GALVANOMAGNETIC PROPERTIES OF LITHIUM CHROMITE FERRITE

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The temperature dependences of the longitudinal and transverse galvanomagnetic effects in polycrystalline lithium chromite ferrite are determined. This ferrite exhibits a compensation point of the magnetic sublattices. Anomalies observed in the behavior of these effects above and below the compensation point are explained on the assumption that each magnetic sublattice of a ferrite makes a separate "characteristic" contribution to its galvanomagnetic properties.

1. The investigation of physical phenomena in ferrites having a compensation point Θ_C (the temperature at which the magnetic moments of the sublattices are "in balance"[1]) is important for the theory of ferrimagnetism. The individual characters of the different sublattices are especially pronounced near Θ_C, and it is easiest in this temperature range to determine the parts played by the different sublattices in producing ferrimagnetism and the accompanying effects (magnetoelastic, galvanomagnetic etc.) in ferrites.

We recently[2] reported the unusual behavior of the longitudinal galvanomagnetic effect in the ferrite $Li_2O \cdot 2.5\, Fe_2O_3 \cdot 2.5\, Cr_2O_3$, where this effect is reversed from negative to positive near Θ_C. Our attempted explanation was based on the assumption that each of the magnetic sublattices of the ferrite makes its own characteristic contribution to galvanomagnetic effects.[2]

The present paper reports detailed experimental data on even-order (longitudinal and transverse) galvanomagnetic effects in lithium chromite ferrite, with an interpretation based on the aforementioned hypothesis.

2. We prepared a ceramic ferrite with composition $Li_2O \cdot 2.7\, Fe_2O_3 \cdot 2.3\, Cr_2O_3$, which, like that mentioned in reference 2, had a compensation point. The sample was pre-annealed in air for four hours at 1000° C. The final sintering in air for three hours at 1200° C was followed by slow cooling. Electrical contacts were attached to the 5-mm cube with silver paste at 500° C. The galvanomagnetic effect $r = \Delta R/R$ was measured in a solenoid up to 2000 oe and in an electromagnet up to 12 000 oe, by comparison with a standard resistance in an unbalanced bridge. Since the resistance of the ferrite was strongly dependent on current strength, all measurements of r were obtained at 1 ma.

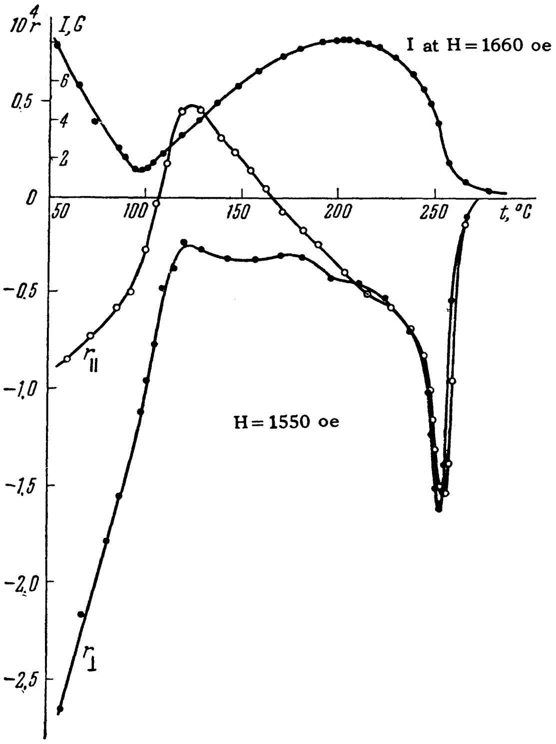

FIG. 1. Temperature dependence of magnetization I, and longitudinal ($r_{\parallel}$) and transverse ($r_{\perp}$) galvanomagnetic effects in the ferrite $Li_2O \cdot 2.7Fe_2O_3 \cdot 2.3Cr_2O_3$.

The magnetization I was measured ballistically in the solenoid. The temperature dependences of r and I from room temperature to 300° C were measured in an electric furnace with a bifilar winding of nonmagnetic nichrome. Since the galvanomagnetic properties of ferrites are strongly temperature dependent, the temperature was kept constant by placing the furnace in a molybdenum glass tube connected to a fore pump. The furnace current was stabilized electronically. The temperature of the sample was measured with a

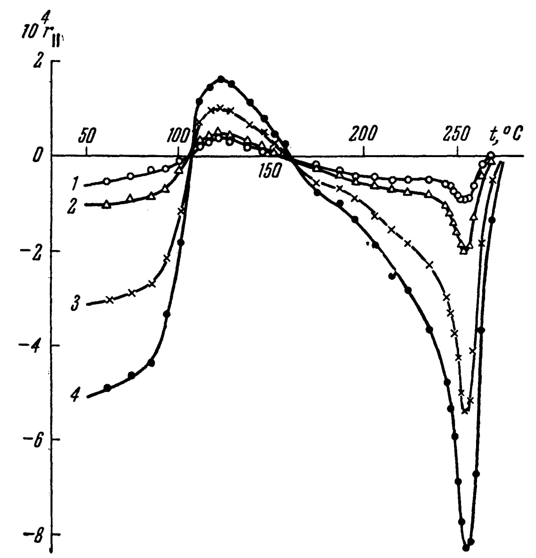

FIG. 2. Temperature dependence of the longitudinal galvanomagnetic effect in $Li_2O \cdot 2.7Fe_2O_3 \cdot 2.3Cr_2O_3$ in different magnetic fields: 1 – 1080 oe, 2 – 2260 oe, 3 – 6800 oe, 4 – 11 070 oe.

copper-constantan thermocouple and a PPTV-1 high-resistance potentiometer.

3. The galvanomagnetic effects and magnetization were measured at first in relatively small fields (in the solenoid). Figure 1 shows the temperature dependences of the longitudinal ($r_{\parallel}$) and transverse ($r_{\perp}$) galvanomagnetic effects (at H = 1550 oe) and magnetization I (at H = 1660 oe) for a sample of $Li_2O \cdot 2.7\ Fe_2O_3 \cdot 2.3\ Cr_2O_3$.

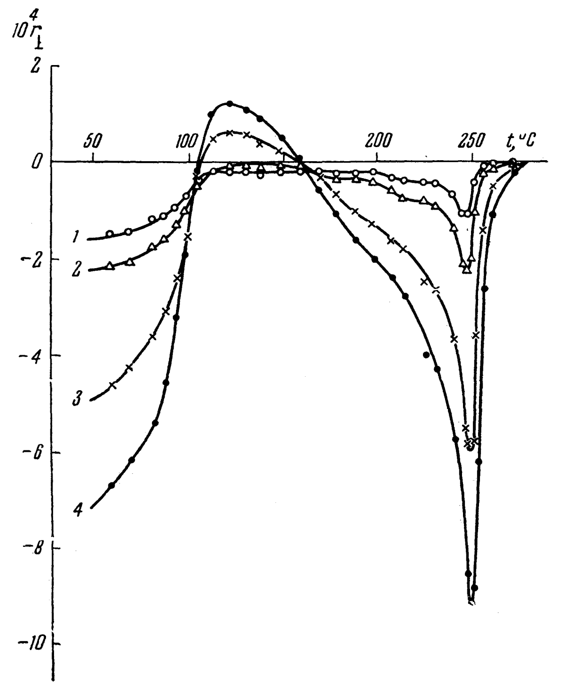

FIG. 3. Temperature dependence of the transverse galvanomagnetic effect in $Li_2O \cdot 2.7Fe_2O_3 \cdot 2.3Cr_2O_3$ in different magnetic fields: 1 – 1080 oe, 2 – 2260 oe, 3 – 6800 oe, 4 – 11 070 oe.

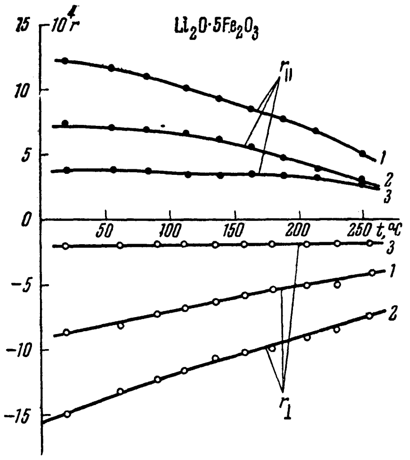

FIG. 4. Temperature dependences of $r_{\parallel}$ and $r_{\perp}$ in the ferrite $Li_2O \cdot 5Fe_2O_3$: 1 – 2080 oe, 2 – 10 370 oe, 3 – 6000 oe.

The magnetization curve shows that although complete compensation of the magnetic sublattices does not occur, the compensation point Θ_C is easily found at 98° C. The temperature dependences of $r_{\parallel}$ and $r_{\perp}$ show that below Θ_C the galvanomagnetic effects have the same sign in both longitudinal and transverse fields; this is similar to observations on magnetite[3] and many ferrites. Above Θ_C the signs of the effects differ; this corresponds to the "normal" behavior characteristic of most ferromagnetic materials.

In addition to the identical (negative) signs of $r_{\parallel}$ and $r_{\perp}$, their anomalous behavior below Θ_C lies in the fact that the transverse effect is almost three times as large as the longitudinal effect. Above Θ_C, $r_{\parallel}$ is larger in absolute value than $r_{\perp}$; this is the normal behavior. In a certain temperature range the so-called second rule of even-order effects, $r_{\perp} = -\frac{1}{2} r_{\parallel}$, is observed.

As the Curie point is approached a galvanomagnetic effect r_p due to spontaneous magnetization (the "para-process"), the magnitude and (negative) sign of which are independent of the applied

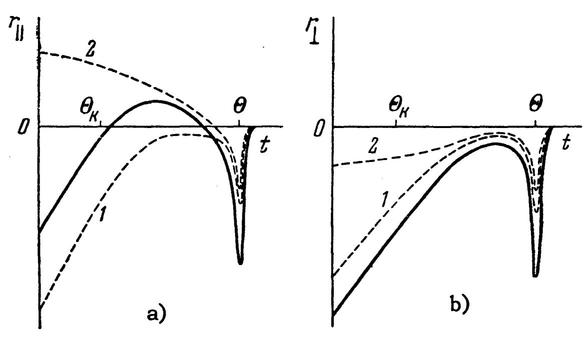

FIG. 5. Schematic temperature variation of the galvanomagnetic effects in lithium chromite ferrites; a – longitudinal, b – transverse galvanomagnetic effect.

field direction, is superposed on the $r_{\parallel}$ and $r_{\perp}$ effects due to technical magnetization. The negative maximum of r_p is located precisely at the Curie point, where $r_{\parallel} \rightarrow 0$ and $r_{\perp} \rightarrow 0$.

Figures 2 and 3 show the temperature dependences of $r_{\parallel}$ and $r_{\perp}$ in stronger fields up to about 12 000 oe. The behavior shown in Fig. 1 is repeated on the whole. Below Θ_c, $r_{\perp} > r_{\parallel}$, and both effects are negative. At 112° C (Θ_c = 98° C) the longitudinal effect becomes positive in all fields. The transverse effect is negative in not very strong fields (as in Fig. 1), but becomes positive in stronger fields. We are at present making a detailed investigation of this behavior, which is not yet understood. It should also be noted that at the Curie point the negative maximum of the "para-process" galvanomagnetic effect is of smaller magnitude in Fig. 2 than in Fig. 3.

4. The galvanomagnetic anomalies can be accounted for by individually different characteristic galvanomagnetic properties of the sublattices in a given ferrite. These differences are due to the nature and arrangement of the sublattice ions. The galvanomagnetic effects in the sublattices are superposed to produce the galvanomagnetic effect of the ferrite as a whole, with a temperature dependence that, as we have seen, exhibits very complicated and anomalous behavior in the case of chromite ferrite.

According to Gorter,[1] lithium chromite ferrite contains two sublattices, one with Fe, Cr, and some Li ions in octahedral sites, and the other with Fe and Li ions in tetrahedral sites. Below Θ_c the octahedral sublattice dominates the magnetic behavior of the ferrite; its galvanomagnetic properties are, according to our hypothesis, anomalous and "magnetite-like" ($r_{\parallel}$ and $r_{\perp}$ having like signs). Above Θ_c the tetrahedral sublattice dominates; it has "normal" galvanomagnetic properties, $r_{\parallel}$ being positive and $r_{\perp}$ being negative. It is interesting that our measurements (Fig. 4) show the galvanomagnetic properties of the simple ferrite $Li_2O \cdot 5Fe_2O_3$ to be "normal," i.e., above Θ_c lithium chromite ferrite has the same galvanomagnetic properties as $Li_2O \cdot 5Fe_2O_3$. The dashed schematic curves in Fig. 5 depict the temperature behavior of the $r_{\parallel}$ and $r_{\perp}$ effects in the octahedral and tetrahedral sublattices; the solid curves represent the combined effect for the ferrite. The scheme of Fig. 5 furnishes a very good explanation of our experimental findings given in Figs. 1 — 3. It appears that 1) when $T < \Theta_c$ the transverse effect $r_{\perp}$ is much greater than $r_{\parallel}$ and both are negative; 2) when $T > \Theta_c$, $r_{\parallel}$ is reversed from negative to positive, the zero point of $r_{\parallel}$ (the compensation point Θ_c' for the longitudinal galvanomagnetic effect) does not necessarily coincide with Θ_c, and the position of Θ_c' is determined by the behavior of the dashed curves around Θ_c in Fig. 5; 3) at the Curie point the "para-process" galvanomagnetic effect has a somewhat greater negative maximum in Fig. 5b than in Fig. 5a. This difference is accounted for by the fact that $r_{\parallel}$ and $r_{\perp}$ do not disappear completely at the Curie point. In Fig. 5a the $r_{\parallel}$ effect due to technical magnetization processes (the positive effect) partially cancels the maximum of r_p, whereas in Fig. 5b, since $r_{\perp}$ and $r_{\parallel}$ are both negative, the maximum negative effect is somewhat greater at the Curie point.

Our experimental investigation of the galvanomagnetic properties of lithium chromite ferrite furnishes additional evidence that the ferrite contains magnetic sublattices with different temperature dependences of spontaneous magnetization.

The disclosure and study of the galvanomagnetic properties of each magnetic sublattice will help to reveal the character of the electrical properties of ferrite crystals.

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[2] Belov, Goryaga, and Lin Chang-Ta, JETP **38**, 1914 (1960), Soviet Phys. JETP **11**, 1376 (1960).

[3] P. A. Khalileev, Sow. Phys. **7**, 108 (1935); M. A. Grabovskii, Izv. Akad. Nauk SSSR, Ser. Geofiz. No. **4**, (1951).

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