Magnetoelectric effect in lead manganate

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We report experimental observation of the magnetoelectric effect in single-crystal lead manganate ($PbMn_2O_4$) below 82°K. It is concluded that below this temperature lead manganate is a ferroelectric antiferromagnet with weak ferromagnetism.

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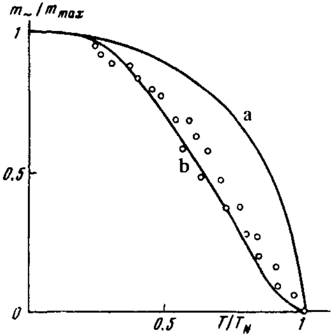
The magnetic properties of single-crystal lead manganate ($PbMn_2O_4$), the symmetry class of which is D_{3h} or D_{6h} at room temperature in accordance with x-ray data, were investigated in[1].

It was shown that antiferromagnetic order is present with weak ferromagnetism below 63 °K. At higher temperatures (at least up to 75 °K), the magnetization curves had a nonlinear character. An exact determination of the point of magnetic transition was impossible because of the low susceptibility and its weak temperature dependence.

It was suggested on the basis of a thermodynamic investigation[2] of the magnetic properties of lead manganate that the symmetry of the paraphase of the crystal near the magnetic-transition points belongs to one of the crystallographic classes C_{3v} or C_{6v}, and this



a) The Brillouin function $B_{5/2}(T/T_N)$ for spin $\frac{5}{2}$; b) the function $[B_{5/2}(T/T_N)]^3$; ○—experimental values of m.

made it possible to explain the main experimental data of[1].

A consequence of this assumption was the presence, in the expansion of the thermodynamic potential near T_N, of a magneto-electric term in the form $P_z(m_x l_y - m_y l_x)$ (the direction of z coincides with the symmetry axis), whereas this term is absent in the case of symmetry classes D_{3h} and D_{6h}.

To check on the results of[2] we have attempted to observe the magnetoelectric effect on a lead-manganate single crystal weighing ~5 mg. The measurements were made at 10 and 30 kHz in the interval 20–100 °K. The alternating electric field E was applied along a higher-order axis. The signal was registered in one of the directions in the basal plane of the crystal. To produce a one-domain magnetic state in the sample, a constant magnetic field ~1 kOe was applied along the axis of the measuring coils during the course of cooling.

Whenever the crystal was cooled, a magnetoelectric signal was produced at the temperature 82 ± 1 °K. The magnitude of the signal at 20 °K did not change when a magnetic field ~1 kOe was either removed or applied, and was linearly dependent on $E_{\sim}$, indicated that we have observed the linear magnetoelectric effect. The magnitude of the magnetoelectric constant is estimated at not less than 10^{-5}. The temperature dependence of the magnetoelectric signal is shown in the figure in comparison with the Brillouin function.

The presence of the magnetoelectric effect for the indicated directions of $E_{\sim}$ and $m_{\sim}(E_{\sim})$ thus indicates that the symmetry of the paraphase near the magnetic transition point is different than at room temperature. The magnetic-transition temperature must be identified with $T_N \approx 82$ °K. A quantitative measurement of the magnetoelectric constant and of its temperature dependence and a more accurate determination of T_N were impossible because the sample was too small.

[1] B. I. Al'shin, R. V. Zorin, L. D. Drobyshev, and S. V. Stepanishchev, Kristallografiya **17**, 562 (1972) [Sov. Phys.-Crystallogr. **17**, 489 (1972)].

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