Linear and quadratic magnetoelectric effect in boracite Co3B7O13Br

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Reference

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LINEAR AND QUADRATIC MAGNETOELECTRIC EFFECT IN BORACITE

Co$_3$B$_7$O$_{13}$Br

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Abstract Linear and quadratic magnetoelectric (ME) effects have been simultaneously detected in Co-Br boracite (Co$_3$B$_7$O$_{13}$Br) ME coefficients $\alpha_{23}$, $\alpha_{32}$ and $\beta_{31}$ have been measured versus temperature. The results are consistent with the symmetry m'm2' down to 4 K.

INTRODUCTION

The first experimental evidence of a ME effect in ferroelectric boracites has been established in Ni-I boracite. Afterwards a linear ME effect was detected and measured in Co-Cl, Ni-Cl, Ni-Br and Cu-Cl boracites. In this paper we report ME investigations on Co-Br boracite. This compound undergoes a weak ferromagnetic transition at about 17.5 K with the symmetry change mm21' $\rightarrow$ m'm2'. A magnetic field $H$ applied on a sample induces a polarization $P_1 = \alpha_{ij} H_j + \beta_{ijk} H_j H_k + \ldots$ where $\alpha_{ij}$ and $\beta_{ijk}$ are the components of second and third order ME tensors, respectively. For the m'm2' symmetry and our choice of axes, 3 // spontaneous polarization $P_s$ // twofold axis and 2 // spontaneous magnetization $M_s$, the second and third order ME coefficients allowed are $\alpha_{23}$, $\alpha_{32}$, $\beta_{113}$, $\beta_{223}$, $\beta_{311}$, $\beta_{232}$ and $\beta_{333}$.

EXPERIMENTAL PROCEDURE

Single crystals of Co-Br boracite were grown in the cubic phase $F43c1'$ by chemical vapour transport. At room temperature Co-Br
boracite is ferroelectric mm2'1. Ferroelectric single domain (100) \( c \) and (110) \( c \) cut platelets electroded with semi-transparent gold on chromium were used. The areas of the (100) \( c \) and (110) \( c \) cuts were 0.94 mm\(^2\) and 0.41 mm\(^2\), respectively. The thickness was about 45 \( \mu \)m. Two methods were used to detect the ME effect. i) Quasistatically by measuring the electric charges induced by slowly increasing or decreasing the magnetic field at constant temperature. ii) Dynamically by detecting the charges induced by an ac magnetic field of about 10 Oe and 150 Hz. A static magnetic bias field of at least 100 Oe was superposed parallel to the former one. This technique permits to measure continuously the ME effect as a function of temperature.

RESULTS

On a (100) \( c \) cut with \( \overrightarrow{P_s} \) perpendicular to it, the induced polarization has been measured as a function of a magnetic field applied in the (100) \( c \) plane. For different directions of the field, indicated by the angle magnet \( \theta \), experimental points are well fitted by the expected function 
\[
P_3 = \alpha_{32} H_2 + \beta_{311} H_1^2 + \beta_{322} H_2^2
\]
(Fig.1). This result is consistent with the symmetry mm2' down to 4 K. The coefficient \( \alpha_{32} \) was determined by fitting the induced polarization as a function of field (Fig.2). Dynamical measurements of \( \alpha_{32} \) versus temperature (Fig.3) also show a fast increase followed by a drop just before the transition. This behaviour does not seem to result from a reversal of ferromagnetic domains which should be frozen by the static magnetic field. We can note that a similar behaviour has been observed in other boracites \(^1,3,4\). The third order coefficients \( \beta_{311} \) and \( \beta_{322} \), calculated from quasistatic measurements, show an anomaly at the magnetic transition as does \( \alpha_{32} \) (Fig.4).

On the (110) \( c \) cut with \( \overrightarrow{M_s} \) perpendicular to it, quasistatic and dynamical measurements have permitted to determine the coefficient
FIGURE 1  Fit of theoretical curve
\( P_3 = \alpha_{32} H_2^2 + \beta_{311} H_1^2 + \beta_{322} H_2^2 \) to
experimental points of polarization
versus applied magnetic field angle \( \theta \)
(\( H \) rotated around \([100] \parallel \hat{P}_S, \hat{H} \parallel M_S \)
for \( \theta = -15^\circ \)). \( P_3 = \alpha_{32} H \sin(\theta+\phi) + \beta_{311} H^2 \cos^2(\theta+\phi) + \beta_{322} H^2 \sin^2(\theta+\phi). \)
\( H_0 = 10 \) KOe, \( \phi \) is a non intrinsic
phase difference due to the experimental set-up.

FIGURE 2  Quasistatic
measurements of magnetoelectric
coefficients \( \alpha_{23} \) and \( \alpha_{32} \) versus
temperature.

FIGURE 3  Dynamical
measurements of magnetoelec-
tric coefficients \( \alpha_{23} \) and \( \alpha_{32} \)
versus temperature.
\( \alpha_{23} \) (Fig. 2 and 3). This coefficient changes sign at about 8.5 K and vanishes continuously at the transition. The reasons for the temperature dependence of these coefficients are not yet understood, and a more complete report will be given elsewhere.

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