on the jet and purely gasdynamic spontaneous twisting [5]. The importance of electromagnetic fields in the formation of the helical instability is confirmed by the fact that the cathode spots rotate in external magnetic fields [6] and by the decrease in the rotation frequency by the end of the pulse, which can be attributed to a decrease in the strength of the self-field.

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ELECTRICAL BREAKDOWN IN AMMONIUM PERCHLORATE

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The study of electrical breakdown of thermodynamically labile materials (that is, materials which decompose under external stimuli with an exothermal effect) is of great interest, since in such materials charge carriers may enter into a chemical reaction which leads to decomposition of the material, passing through a stage of conversion of electrical energy into heat [1, 2]. Nor can it be excluded that as a result of chemical conversions initiated by charge carriers additional electrons or holes will be formed, which support conductivity during the breakdown process or in prebreakdown stages. It was shown previously in studies of electrical initiation in heavy metal azides [3-6] that depending on the macroscopic parameters (density ρ interelectron distance L) three processes which differ in their electrophysical nature may exist: discharge between grains of polycrystalline material, microdischarges in pores, and indirect electrical breakdown with an exothermal decomposition reaction. Ammonium perchlorate (APC) is a well-known representative of the class of thermodynamically labile solids [7], which differs significantly from azides in the nature of its conductivity and decomposition reaction [8]. The goal of the present study is to study the phenomenology of electrical strength loss in single-crystals and polycrystalline pressed specimens of APC to the point of distinguishing macroscopic stages of the process.

1. Polycrystalline APC powder, chemically pure grade, with granulometric composition characterized by a maximum in the size distribution at 30 µm was used in the study. The polycrystalline specimens were prepared by pressing the powder on the polished surface of a quenched roller (ShKh-15 steel) into a polymethyl methacrylate shell. A 1/4-sphere electrode of the same material was pressed to the free surface of the tablet at constant pressure, with no deformation of the specimen. Preliminary experiments showed that introduction of a protective medium between the tablet surface and the 1/4-sphere electrode had no effect on the value of the breakdown voltage or its dependence on interelectrode dis-

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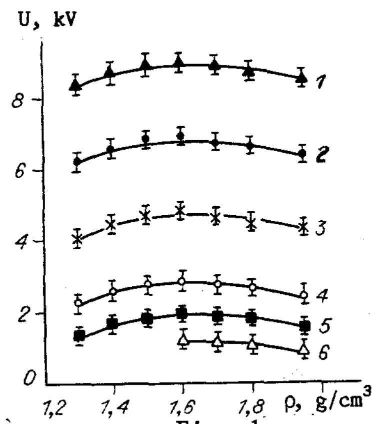

Fig. 1

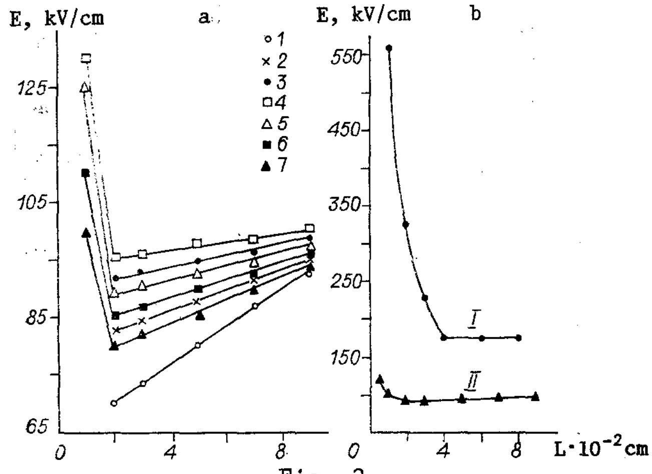

Fig. 2

tance, which indicates the absence of glancing discharges, so that the shield medium was not used thereafter. In developing the experimental technique it was established, first, that specimen pressing was accompanied by intense electrostatic charging and, second, that pressing led to corrosion of the electrode material. The time required for discharge of the specimens while not producing corrosion comprised 3-5 h at which point the electrical strength determinations were carried out.

The single-crystals were placed under a microscope in a jig of the type described in [9]. Holes 0.7 mm in diameter were then drilled in them to the required interelectrode distance. A saturated APC solution in the holes served as the electrode. A polarization microscope revealed that residual mechanical stresses were absent from the single-crystal specimen interelectrode gap. The breakdown voltage was determined along the leading edge of a 10 kV pulse with risetime of 1.5 μsec.

2. The dependence of breakdown voltage of single-crystal and polycrystalline APC specimens on interelectrode distance was studied over the range 100-900 μm, with pressed specimens of different densities being used — from close to single-crystal density (1.95 g/cm^3) to practically loose-poured density (1.3 g/cm^3). The basic experimental data are shown in Fig. 1 in the form of the dependence of breakdown voltage upon specimen density for various interelectrode distances (1-6, L = 0.09, 0.07, 0.05, 0.03, 0.02, 0.01 cm). Figure 2 shows the dependence of electrical strength on the size of the interelectrode distance: a) for various polycrystalline specimen densities (1-7, ρ = 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.95 g/cm^3) and b) for a density of 1.95 g/cm^3 in the polycrystalline specimen (I) and for a single-crystal (II). It can be seen that for the test single-crystal an electrical strength pattern typical of a test dielectric exists — an increase in electrical strength with decrease in interelectrode distance in the range of thicknesses less than 400 μm. For breakdown of the polycrystalline specimens together with strengthening there is an increase in electrical strength with increase in interelectrode distance, an effect opposite to strengthening. We will also note that in breakdown of APC the principle so well expressed in heavy metal azides which is an analog of Paschen's law in a solid [2], i.e., an unambiguous relationship between the breakdown voltage and the product of the density times the interelectron distance, is absent. We will describe the results obtained from a qualitative viewpoint.

The electrical strengthening effect is widely known in the physics of solid dielectric breakdown and its soundest explanation is spatial limitation of the avalanches of charge carriers which produce the electrical breakdown [9, 10]. We do not feel that other explanations, related to consideration of the increase in macroscopic defects with increase in thickness need be considered, since the macroscopic defect rate in the present study was varied over wide limits by change in specimen density. The possibility of charge carrier avalanche development in porous systems has apparently not been considered previously, although we see no limitations in principle upon such a process, since charge carriers which acquire excess energy upon motion within a crystal should retain that energy upon passage through a pore, since the efficiency of electron scattering in gases is less than in solids, if we do not consider scattering on defect surfaces, which depends on the value of surface zone inflection and its sign. In the latter case we have sequential passage of the electron through two barriers related to the contacting crystals, in one of which the surface zone inflection field is directed parallel to the external field, while in the other it is antiparallel. Therefore, in a first approximation we may consider their effects to be compensating. Thus, the experimental data obtained on electrical strengthening of APC do not contradict the hypothesis of avalanche multiplication as the process responsible for electrical breakdown in the material.

The "inverse strengthening" effect is known in breakdown of thin layers [11]. In our case the nature of this space charge is apparently related to interphase boundaries, since it increases with increase in specimen porosity (decrease in density). In localization of charges on interphase boundaries we deal with localization of space charge.

As for the effect of density on breakdown of polycrystalline pressed APC specimens, the character of that dependence contradicts that known in other thermodynamically labile systems [2, 5, 6]. However, in an earlier study of the effect of density on electrical strength of polycrystalline pressed lead azide specimens, the case of breakdown of a low strength solid phase leading to initiation of the entire specimen was analyzed [2]:

$$E_{\mathrm{br}} = E_1[(1/f - 1)p + 1]e^{-\alpha L},$$

where E_1 is the electrical strength of the reactive phase, p is the porosity, f is the ratio of pore surface to crystal surface, α is the shock ionization coefficient, L is the interelectrode distance. In this case, with increase in porosity the electrical strength increases due to additional voltage drop across pores. In specimens with a density less than 1.6 g/cm^3 breakdown occurs due to microdischarges in pores, i.e., the electrical strength decreases with decrease in specimen density. Considering both processes, the extremal character of the breakdown voltage vs. density dependence can be explained.

Thus, electrical pulse breakdown of APC is a process related to development of avalanches of nonequilibrium carriers, limited by the space charge field.

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