The influence of magnetic field on the phase boundary in $BaTiO_3$ crystals

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It was observed experimentally that under the influence of a constant magnetic field the front of a ferroelectric phase transition in $BaTiO_3$ crystals is oriented along the lines of force and moves perpendicularly to the direction of the magnetic field. The temperature at which the phase boundary begins to move increases by 0.6–1.1 °C in different samples.

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The experiments were performed using laminar, 0.2-mm to 0.4-mm thick, a-c domain, $BaTiO_3$ crystals grown from a solution in a KF melt and "OSCh"-extreme purity brand reagents. The electrical conductivity, which was measured along the [100] direction in the phase-transition region, was equal to 10^{-5}–10^{-6} $\Omega^{-1} \cdot cm^{-1}$. The crystals, which were held in a special crystal holder equipped with a heater and a thermostat, were placed on a polarizing-microscope table situated between the poles of an electromagnet that was connected to a stabilized power supply. The limiting

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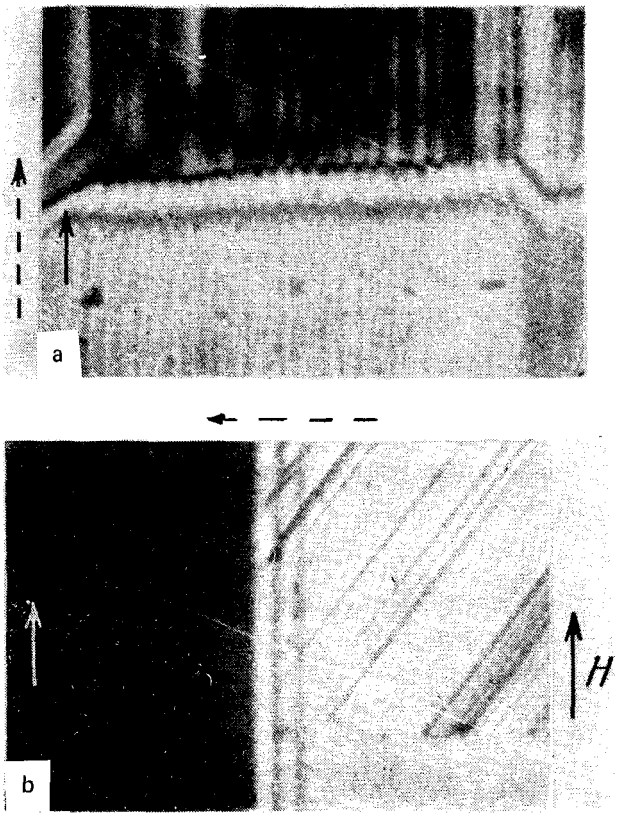

FIG. 1. A change in the direction of motion of the front of a phase transition from a cubic phase to a tetragonal phase of $BaTiO_3$ in the magnetic field. (a) A cooled crystal without a magnetic field (the phase boundary can be seen at the center of the frame) and (b) the same crystal cooled in a 23-kOe magnetic field (the phase boundary is oriented along the lines of force of the magnetic field). The dashed arrow indicates the direction of motion of the phase boundary and the solid arrow indicates the direction of the magnetic field. The magnification is 60.

intensity of the magnetic field was 25 kOe. The thermostat allowed heating and cooling of the crystal in the region of the ferroelectric phase transition (120 ° C) at the rate of about 1 degree per minute. The negligible temperature gradients in the crystal holder did not vary as a result of application of the magnetic field. The motion picture and photographic recording of the domain structure were accomplished in the (001) plane of the crystal in the transmitted light with crossed polaroids. The orientation of the magnetic field was changed in the observation plane by rotating the crystal around the [001] direction.

Frequently repeated experiments established that as a result of cooling a $BaTiO_3$ crystal the phase boundary between the cubic and the tetragonal phases (this first-order transition occurs in a sufficiently narrow temperature region) begins to move in the presence of a magnetic field at a temperature that is 0.6-1.1 ° C higher than without a magnetic field. In this case it is oriented along the lines of force of the magnetic field and moves perpendicularly to their direction. The photomicrographs of

the domain structure in Fig. 1 illustrate the changes in orientation, in the shape and in direction of motion of the phase boundary in a magnetic field. It should be noted that a prolonged after-effect occurs after the crystal is cooled via the phase transition in a magnetic field. The crystal slowly relaxes, sometimes in a day (24 hours) to the initial state. The tapered domains, which occur in the ferroelectric phase (Fig. 1b) due to a change in the direction of motion of the phase-transition front, indicate that there is an additional mechanical stress in the crystal.

It was unambiguously determined that only the moving boundary interacts with the magnetic field. If the temperature is stabilized at the moment the phase boundary is located at the center of the crystal, then the magnetic field will have almost no effect on such fixed phase boundary. The observed effect cannot be considered in this case in the context of the theories which take into account the influence of magnetic field on the phase transition, for example, the vibron theory,[1,2] nor can it be compared with the results obtained by using a narrow-gap, A_4B_6-type, ferroelectric material.[3,4]

It cannot be ruled out that the recorded peculiarities in the behavior of the phase boundary are attributable to a change in shielding of spontaneous polarization in the magnetic field[5] if we assume that the motion of the phase boundary is a nonequilibrium process that is accompanied by a shielding. It is possible, on the other hand, that the phase boundary ionizes the defects as a result of its motion. Among these defects there can even be paramagnetic centers whose ionization is associated with the interaction of the phase boundary with the magnetic field, as is the case in inorganic solids.[6]

Further research is necessary to determine the mechanism for interaction of a moving phase boundary with the magnetic field.

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[1] P. Konsin and N. Kristofel', Izv. Akad. Nauk Estonian SSR, Physical and Mathematical Series, 20, 37 (1971).
[2] I. B. Bersuker and B. G. Vekhter, Ferroelectrics 19, 137 (1978).
[3] K. Murase, S. Sugai, S. Takaoka, and S. Katayama, Phys. Semicond. Proc. 13 Int. Conf., p. 305, Roma, 1976.
[4] V. I. Litvinov, V. L. Volkov, and V. K. Dugaev, Fiz. Tverd. Tela 21, 1921 (1979) [Sov. Phys. Solid State 21, 1105 (1979)].
[5] S. A.. Flerova, S. A. Popov, and V. S. Shchetinkin, Proc. IX All-Union Conf. on Ferroelectricity, Part II, p. 257, Rostov-on-Don, 1979.
[6] I. A. Sokolik and E. L. Frankevich, Usp. Fiz. Nauk 111, 261 (1973) [Sov. Phys. Uspekhi 16, 687 (1973)].

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