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OPPOSING FERROELECTRIC DOMAINS IN SbSI SINGLE CRYSTALS

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It was predicted in [1] that opposing ferroelectric domains can be produced in semiconducting ferroelectrics by an injecting contact field. The formation of these domains should lead to a number of singularities in the electric characteristics of the ferroelectric, such as nonmonotonic distribution of the potential, jumps of the electric conductivity, etc. According to [2], analogous phenomena can appear also in a ferroelectric under the field effect. Obviously, these phenomena are particularly easy to observe in the presence of barrier contacts (e.g., Schottky contacts [3]), which ensure, under definite conditions, both carrier injections (Schottky emission) and the field effect (the depleted layer can be regarded as a "dielectric" insulating the metallic contact - "field electrode").

One of the main consequences of the existence of opposing domains is the nonmonotonic distribution of the potential along the ferroelectric axis of the crystals [1]. It can be observed in principle by a probe method, but such measurements, performed on SbSI [3, 4] and $BaTiO_3$ [5], revealed no singularities of this type. We investigated qualitatively the distribution of the potential in SbSI single crystals by methods of raster electron microscopy [6]. We used the ISM-U3 raster electron microscope operating in the secondary electron emission regime. The investigations were carried out in the ferroelectric and in the para-phases at different voltages on the samples, on which Sb contacts were sputtered on the {110} face; the direction of the external field coincided with the direction of the C axis.

The measurements performed in the para-phase have shown that the external voltages concentrated mainly at the anode (Fig. 1a). This can be readily understood by recognizing that the electric conductivity of SbSI is of the p-type [3, 8, 9]. For the ferroelectric phase there appear in the potential distribution a number of singularities connected with the occurrence of spontaneous polarization and with the existence of a preferred direction, the presence of which causes, in the absence of an external field, the spontaneous polarization to have a definite direction (this polarization can be readily revealed by the pyroelectric current). In the absence of voltage, in the ferroelectric phase, as well as in the para-phase, one can see jumps of the contact potential near the electrodes (Figs. 1a and b; U = 0). When an external field opposing the spontaneous polarization is turned on, at relatively low voltages ($U \leq 20$ V), the entire applied field is concentrated at the anode (Fig. 1b). With increasing voltage, the external field begins to penetrate into the interior of the

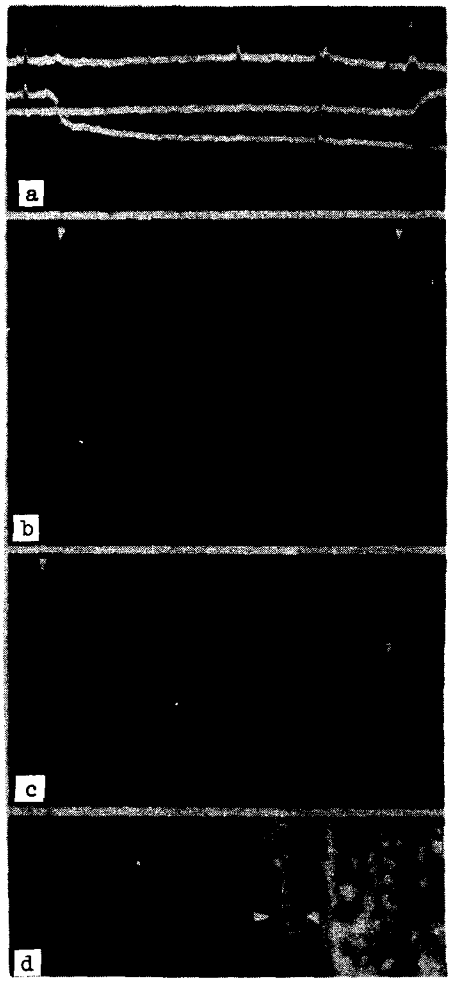

Fig. 1. Distribution of the current density of secondary electrons over the surface of an SbSI crystal (Curie temperature +21.5°C) at different values of the applied voltage (U). Width of contact gap - 1 mm. The vertical arrows denote the boundaries of the contact: a - paraphase; T = 60°C. Upper curve U = 0; lower curves U = ±100 V (the main voltage drop is concentrated at the anode); b - ferroelectric phase; T = 18°C, the external field is connected opposite to the spontaneous polarization, U = 0, 10, 20, 40, 60, 100 V (reading downward, respectively); c - T = 18°C, U = ±40 V (at U = +40 V the external field is connected opposite to the spontaneous polarization); d - electron microphotograph of the boundary of the opposing domains (the boundary is indicated by the horizontal arrows).

sample, and at a certain value of the voltage a negatively charged region is produced in the crystal (Fig. 1d), thus evidencing a nonmonotonic distribution of the potential in the contact gap. This is illustrated (Fig. 1b, U = 40 and 60 V) by the inhomogeneous secondary-electron current-density distribution, which is directly connected with the distribution of the potential in the sample [7]. According to the concepts of [1], this is due to reversal of the polarization of the near-anode region of the ferroelectric and to the occurrence of opposing domains. It is interesting that the near-anode barrier layer disappears following a change of direction of polarization in the near-anode region, and the applied voltage becomes entirely distributed in the volume of the SbSI. The influence of the polarization on the height of the contact barrier is evidenced by the rectification of the current in a polarized sample with symmetrical contacts; in fields weaker than coercive, the current through the crystal is maximal if the field is opposite to the polarizing field. The maximum rectification coefficient reaches 100. At large voltages (U > 60 V), the nonmonotonicity in the potential disappears, meaning vanishing of the opposing domains, and the entire applied voltage is concentrated at the cathode, apparently in the Sb-SbSI contact gap.

When the external field is turned on in the direction of the spontaneous polarization, there is naturally no nonmonotonicity in the potential, and consequently no opposing domains are produced (Fig. 1c). Just as in the preceding case, however, there is the characteristic redistribution of the potential from the anode towards the cathode.

The observed singularities of the distribution of the potential are reflected in the current-voltage characteristics (CVC) (Fig. 2): in the initial sections of the CVC there is observed the current saturation characteristic of the barrier contact [3]; the vanishing of the depleted layer at large voltages is accompanied by a transition to a quadratic CVC, and when the field is concentrated on the cathode the CVC becomes more gently sloping.

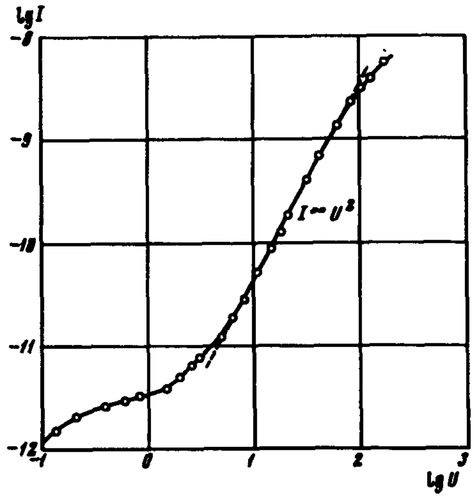

Fig. 2. Current-voltage characteristic of single-crystal SbSI: I - amperes, U - volts. The measurement conditions correspond to Fig. 1b.

We note in conclusion that all the potential distributions observed previously in SbSI by the probe method [3, 4] are contained, as particular cases, among the curves given above.

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CURRENT INSTABILITY AND MICROWAVE RADIATION OF n-CdHgTe

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Although the results of investigations of coherent microwave radiation in InSb [1, 2] have not yet made it possible to establish the concrete mechanism whereby this radiation is excited, they do show that this mechanism is based apparently on an electron-hole plasma instability that is not connected directly with the singularities of the energy spectrum of the carriers and their interaction with the crystal-lattice vibrations. It was therefore natural to assume that analogous phenomena can be observed also in other semiconducting materials, in which moderate electric fields can produce a non-equilibrium plasma with high mobility and not too high a carrier density. Such materials include, in particular, the solid solution $Cd_xHg_{1-x}Te$, which at $x \leq 0.15$ is a semimetal, and at $x > 0.15$ is a semiconductor whose band structure is similar to the band structure of InSb, and the mobility of the electrons at T = 77°K reaches 10^4 - 5×10^5 cm²/sec.