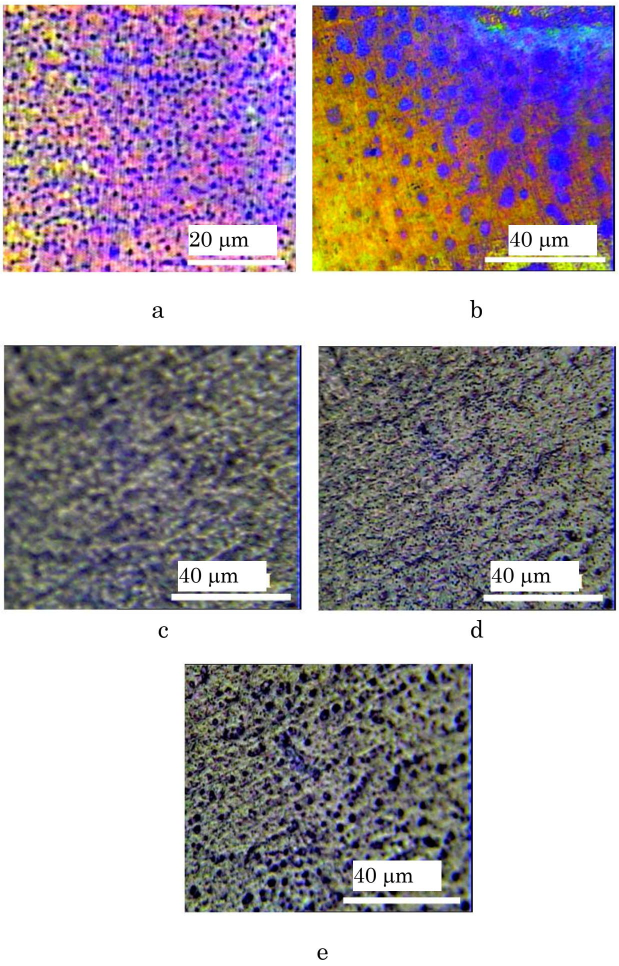
1. INTRODUCTION

Electrohydrodynamics as a science emerged in the 60s. It is relatively young. And the level of practical application of electrohydrodynamic flows in devices of heat and mass exchange is insufficient. It is explained by existence of rather large number of the interconnected unresolved scientific problems such as difficulties of the description of injection functions at the interface of liquid dielectric – a metal electrode, problems of removing of a parasitic charge from liquid and electrochemical pollution of working liquid and surface of electrodes, problems of research and describe the functions of the electric double layer in the dynamic mode and the complex formation descriptions, etc. Now possibility of successful overcoming of these problems arose with development and dense application of new methods of research (atomic force and electron microscopy, X-ray and Raman scattering methods of research, etc.). One task is to describe and manage charge formation at the interface of metal-dielectric liquid.

Its solution is connected with the creation on the electrodes surface of ordered arrays of micro-or nanostructures and a description of the charge injection from their tops depending on geometrical parameters of structures and their relative positioning.Works on autoelectronic issue from tops of carbon nanotubes in cold cathodes [1, 2] confirm it. Also researches of dimensional effects and dimensional properties of a electric double layer [3] are required concerning nanostructures at interface of metal-liquid dielectric

2. STRUCTURING AFTER ELECTROCONVECTION

Experience with previously cleared, dried-up and decontaminated dielectric liquids showed emergence after the developed electroconvection (EK) a set of types of the various self-organized structures which are forming on a surface of nanostructured electrodes both on the anode and on the cathode. The electrode surfaces were polished with the elements of acid etching by quality 20 nm. Images of microstructures of the anode are shown in Fig. 1, they are received at field intensity between plane-parallel copper electrodes of 20 kV/cm for pure polymethylsiloxane PMS-50 liquid. The total time of EC is 4 hours. The control of development of structures was exercised every 15 minutes. The Fig 1a is near edges of the anode. Structures about 200-300 nanometers in size are the centers of charge formation. The size of structures is increased at electrode edge (Fig. 1b) due to higher electric field.



a b

c d

e

Fig. 1 – The microstructures of the anode for PMS-50 at a voltage of 20 kV/sm (EC 4 hours)

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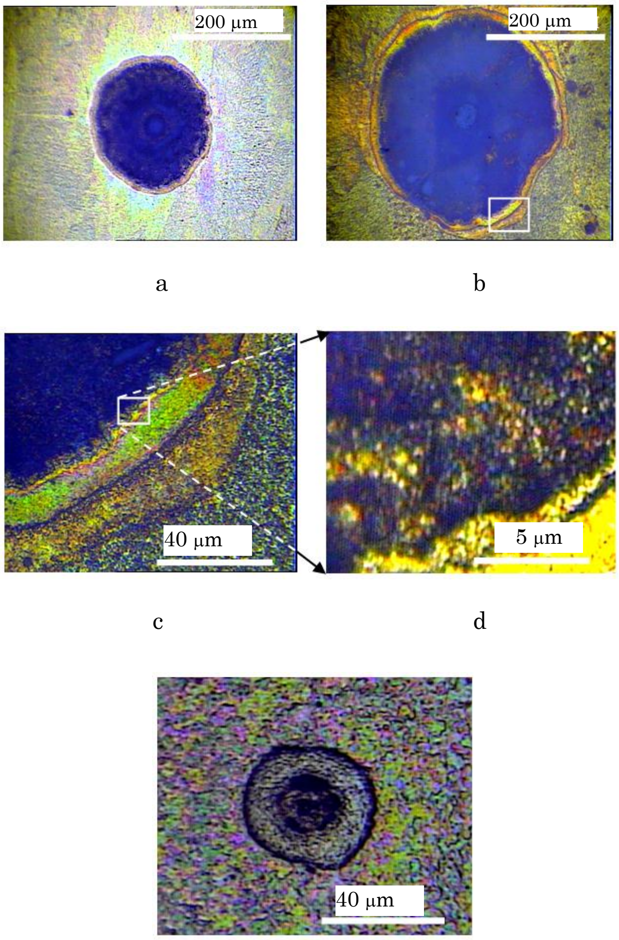
In the central region of electrodes PMS-50 liquid formed on an electrode surface a layer with the holes (pores), polymerized under the influence of local electric fields of structures. This phenomenon is similar to contamination. In Fig. 1c, d, e this is visible at consecutive focusing of the confocal camera on an electrode surface (c), the polymerized layer (d) and on its surface (e). The movement of charges takes place via holes in the surface layer of copper (this is light areas in fig. 1c and they are the centers of charges injection in liquid). Such polymerized layer can exfoliate at breakdown with formation of bubbles forming a sieve with a micro (or nano) pores. The characteristic structures of the cathode are shown in Fig. 2. Their forms are dark spots (a) and rings (d) which were formed at 5 kV/cm. Fig. 2a, b correspond to the same structure respectively after 15 and 45 minutes of EC. We see an increase on the area by 2.5 – 3 times and education on the periphery of the complex adsorption structures (Fig. 2b, c) is visible. Nanostructures in the form of copper crystallites (Fig. 2d) are observed on boundary of dark internal area (the adsorbed iodine).



a b

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Fig. 2 – Erosion in the form of a dark spot on the cathode ($E = 5$ kV/sm): after 15 minutes of electroconvection (a), after 45 minutes (b), the edge of structure (c) (cutting on (b)), an exposure of crystallite nanostructures of Cu (d) (cutting on (c)), a ring erosion (e)

3. EXPLANATION

Charge injection at EC starts from the top of the tallest structures in our case (polishing to 20 nanometers) it is nanostructures. A number of mechanisms [4] participates in charge formation during the electroconvection. Electrons injection from tops of structures is facilitated not only fall of a potential barrier by the high-voltage local electric field created by an external field [5] as on border vacuum metal, but also increased field molecules of the electric double layer (EDL) directly adjacent to structure top and as electron acceptor impurities.

Therefore the electron is taken at once molecules of liquid or impurity molecules, resulting ionic charges injection. On the other side of a molecule of liquid of EDL reduce a potential barrier of exit of ions of a crystal lattice of metal that leads to emergence of the erosive structures at the developed electroconvection and at a set of oxidation-reduction reactions. If the oxidic film isn't metallized at current breaking of structure the erosion of metal proceeds in space under an oxidic film of a metal surface. In Fig. 3 the sequence of destruction of peaks metal structures is presented. The electric double layer has the same nanoscale dimensions [3, 4] as discussed nanostructures. Even in case of exceeding of the sizes of structure over thickness of a diffusion layer the breakaway of a diffusion layer in the area of top of structure and nanostructures is the most probable which is accompanied resonant neutralization and ionization plus the output of the ion of the crystal lattice (erosion).

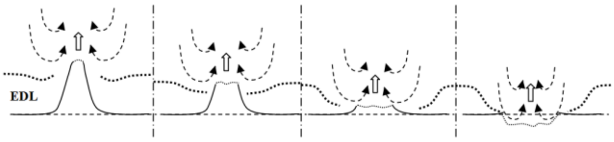

Fig. 3 – The destruction of structure of metal with formation of the area of an erosion

Thinning of the diffusion layer causes erosion continuation including below level of the surface of the metal (horizontal oxide film). Result of such charge formation is emergence of structures which is showed in Fig. 2a, b, there are formation on the periphery of the complex adsorption structure (Fig. 2c, d. Such structure on the periphery of the erosion indicates the complexity of the dissociation-recombination processes associated with presence of EDL.

The presence of two clearly defined boundaries, in our opinion can be explained by the presence of two types of ions injected into the structure, which are recharged in the amount of convection flow near the area of injection and are adsorbed in a thin diffusion layer at the boundary of erosion or by two-layer (of different molecules) structure of EDL. A slight difference in the graphs of the Raman scattering (RS) 3 and 4 (Fig. 4) in the area indicated by the arrow is shows this.

Graphs 3 and 4 show the presence of molecules of the PMS-50 (main peaks graph 2), and in the region of wave numbers from 1000 to 2800 cm^{-1} spectrum is oscillatory inherent metal. Let's notice such structure of DES arises over time as in Fig. 2a it isn't present. If the mechanical inclusions (even dielectric) are in liquid they are adsorbed on the electrode surface and the area of erosion represents a ring form. In this case breakaway of the diffusion layer occurs due to eddy currents occurring due to the surface conduction of structure (from the horizontal surface of metal to the apex of the structure (Fig. 5)). Raman spectra are shown in Fig. 6.

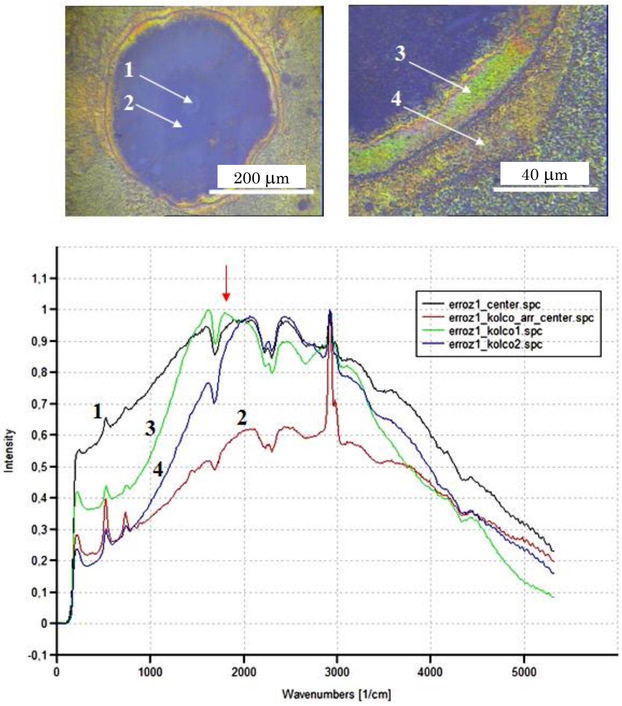

Fig. 4 – Erosion as a dark spot after 45 minutes of EC (PMS-50 with iodine) and Raman spectra in different areas (45 min, 5 kV)

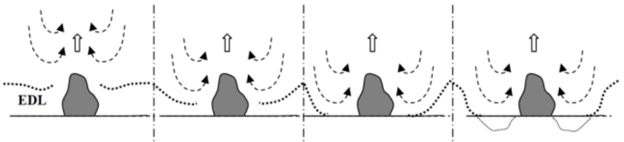

Fig. 5 – Formation of the erosion area in the form of a ring

According to the Raman spectra of the least amount of liquid molecules is in the the center of the structure where there are the adsorbed particles (arrow 1). Small liquid concentration is observed in area of breakaway of the diffusion layer 2 (graph 2) (the area is poorly wetted) unlike well wet area 3. It is noticed the Raman spectra of all the centers of erosive structures is showed the a small number of the working fluid that indicates the absence of wetting in these areas and the absence of a diffusion layer and its breakaway in areas of charge formation at a developed electroconvection (graphs 1 Fig. 4, 6).

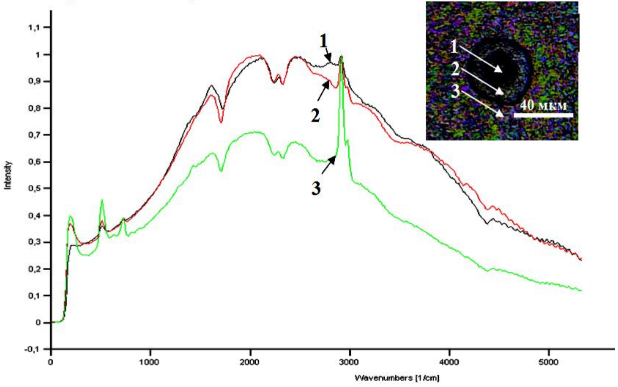

Fig. 6 – Erosive structure in the form of a ring on the cathode and Raman spectra in different areas (15 min, 5 kV)

A more detailed analysis showed that the strong local field, located on the tops of the highest surface nanostructures induce polymerization (Fig. 1) They are the centers of charge injection and areas of initial erosion of the metal. Molecules of liquid are ionized in these areas, radicals causing polymerization are formed. Thus, using of electroconvection it is possible to operate polymerization and to receive porous membranes. Types of structures are defined both the quality of the surface (adsorption centers, defects) and the characteristics of the liquid and its impurity additives, complex formation processes in liquid.

4. CONCLUSION

Experience with previously cleared, dried-up and decontaminated dielectric liquids showed emergence after the developed electroconvection (EK) a set of types of the various self-organized structures which are forming on a surface of nanostructured electrodes both on the anode and on the cathode. Nanostructures are the centers of charge injection and areas of initial erosion of the metal. Main types of structures are formed at the initial stage of electroconvection (till 15 min.). The formations are defined the quality of the surface (adsorption centers, defects) and the characteristics of the liquid and its impurity additives. Therefore for creation of managed electroconvection it is requires the search of redox systems [6] and dimensional effects of EDL and nanostructures of the electrodes surface [3] excluding degradation of nanostructures and providing high level of a charge formation.

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