THE EXPLOSIVE PROCESSES ON POTENTIAL ELECTRODE AT FORMATION OF NANO-SECOND IMPULSE DISCHARGE IN SOLID AIR

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The present paper is dedicated to investigations of cathode surface with different radius of curvature (r=1-8mm) at formation of impulse discharges of nano-second duration in solid air. The influence of field heterogeneity and air pressure in gas interval on micro-crater dimensions forming on electrode work surface after impulse action is shown. The most increase of dimensions of separate micro-crater on cathode surface with small radius of curvature.

The gas disruption at pressures from decades up to thousands torr under influence of high voltage of nano-second duration has been investigated long time [1,2].

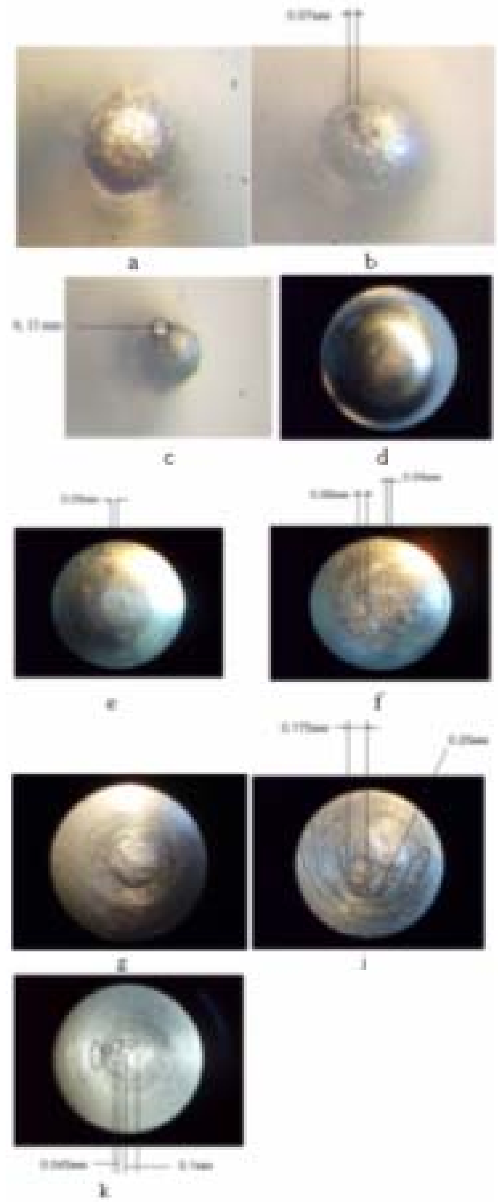

Fig.1. The photos of electrode surfaces with different radiuses of curvature before and after impulse discharges at air pressures: a) rod r=1mm, before discharge; b) rod r=1mm, p=1atm, after discharge;c) rod r=1mm, p=3atm, after discharge; d) rod r=4mm, before discharge; e) rod r=4mm, p=1atm, after discharge; f) rod r=4mm, p=3 atm, after discharge; g) ball r=8mm before discharge; i) ball r=8mm, p=1atm, after discharge; k) ball r=8mm, p=3atm after discharge.

The interest to nano-second discharges in gases has increased in the connection with successes of technique of high-voltage nano-second impulse. In spite of rapid growth of experimental investigation number [3,4] and technical applications [5,6] of nano-second gas discharges, the transition to new temporary scale doesn't lead the corresponding review of fundamental conditions of breakdown classic models developed for conditions close to static ones [7,8] though in work [3] the qualitative new traits of gas discharges in nano-second time range are defined.

The breakdown regularities of solid gases at enough big overstresses in the development of whole gas-discharge process differ from regularities discharge classic forms. The disagreement to general local models especially reveals at overstresses $\Delta \geq 1$. Indeed the discharge parameters strongly change with Δ increase and energy of directed electron motion is compared with total kinetic energy. This leads to the fact that "running electrons" can generate on streamer front at $E_o < E_{кр}$ where $E_{кр}$ is critical field strength providing the continuous electron acceleration beginning from heat energies $T_e \cong$ 1-10 eV [9]. The field displacement on streamer front in the result of its polarization is carried out during time order of "running electron" motion near front beginning from some big enough E_o. As a result the region synchronous motion of increasing boundary field and accelerating electrons [10,11] realizes. The photon output with Δ growth from avalanches strongly decreases [3]. Moreover, at $\Delta >> 1$ this isn't principal one i.e. "running electrons" provide the high speed of propagation of ionized region to anode and attendant roentgen radiation preionizating the gas and causing the photoeffect on cathode, provide the motion of cathode-directed ionization front. Finally the self-consistent field increase of positive volume charge and auto-electron emission [13] as at $\Delta >> 1$ the breakdown is initiated by auto-electron emission [3,4,12] and primary avalanche becomes critical one near initiation point ~ 100 mcm from cathode.

The present paper is dedicated to investigation of explosion processes on cathode at formation of nano-second of impulse discharge in air at different parameters of gas gap.

The impulse discharge of short duration is exited in air gap in strongly heterogeneous field at different air pressure p=1-3 atm. The steel rod with different radius of curvature r=1-4mm and aluminum ball by diameter 16mm is potential electrode. The copper plate is used in the capacity of anode. The nano-second impulse of high voltage of negative polarity with amplitude 80 kV and front duration 8ns are given to electrode of high voltage.

The electrodes are treated by electrochemical treatment. The two electrodes (graphite and tested) are put in solution of distillated water (80%) and $FeSO_4$ (20%). The treatment was longing during 20 minutes. After it the potential electrode is dried and treated by impulse influence of high voltage. The work surface of electrode is investigated in detail with the help of reflecting microscope МПСУ – 1 and is shooted by digital camera SAMSUNG S 500 Digimax 5.1x. The micro-photos of cathode work surface with different radius of curvature *r*=1-8mm are given on fig.1.

The micro-heterogeneities which are whiskers on the place of which the micro-craters by diameter 40-180km diameter form after explosion, take place before excitation of nano-second discharge on electrode surface. On some photos they are situated as groups but on some ones are situated separately and surrounded by melted surface. The erosion character depends on both thermodynamic characteristics of electrode material, its radius of curvature gas pressure in discharge gap. At lowered pressure the erosion is lower expressed. The dependence curves of micro-crater dimensions on parameters of gas gap are given on fig.2.

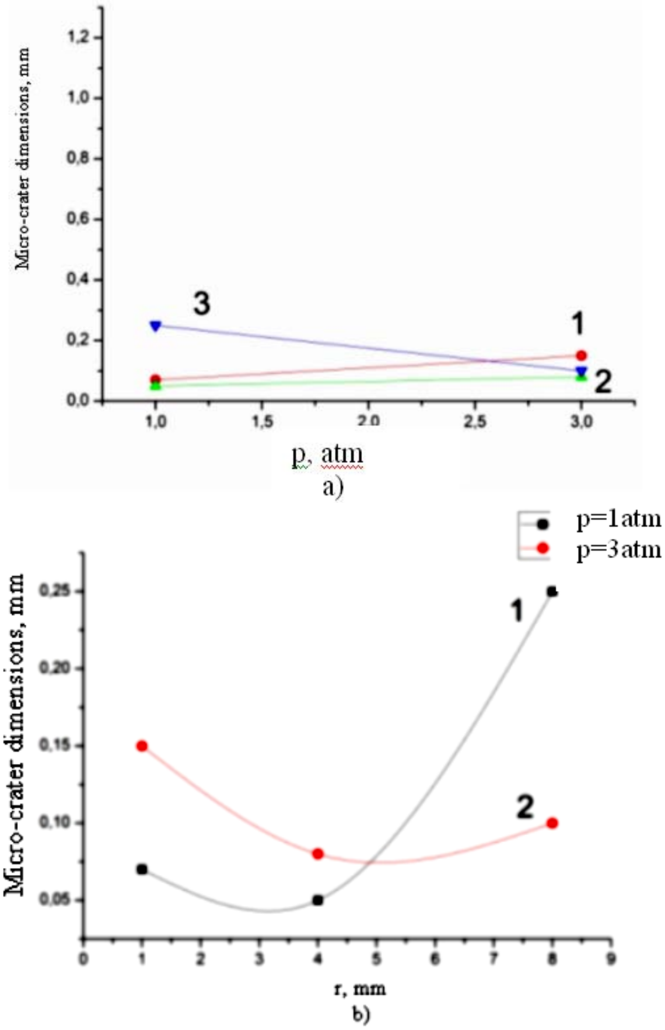

Fig.2. The dependences of micro-crater dimensions on electrodes (cathodes) on parameters of gas gap: a) on air pressure (curves 1-3); b) on electrode radius of curvature at different air pressures.

The micro-craters on rod surface (*r*=1mm) increase from 70 mcm at *p*=1atm up to 130 mcm at *p*=3atm. Note that at *p*=1atm the micro-craters are situated as groups and at *p*=3atm is observed the single micro-crater of bigger diameter. The dimensions of separate micro-craters are smaller in comparison with *r*=1mm with increase of radius of curvature of potential electrode *r*=4mm and at *p*=1atm and they are situated separately on electrode work surface. The dimensions of micro-cavities some increase with pressure increase up to *p*=3atm. As it is seen from fig.1 (e-k) surface of aluminum ball (*r*=8mm) is not ideal. The micro-cavities but on significantly big distances also form at *p*=1atm after application to electrode of high voltage on ball surface. Their dimensions some decrease with increase of air pressure *p*=3atm.

Note quantity of micro-heterogeneities on electrode work surfaces with small radius of curvature (*r*=1mm) is significantly smaller than on developed surfaces and that is why whole field strength concentrates on small quantity of whiskers. This leads to powerful explosive electron emission with each separately taken micro-needle and at pressures higher than atmospheric one leads to formation of big micro-craters on explosion place. The significant increase of micro-crater dimensions on rod surface (*r*=1mm) at *p*=3atm can be explained by field intension in micro-needle zone at strongly heterogeneous field and at high pressure.

The quantity of heterogeneities on work surface increases with increase of radius of curvature of potential electrode. As a result of this fact the weakening of field strength on separately taken heterogeneity that correspondingly leads to weakening of separately of explosion processes on separate whiskers, decrease micro-crater dimensions and increase of their common square.

The explosive change of micro-relief of cathode surface is mainly caused by impulse heating of micro-spikes by current of thermo-auto-electron emission of critic density [4,14,15]. Along with Joule heating of micro-emitter we should take into consideration the percussive heating by ions of gas-discharge plasma obtaining the significant energy in strengthened field near micro-spike focusing ions. This factor significantly simplifies the explosive electron emission in gas discharge. In [14,15,16] works the investigations of optic radiation of volume discharges in air at atmospheric pressure. The continuum with character maximum and also the bands of second positive system of N_2 molecule, NII line, HI line (626, 285nm) and lines of cathode material atoms. In the case of cathode from stainless steel the more than 100 lines of FeII and 17 lines of CrII are observed. The ion lines with more high degree of ionization aren't observed.

According to investigation results one can suppose the following process mechanism taking place at formation of nano-second impulse discharges at the upper air pressure. The local field intension on micro-heterogeneities of potential electrode takes place after application of high voltage to discharge impulse. The process of strong ionization near cathode leads to formation of avalanches on front of which the high-energy electrons concentrate. The positive volume charge forming as a result of this fact near cathode leads to strong field strength and to explosive processes with micro-needles. The "running" electrons forming in the result of such processes cause the roentgen radiation in near-cathode plasma and carry out the further rapid movement of avalanche to anode.

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SIXLIĞI YÜKSƏK OLAN ATMOSFER HAVASINDA NANOSANİYƏ İMPULS QAZBOŞALMASI ZAMANI POTENSİAL DAŞIYAN ELEKTRODDA PARTLAYIŞ PROSESLƏRİ

Məqalə yüksək sıxlıqlı atmosfer havasında nanosaniyə impuls qazboşalması zamanı müxtəlif əyrilik radiusuna malik katodun səthinin öyrənilməsinə həsr olunmuşdur. Elektrik sahəsinin qeyri bircinsliliyi və atmosfer havasının təzyiqinin impuls qazboşalmasının təsiri nəticəsində potensial elektrodun səthində əmələ gələn mikrokraterlərin ölçülərinə təsiri müəyyən edilmişdir. Əyrilik radiusu kiçik olan katodun səthində ayrı-ayrı mikrokraterlərin daha çox böyüməsi məlum olmuşdur.

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ВЗРЫВНЫЕ ПРОЦЕССЫ НА ПОТЕНЦИАЛЬНОМ ЭЛЕКТРОДЕ ПРИ ФОРМИРОВАНИИ НАНОСЕКУНДНОГО ИМПУЛЬСНОГО РАЗРЯДА В ПЛОТНОМ ВОЗДУХЕ

Настоящая статья посвящена исследованиям поверхности катода с различным радиусом кривизны (r=1-8мм) при формировании импульсных разрядов наносекундной длительности в плотном воздухе. Показано влияние степени неоднородности поля и давления воздуха в газовом промежутке на размеры микрократеров, образующихся на рабочей поверхности электрода после импульсного воздействия. Выявлено наибольшее увеличение размеров отдельных микрократеров на поверхности катода с малым радиусом кривизны.

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