lagneto-optical measurement of the orientation of ıe antiferromagnetism vector in a phase transition ı hematites under conditions of uniaxial tension

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A magneto-optical method is proposed for the investigation of the magnetic phase transition in hematite (α-Fe_2O_3) under conditions of uniaxial tension at 300 K. An explicit dependence of a transition parameter (the rotation angle of the antiferromagnetism vector) on the magnetic field and on the mechanical stress is obtained.

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A pressing problem in the investigation of antiferromagnetism is observation of the orienta-n of the antiferromagnetism vector **l**, which can be monitored directly with the aid of nuclear-ysics methods (neutron diffraction etc.), but with low accuracy. In this paper we report servation of the state of the vector **l** with the aid of magneto-optical methods.

Hematite (α-Fe_2O_3, crystal structure D^6_{3d}) in the weakly ferromagnetic phase ($260° < T < 950$) has the property that the vector **l** tends to become oriented in the basal plane perpendicular to ƺ external magnetic field **H**, and at the same time perpendicular to the uniaxial tensile stress **p** plied in the basal plane. The competition of these two factors leads to the onset of a phase ınsition, and the parameter of the transition is the angle ϕ of rotation of the vector **l**. The entations of the vectors **H**, **p**, and **l** is shown in Fig. 1, with $x \| U_2$.

A theoretical analysis based on the use of a very simple thermodynamic potential that leads to $\neq 0$, and with allowance for the magneto-elastic contribution that is bilinear in the components **l**, yields the following formula for the determination of the equilibrium value of ϕ:

$$(U_{11}-U_{12})p\sin 2\phi = m_D H \sin(\phi-\beta) + (\chi_\perp - \chi_\|)H^2 \sin 2(\phi-\beta), \qquad (1)$$

ıere $\frac{1}{2}(U_{11}-U_{12})=M$ is the magnetostriction constant,[1] m_D is the Dzyaloshinskiĭ weak-ferro-ıgnetic moment, $\chi_\perp$ and $\chi_\|$ are the magnetic susceptibilities across and along **l**, respectively, and is the angle between **H** and the x axis.

The stable state corresponds to a solution of Eq. (1) with $\phi \to \beta$ as $H \to \infty$ and $\phi \to \pi/2$ as $\to +0$.

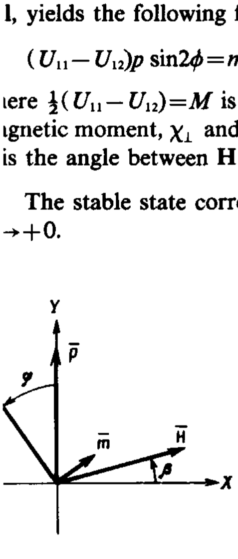

FIG. 1. Orientations of the vectors **l**, **m**, **H**, and **p** under the conditions of the experiment.

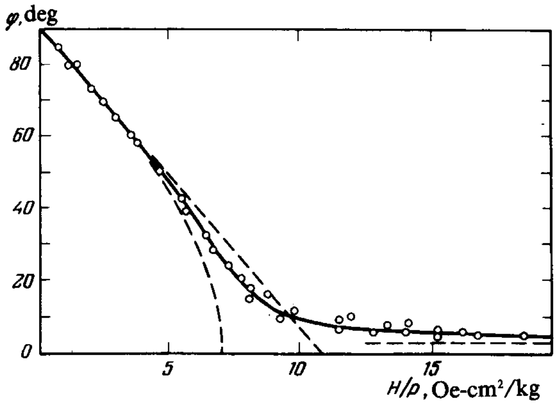

FIG. 2. Dependence of the angle ϕ on H/p. Solid line—theoretical curve.

When $\mathbf{p} \perp \mathbf{H}$ ($\beta=0$) the dependence of ϕ on H at constant p has the character of a secon order phase transition, namely: 1) $\phi=0$ at $H>H_{cr}$,

2) $\phi=\arccos\{m_D H/[2(U_{12}-U_{11})p-H^2(\chi_\perp-\chi_\parallel)]\}$ at $0<H<H_{cr}$, (

where

$$H_{cr}=\frac{\sqrt{m_D^2+8(\chi_\perp-\chi_\parallel)(U_{12}-U_{11})p}-m_D}{2(\chi_\perp-\chi_\parallel)}.$$

In the case when $\chi_\parallel=0$, formulas (2) and (3) coincide with those obtained in[2]. We note t the transition changes the symmetry jumpwise: the more symetrical phase I has symmetry e ments of E, I, σ_d, and U_2, and the less symmetrical phase—only of E. At this orientation rotation of $\mathbf{l}$ is even in ϕ, i.e., a domain structure can be formed. This degeneracy is lifted at $\beta\neq$

For the experimental investigation we used the magneto-optical method described in[3], made it possible to measure the components of the dielectric tensor ϵ_{xy} and $\frac{1}{2}(\epsilon_{xx}-\epsilon_{yy})$, which h the following dependences on ϕ and p:

$$\tfrac{1}{2}(\epsilon_{xx}-\epsilon_{yy})=\eta\cos 2\phi+\zeta p,$$

$$\epsilon_{xy}=\eta\sin 2\phi,$$

where η is the magnetic contribution to the birefringence and ζ is the piezo-optical constant.

The results of the experiment indicate that at a strict orientation $\mathbf{H}\perp\mathbf{p}$ the sample breaks into domains and one cannot speak of the value of the angle ϕ for the sample as a whole i rigorous sense in the transition region.

When $\mathbf{H}$ deviates from the position $\mathbf{H}\perp\mathbf{p}$ ($|\beta|\gtrsim 2°$), the rotation of $\mathbf{l}$ takes place in practica single-domain fashion at $p>100$ kg/cm². Figure 2 shows the values of the angle ϕ as a function H/p for $\beta=3°$ (100 kg/cm² $<p<150$ kg/cm², $0<H<3$ kOe). The experimental points agree w with the theoretical curve drawn in accordance with formula (1) at $m_D/2(U_{12}-U_{11})=1.45\times$ Oe.

Experiment yielded the following dependence of the critical field on the tensile stress

$$H_{cr}(p)=6.75p \text{ (Oe-cm}^2\text{/kgf)},$$

where p is in kg/cm².

The described method is effective for direct observation of the magnetic phase transition in the :inity of the Morin point.

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