# "PREMATURE" VANISHING OF THE RESONANCE IN THE EASY-AXIS PHASE OF HEMATITE

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The increased interest in the properties of antiferromagnetic $\alpha$-$Fe_2O_3$ (hematite) during the last three-four years is due to the fact that a magnetic phase transition, induced by an external field perpendicular to the easy-magnetization axis of the sublattices, was observed in it at $T < T_M = 260°K$ [1,2]. A similar transition should take place in all easy-axis antiferromagnets in which the Dzyaloshinskii vector $\vec{\beta}$ is parallel to the easy axis [3-5]. It is accompanied by a change in the form of the magnetization curve $m_\perp(H_\perp)$ at a certain critical value of the external magnetic field $H_\perp = H_\perp^{tr}$ and, according to calculations, by vanishing of one of the antiferromagnetic-resonance frequencies [6-8].

It was noted on the basis of static measurements [9,10] that in hematite this transition has an interesting singularity. At low temperatures (~77°K) the transition is close in character to a second-order phase transition; a jump in the value of $dm_\perp/dH_\perp$, but not of the magnetic moment $m_\perp$ itself, is noted in a field $H_\perp = H_\perp^{tr}$. With increasing temperature, the anomaly of $m_\perp(H_\perp)$ at $H_\perp = H_\perp^{tr}$ becomes more sharply pronounced, and quite close to the Morin temperature ($T_M$) the rise of $m_\perp$ in the transition field occurs jumpwise [1], and, as shown directly with the aid of the Mossbauer effect [11], it is accompanied by a jumplike change of the direction of the antiferromagnetism axis (i.e., of the vector $\vec{l} = \vec{M}_1 - \vec{M}_2$, where $\vec{M}_1$ and $\vec{M}_2$ are the sublattice magnetizations) from a certain critical value $\theta_c$ to $\theta = 90°$ ($\theta$ is the angle between the antiferromagnetic vector $\vec{l}$ and the easy axis of the crystal $OZ \parallel C_3$). The increase of $\theta$ from zero to $\theta_c$ as $H_\perp$ increases from zero to $H_\perp^{tr}$ is smooth.

It was of considerable interest to investigate the influence of the described changes of the character of the phase transition in hematite on its dynamic properties. To this end, we undertook a study of the temperature variation of resonance absorption in hematite in a magnetic field perpendicular to the easy axis of the crystal. This resonance was predicted in [6] and [8] and was observed experimentally in [8]. The measurements were made with a reflection radiospectrometer ($\nu$ = 37.7 GHz) using both a pulsed ($H_{max}$ = 250 kOe [8]) and a constant ($H_{max}$ = 110 kOe *) magnetic field. The $\alpha$-$Fe_2O_3$ samples were placed in a waveguide in such a way that the constant (pulsed) field and the microwave field parallel to it were in the basal plane of the crystal. We investigated single-crystal samples measuring 1 x 3 x 3 mm, grown at the USSR Academy of Sciences Institute of General and Inorganic Chemistry (sample No. 1) and at the USSR Academy of Sciences Crystallography Institute (sample No. 2).

The picture of the resonance absorption in sample No. 1 (two closely lying peaks at $H_\perp = H_r^{(1)}$ and $H_\perp = H_r^{(2)}$) in the setup with the pulsed field was practically the same at all the investigated temperatures (T = 77 - 250°K) as that given in [8,12] for T = 77°K. The

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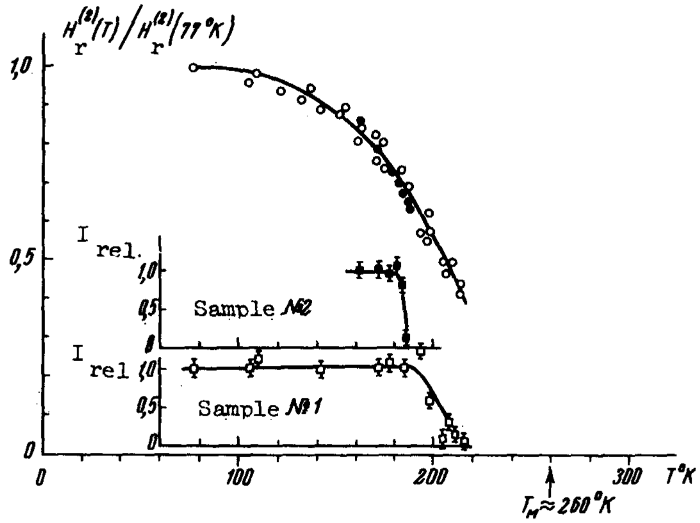
* The setup for obtaining strong magnetic fields was that of the Oscillation Laboratory of the USSR Academy of Sciences Physics Institute.

absorption lines of sample No. 2 obtained with the constant-field spectrometer had a similar form.

As expected, the resonance field decreased with increasing temperature. The figure shows the temperature dependences of the relative resonance field (which was measured by us, for concreteness, at the location of the second strong-field absorption peak) for both samples. The absolute values of the resonance fields coincide within the limits of measurement accuracy: $H_r^{(2)}(160°K) = 109 \pm 4$ kOe.

The most interesting experimental fact observed in both samples is the unexpected abrupt vanishing of the resonance absorption much below the Morin temperature. This is clearly illustrated by the temperature dependence of the relative intensity of the resonance-absorption line (determined from the maximum height of the peaks), as shown in the figure. The temperatures at which the resonance-absorption lines disappear completely differ somewhat for single crystals of different origin. The vanishing of the resonance occurs in the temperature region where, according to the static data [10], no jumps of the magnetization $m_\perp(H_\perp)$ were observed within the measurement accuracy (this made it possible earlier to regard this transition as a second-order phase transition [9]). Apparently, however, the vanishing of the resonance is connected with a jumplike transition of the z-component of the antiferromagnetism vector $\vec{l}$ in the basal plane of the crystal (first-order phase transition). This transition causes a smooth change of $m_\perp(H_\perp)$, which is difficult to observe experimentally with the aid of static measurements when $T < T_M$, but leads to a qualitative change of the spectrum of the antiferromagnetic resonance (AFMR), since the same component $l_z$ enters in the formula for the resonance frequency in an external magnetic field perpendicular to the easy axis of the crystal, a formula which is valid in first approximation (i.e., with allowance for only second-order terms) in the expression for the magnetic energy of the crystal. We must therefore assume that the lower branch of the AFMR spectrum has a gap which apparently increases with temperature. In this case the resonance absorption vanishes when



Temperature dependence of resonance field $H_r^{(2)}$ and of the intensity $I_{rel}$ of the AFMR line in single-crystal hematite in the interval 77 - 250°K. Operating frequency 37.7 GHz. Magnetic field $H_\perp \perp C_3$; $h_{hf} \parallel H_\perp$: light circles and squares - respectively $H_r^{(2)}(T)/H_r^{(2)}(77°K)$ and $I_{rel}(T)$ for sample No. 1 (pulsed field); full circles and squares - the same for sample No. 2 (constant magnetic field).

the gap becomes comparable with the operating frequency.

The discontinuous character of the transition induced in the hematite by an external magnetic field perpendicular to the easy axis of the crystal between the phases "$l_z \neq 0$" and "$l_z = 0$" can be explained, for example, by taking into account the "second anisotropy constant" [11,13]. Other interactions of order higher than the second can also lead in principle to a jump of the transition between phases [14], but a comparison of their relative role in the concrete case of hematite calls for a special investigation.

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# ANOMALOUS SIGN OF THE MAGNETOCALORIC EFFECT IN FERRITES IN THE REGION OF THE COMPENSATION POINT

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There are only three published papers [1-3] reporting measurements of the magnetocaloric effect ΔT(H) in ferromagnets. Yet a study of this effect in ferrites is of considerable interest; since the ΔT(H) effect is an "energy" characteristic of a magnet, its measurement can yield useful information on the manifestation of complicated magnetic-sublattice interactions in ferrites.

We measured the ΔT(H) effect in the iron garnet $Gd_3Fe_5O_{12}$ and in the ferrite-spinel $Li_2O \cdot 2.5Fe_2O_3 \cdot 2.5Cr_2O_3$ in a wide interval of temperatures. The ferrite samples were spherical with 5 mm diameter. The hot junction of a copper-constantan thermocouple was inserted in a narrow cut in the sphere. The temperature change ΔT following the adiabatic application of the magnetic field was registered with a potentiometer setup with an amplifier having a sensitivity $0.5 \times 10^{-3}$ deg. The sample was placed in an evacuated glass ampoule on which a