MAGNETOELECTRIC EFFECT IN $BaCoF_4$

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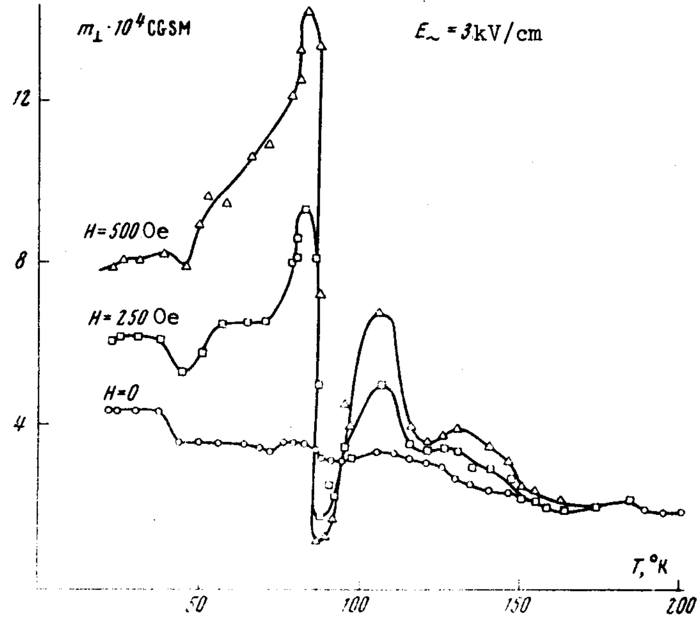
A phenomenological description of magnetoelectric interactions in substances possessing the symmetry group C_{2V} was proposed earlier with nickel-iodide boracite as an example. It was deemed of interest to investigate the magnetoelectric effect in substances having the same symmetry group.

We investigated single-crystal $BaCoF_4$, which has, according to x-ray data [2], a symmetry group C_{2V}^{12} or C_{2V}^{16} and is simultaneously piezoelectric. This makes it possible to assume immediately that magnetoelectric interactions should exist in it in the magnetically-ordered state.

Fig. 1.



The compound $BaCoF_4$ was synthesized by fusing single-crystal BaF_2 and single-crystal CoF_2 in an HF atmosphere. The melting temperature of $BaCoF_4$ was found to be 852 ± 10°C. The unit cell parameters are a = 14.62 ± 0.01 Å, b = 4.20 ± 0.01 Å, and c = 5.85 ± 0.01 Å. The $BaCoF_4$ single-crystal was grown by the Bridgman method using a setup described in [3], in a helium atmosphere, inasmuch as our observations have shown that HF destroys this compound slowly at temperatures below about 400°C, and rapidly at room temperature (in the latter case, $BaCoF_4 \cdot 1.5HF$ is produced).

The investigated single crystal was about 0.1 cm^3 in size, transparent, and dark-violet in color. The crystal was oriented in accordance with x-ray measurements which made it possible to separate a twofold axis, the direction of which almost coincided with that determined from the outer faceting of the crystal.

A preliminary investigation of $BaCoF_4$ by the Faraday method in the temperature interval 1.5 - 300°K, using a torsion balance with a cryostat [4], has shown that, judging from the form of the magnetization curves, the substance has magnetic ordering already at room temperature in fields up to 8 kOe. The magnetization curves are nonlinear and reveal no noticeable hysteresis. In weak fields, the magnetization curves pass through zero, a fact attributable to the breakdown of the sample into domains.

The magnetoelectric effect was observed upon application of an alternating electric field of frequency 10^4 Hz by a method described in [5]. Figure 1 shows plots of the temperature dependence of the resultant alternating magnetic moment in the basal plane of the crystal following application of an electric field along the twofold axis. The occurrance of a multidomain state causes the alternating magnetic moment, in the case of zero external magnetic field, to be quite small and to vary little with temperature (the H = 0 curve).

When a magnetic field of intensity up to 500 Oe, directed parallel to the alternating magnetic moment produced in the electric field is turned on, the magnetic moment reveals a sharp dependence on the magnetic field (the curve H = 250 Oe and H = 500 Oe).

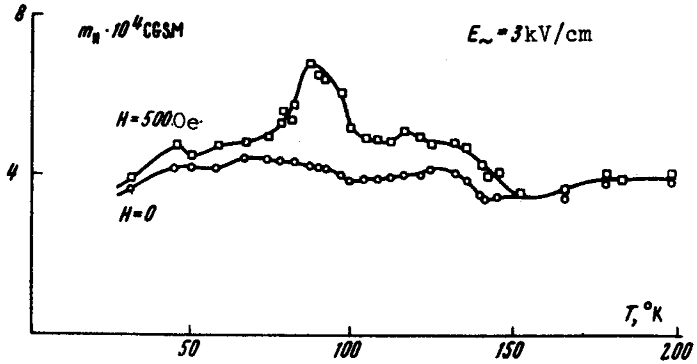


Fig. 2.

The sign of the magnetoelectric moment, relative to the applied electric field, reverses when the constant magnetic field is reversed, a fact established by phase measurements. This proves the existence of two different types of antiferromagnetic domains, each corresponding to a definite sign of the magnetoelectric effect [6]. The possibility of obtaining a definite type of domains by only a magnetic field is connected with the presence in the sample of a small spontaneous moment in the entire temperature range.

The temperature dependence of the magnetoelectric moment has a very complicated form and indicates the existence of magnetic phase transitions near T = 95°K and T = 45°K, which coincides with the temperatures at which singularities are observed in the behavior of the magnetic susceptibility.

A verification of the dependence of the signal on the applied electric field, up to 3 kV/cm, carried out at 80°K in a constant magnetic field of 500 Oe, has shown that the effect is linear within the limits of the measurement errors.

Measurements of the magnetoelectric moment $m_{\parallel}$ parallel to the electric field applied along the twofold axis of the crystal have shown that this moment is also strongly dependent on the external field. The magnitude of the moment in this direction is much smaller than $m_{\perp}$ (Fig. 2). This makes the measurements very difficult, but it can be assumed that the observed magnetic moment is not connected with inaccurate orientation of the crystal, inasmuch as the maxima of the signals do not occur at the same temperature.

Investigations of the magnetic properties of $BaCoF_4$ now in progress will make it possible to determine more accurately the features of the magnetic ordering of this substance.

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