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THE RELATION BETWEEN PHOTON EMISSION AND DOMAIN-DEFECT INTERACTIONS

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The purpose of this investigation was to provide new information on the properties of materials. One of the sources of information on the properties of solids is provided by photon emission as caused by mechanical stresses or electric fields, which can alter the structure of the solid. Here some energy relationships are altered. The process is accompanied by energy release, including as electromagnetic oscillations in the optical range. External and internal factors can influence the energy relationships in a solid, which may substantially affect the mechanical and electrical characteristics.

One such factor is the defectiveness. It is not a simple matter to determine a defect concentration or to produce a given concentration in a material. Experiments have been performed with a ferroelectric: a triglycine sulfate crystal TGS. This was chosen because of the intensity of the photon emission during polarization reversal, which is accessible to experiment. That factor is important at the present stage, as it enables one to use sensitive photometric equipment.

The photon emission from TGS is very sensitive to x-ray irradiation. TGS emits light on polarization reversal not at once but when the field strength attains a certain value. The threshold is about 5 kV/m for an unirradiated crystal, and it increases substantially on irradiation.

TGS specimens were irradiated with a DRS-2M x-ray equipment at room temperature. The BKhV-7 tube with gold anode was used at 30 kV and 40 mA. The specimens were prepared by a standard method [1].

The threshold rise (Fig. 1) is related to the defect concentration. There is an analogy with the threshold for Barkhausen steps as a function of ionizing-radiation dose [2]. The rise in photon-emission threshold is related to the accumulation of additional defects produced by the radiation, which hinder domain boundary displacement on polarization reversal.

The defect accumulation is due to the repeated ionization. Positions containing doubly or trebly ionized particles at the lattice nodes are unstable. Electrostatic forces displace them from the nodes, and consequently defects arise. Such ions arise from repeat ionization such as Auger transitions in singly ionized atoms. Radiation produces radicals of NH_3COO type in glycines [3].

The photon emission threshold is related to the field strength at which domains are detached from boundaries bearing defects. The relation between the threshold field E for domain detachment and the mean distance d between defects holding the boundaries is [4]

$$E = (\pi\gamma W)^{1/2} (\ln d/\delta)^{-1/2} \cdot p^{-1} \cdot d^{-2},$$

in which p is the spontaneous polarization, γ surface tension at the boundary, W the interaction energy for the boundary with defects, δ domain boundary width, and $d = N^{-1/3}$ (N is defect concentration). The orders of p, γ, W, and δ are

$$p = 3\cdot 10^{-2}\ \mathrm{Cu}\cdot\mathrm{M}^2\,[5];\quad \gamma = 10^{-11}\ \mathrm{J}/\mathrm{M}^2\,[6];\quad W = 1{,}6\cdot 10^{-19}\ \mathrm{J}\,[4];$$

$$\delta = 10^{-9}\ \mathrm{M}\,[6].$$

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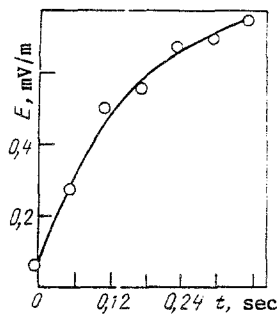

Fig. 1. Threshold electric field strength as a function of x-irradiation time.

Figure 1 shows the behavior of E. For unirradiated crystals, $N \approx 10^{22}$ m^{-3}, while in specimens irradiated for an hour, $N \approx 10^{25}$ m^{-3}.

There is thus a substantial change in defect concentration, namely by three orders of magnitude, as is indicated by the photon emission. That emission does not display all the major changes that arise from irradiation in the crystals. Some details of the processes after irradiation can be derived from the luminescence, whose intensity falls hyperbolically, which indicates that it is of recombination type and related to bimolecular interactions.

SUMMARY

It is shown to be possible to determine defect concentrations in crystals from the photon emission intensity arising by mechanical loading or from electrical fields. Experiments have been performed with a ferroelectric: triglycine sulfate crystals. Controlled defect concentrations have been provided by x-irradiation. An indicator for the defect concentration is provided by the electric field at which photon emission begins.

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