LOW TEMPERATURE MAGNETIC ANOMALIES IN LITHIUM FERRITE CHROMITES

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The temperature dependences of spontaneous magnetization, coercive force, magnetic susceptibility, and electrical resistance were measured for lithium ferrite chromites which have compensation points of the magnetic moments of the sublattices. The anomalies found in the temperature variation of such magnetic and electrical characteristics at low temperatures in these ferrites confirm Belov's suggestion[1] that ferrites possessing compensation points should display low-temperature magnetic anomalies that correspond to a sharp change in the magnetic order in a sublattice with "weak" exchange interaction.

1. Lithium ferrite chromites are of note in that in some the magnetic moments of the sublattices have compensation temperatures, Θ_{comp}. Investigations[1,2] made earlier established that the physical properties of the ferrites change sharply on going through the temperature Θ_{comp}. The reason for this is that the magnetic properties, and the physical properties of the ferrite associated with them, are determined in the region below Θ_{comp} by an octahedral sublattice and above Θ_{comp} by a tetrahedral sublattice. A study of ferrites with a compensation point is therefore of great interest to the theory of ferrimagnetism.

The work cited above was mainly devoted to a study of the physical properties of lithium ferrite chromites in the region of the compensation point. In the present work we have undertaken the measurement of the magnetic and of some electrical characteristics of lithium ferrite chromites at low temperatures ($T < \Theta_{comp}$).

2. The following ferrites were prepared by ceramic methods for the investigation: $Li_2O \cdot 3Fe_2O_3 \cdot 2Cr_2O_3$ ($\Theta_{comp} = 523.5$ °K) $Li_2O \cdot 2.5Fe_2O_3 \cdot 2.5Cr_2O_3$ ($\Theta_{comp} = 326°$ K) and $Li_2O \cdot 5Fe_2O_3$ (without a compensation point). A preliminary annealing was carried out for four hours at 1000° C in air. The final sintering was made for three hours at 1200° C in air, followed by slow cooling. The magnetization σ, the magnetic susceptibility χ in a field H = 10 oe, and the coercive force H_c were measured by a ballistic method in a solenoid. All the specimens were parallelepipeds with pointed ends.

The electrical resistance R was measured on a dc Wheatstone bridge. In view of the fact that the electrical resistance of ferrites at the temperatures of interest to us is very high, we chose speciments in the shape of thin plates 1 mm thick and 9×9 mm in area. Electrical contacts were produced on the specimens by baking a silver paste at a temperature of 500° C. In order to obtain a continuous range of temperatures—from liquid-nitrogen to room temperature—the specimen was contained in a special molybdenum glass oven, placed in a dewar containing liquid nitrogen.

3. As a result of the investigations it was established that in ferrites with a compensation point Θ_{comp}, the temperature dependence of spontaneous magnetization σ_s has a noticeable break in the region of liquid nitrogen temperature. Corresponding to this, minima and maxima are observed on the curves of H_c and χ vs. temperature.

The temperature dependences of σ_s, H_c and χ for the ferrites $Li_2O \cdot 3Fe_2O_3 \cdot 2Cr_2O_3$ and Li_2O

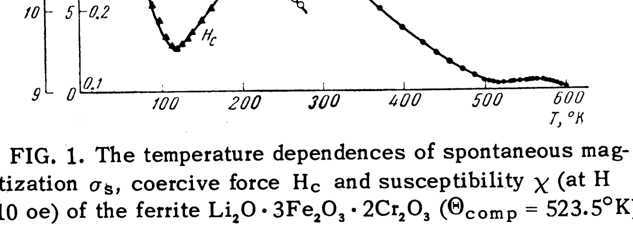

FIG. 1. The temperature dependences of spontaneous magnetization σ_s, coercive force H_c and susceptibility χ (at H = 10 oe) of the ferrite $Li_2O \cdot 3Fe_2O_3 \cdot 2Cr_2O_3$ ($\Theta_{comp} = 523.5$°K).

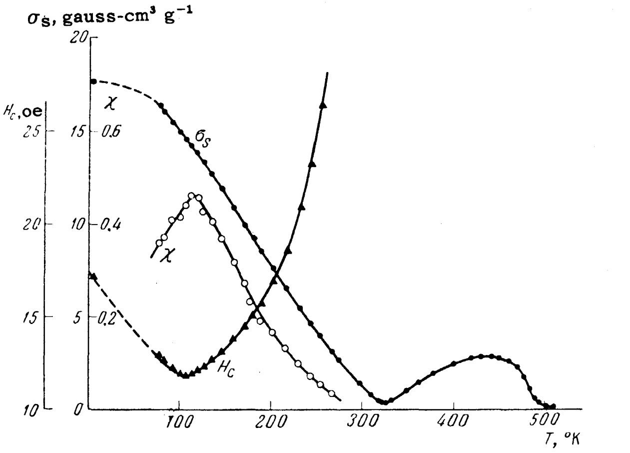

FIG. 2. The temperature dependences of the spontaneous magnetization σ_s, H_c and χ of the ferrite $Li_2O \cdot 2.5Fe_2O_3 \cdot 2.5Cr_2O_3$ ($\Theta_{comp} = 326°K$).

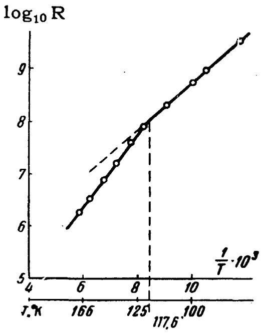

FIG. 4. The temperature dependence of electrical resistance of the ferrite $Li_2O \cdot 2.5Fe_2O_3 \cdot 2.5Cr_2O_3$.

$\cdot 2.5Fe_2O_3 \cdot 2.5Cr_2O_3$ are shown in Figs. 1 and 2. It can be seen that the magnetization σ_s of both ferrites changes little with increasing temperature up to liquid-nitrogen temperatures, but then decreases rapidly (showing a break) up to the compensation temperature. The susceptibility χ has a maximum where the spontaneous magnetization starts to fall rapidly. The coercive force has a minimum at this temperature and then increases rapidly as the temperature increases.

Analogous behavior of the temperature curves of σ_s, H_c and χ is observed for all compositions of lithium ferrite chromites which have a compensation point. In lithium ferrite chromites without a compensation point, the $\sigma_s(T)$, $H_c(T)$ and $\chi(T)$ curves do not have low temperature anomalies. This can be seen in Fig. 3, which gives measurement data on the ferrite $Li_2O \cdot 5Fe_2O_3$; here σ_s and H_c decrease smoothly while χ increases. We also measured the temperature dependence of the electrical resitance R for lithium ferrite chromites with a Θ_{comp} point. We established that at the temperatures at which anomalies in the temperature variation of σ_s, H_c and χ are observed, the $\log_{10}R(1/T)$ curve shows a break (Fig. 4). It can be seen from Figs. 1, 2, and 4 that the anomalies in the temperature variation of σ_s, H_c, χ and R are analogous to those observed in ferromagnets near the Curie point.

4. The anomalies appearing in the temperature variation of the magnetic and electric characteristics at low temperatures are related to the occurrence of a rapid change in the long range magnetic order in the ferrites studied. According to Belov,[3] such a change must take place in ferrites which have compensation points in a sublattice with "weak" exchange interaction. The existence of such a "weak" sublattice in a ferrite is a condition for the appearance of a compensation point. In lithium ferrite chromites the octahedral sublattice is the "weak" sublattice, in which there is a considerable amount of chromium and lithium ions as well as iron ions. The presence of the lithium leads to a great weakening of the exchange interaction.

In the tetrahedral sublattice, on the other hand, there is a stronger exchange interaction, since there are many Fe ions in it (and a negligible amount of Li ions). Since there is a strong negative exchange interaction between the sub-

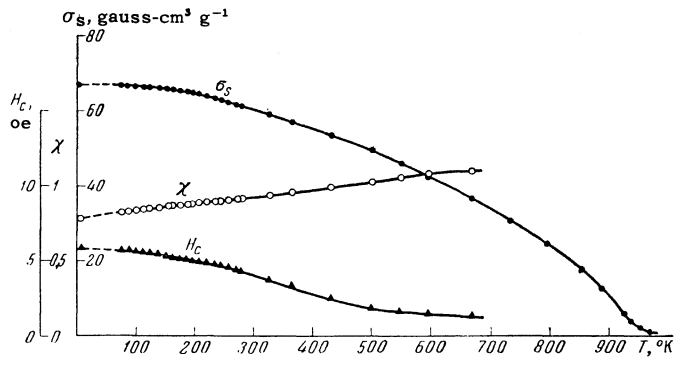

FIG. 3. The temperature dependences of σ_s, H_c and χ of the ferrite $Li_2O \cdot 5Fe_2O_3$.

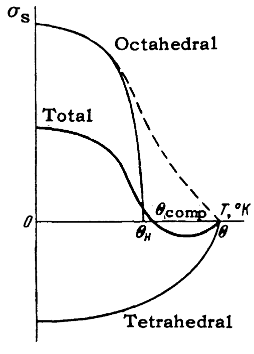

FIG. 5. Schematic curves of the temperature dependence of the spontaneous magnetization of each sublattice separately and the total magnetization of a ferrite; Θ is the Curie point, Θ_{comp} the compensation point and Θ_H the temperature at which a sharp change in magnetic long range order takes place.

lattices, it can exert a considerable influence on the magnetic ordering in them, especially in the "weak" sublattice. As a result of this, the temperature dependence of the spontaneous magnetization of the sublattice with weak interaction can have a spread out appearance. In other words, the long range magnetic order in the weak sublattice does not completely disappear as a result of the influence of the negative exchange interaction between the sublattices.

The temperature dependence of the spontaneous magnetization of each sublattice separately and of the ferrite as a whole is shown schematically in Fig. 5. The dashed curve also shows the $\sigma_s(T)$ curve for the octahedral sublattice, spread out as a result of the influence of an antiferromagnetic interaction. The influence of the negative exchange interaction apparently shows up most strongly in that part of the $\sigma_s(T)$ curve where a partial destruction of long range order has already taken place, i.e., the spontaneous magnetization has decreased strongly compared with the value of σ_s of the other sublattice. The $\sigma_s(T)$ curve for the octahedral sublattice will, therefore, have a long "tail" up to the Curie temperature Θ of the tetrahedral sublattice. The $\sigma_s(T)$ curve for the octahedral sublattice is not, consequently, of the Weiss type. According to Belov,[3] the presence of such a "tail" in the spontaneous magnetization is the cause of the appearance of a compensation point Θ_{comp}.

The reason for the anomalies observed by us in the temperature dependence of σ_s, H_c, χ and R at low temperatures ($T < \Theta_{comp}$) is thus related to the fact that in these ferrites the octahedral sublattice shows a weak positive exchange interaction, as a result of which the long range magnetic order, produced by the interaction, is destroyed at low temperatures.

In conclusion the authors thank Professor K. P. Belov for his valuable advice during the carrying out of this work.

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

[2] K. M. Bol'shova and T. A. Elkina, Fiz. Metal. metalloved (Physics of Metals and Metallography) **8**, 461 (1959). K. P. Belov and A. V. Ped'ko, JETP **39**, 961 (1960), Soviet Phys. JETP **12**, 666 (1961).

[3] K. P. Belov, JETP **41**, 692 (1961), this issue, p. 499.

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