periods, an important role is played by long-range forces connected with the fact that the adsorbed sodium atoms have an appreciable positive charge [4]. Thus, a study of phase transitions in monatomic films can yield new data on the electronic properties and on the interaction of adsorbed atoms. On the other hand, the possibility of changing the surface concentration of the adsorbed atoms in a wide range, and of using substrates with various structures, makes such films convenient for the verification of theoretical models of phase transitions.

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[1] L. D. Landau and E. M. Lifshitz, Statisticheskaya fizika (Statistical Physics), Ch. 14, Nauka, (1964) [Addison-Wesley, 1958].
[2] J. J. Lander, Surf. Sci. 1, 125 (1964).
[3] E. V. Klimenko and V. K. Medvedev, Fiz. Tverd. Tela 10, 1986 (1968) [Sov. Phys.-Solid State 10, 1562 (1969)].
[4] E. V. Klimenko and A. G. Naumovets, Surf. Sci. 14, 141 (1969)

INFLUENCE OF "INDUCED" ANGULAR MAGNETIC STRUCTURE ON THE MAGNETOSTRICTION OF DYSPROSIUM IRON GARNETS

K. P. Belov, R. Z. Levitin, B. K. Ponomarev, and Yu. F. Popov
Moscow State University
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It was shown theoretically in [1-4] that a noncollinear angular magnetic structure may be produced in ferromagnets in a certain interval of magnetic fields ($H_1 < H < H_2$). This structure is produced as a result of competition between the exchange interaction, which tends to produce an antiparallel orientation of the sublattice magnetic moments, and the external field, which tends to turn both sublattices parallel to the external field.

A convenient object for the investigation of angular structures "induced" by the magnetic field are rare-earth iron garnets (REIG). They can be described approximately within the framework of the two-sublattice model with strong exchange interaction inside the resultant iron sublattice, with a relatively weak negative interaction between the iron and rare-earth sublattices, and with a negligibly small interaction inside the rare-earth sublattice [5, 6]. The temperature dependences of the critical fields H_1 and H_2 of REIG were calculated by the molecular-field approximation in [4], where it was shown that the angular structure can exist only below a certain temperature T_{cr}, and that only collinear structures exist above this temperature. For REIG with a compensation point the critical temperature is somewhat lower, but is close to the compensation temperature θ_c.

Calculations show that at helium temperatures the critical fields of most REIG exceed 500 kOe. Near the compensation point, H_1 and H_2 decrease greatly, but the singularities on the magnetization isotherms become barely noticeable in such fields, owing to the masking effect of the paraprocess. These experimental difficulties explain the paucity of data on the critical fields of REIG. There are published data only for ytterbium iron garnets [4]1).

In the present investigation we used measurements of the magnetostriction to determine the critical fields of dysprosium iron garnets. It was indicated in [4, 8, 9] that the occurrence of angular structures should lead to singularities on the plots of the magnetostriction against the field and against the temperature, since a transverse magnetostriction component, with a sign opposite that of the longitudinal striction, appears when the magnetic moments of the sublattices have directions other than that of the field. Therefore, measurement of the magnetostriction uncovers better possibilities for determining the crystal fields than measurements of magnetization.

We investigated the magnetostriction of dysprosium iron garnet in the temperature interval 80 - 300°K and in pulsed magnetic fields up to 200 kOe, using the setup described in [10]. In the vicinity of the compensation point (θ_c = 218°K), kinks appear decreased sharply in magnitude as the compensation point is approached, in accordance with the theoretical predictions for the critical field H_1. Figure 2 shows theoretical plots of $H_1(T)$ and $H_2(T)$, calculated from the formulas of [4] with slight modifications

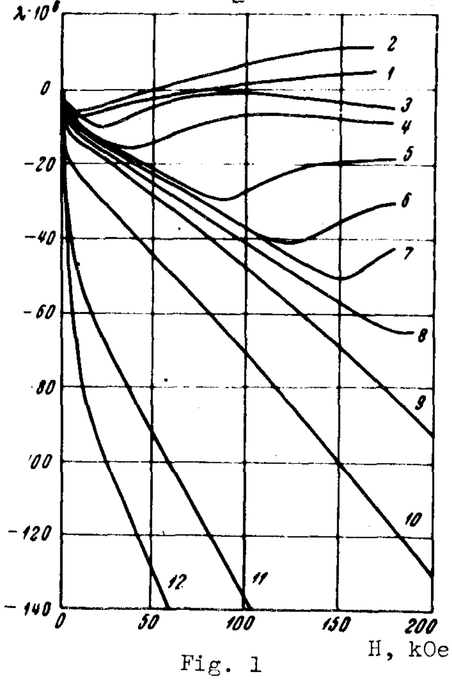

Fig. 1

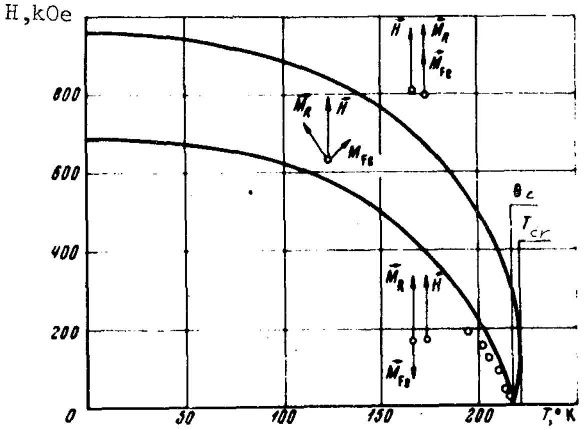

Fig. 2

Fig. 1. Isotherms of magnetostriction of dysprosium iron garnet: 1 - 294°K, 2 - 227°K, 3 - 216°K, 4 - 214°K, 5 - 210°K, 6 - 205°K, 7 - 202°K, 8 - 195°K, 9 - 173°K, 10 - 143°K, 11 - 106°K, 12 - 84°K.

Fig. 2. Temperature dependence of critical fields H_1 and H_2 of dysprosium iron garnet. Solid curves - calculation by molecular-field theory, light circles - values of H_1 obtained from magnetostriction measurements.

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1) The critical fields of holmium iron garnets were determined from measurements of the Faraday effect.

(unlike [4], we assume, in accord with the results of [5, 6], that the interaction between the rare-earth and iron sublattices is proportional to the spin of the rare-earth ion, and not to its total angular momentum). The figure shows also the values of the field at which kinks are observed on the magnetostriction isotherms. Taking into account the approximate character of the calculation, the agreement can be regarded as good.

It is shown in [9] that the anisotropic magnetostriction of the dysprosium iron garnet is of the single-ion type, and consequently can be represented as the sum of the magnetostrictions of the rare-earth and the iron sublattices. We can then write for the magnetostriction of a polycrystalline dysprosium iron garnet the relation

$$\lambda = \frac{1}{2}\lambda_s^{\mathrm{Fe}}(3\cos^2\phi_{\mathrm{Fe}} - 1) + \frac{1}{2}\lambda_s^{R}(3\cos^2\phi_R - 1) + \\ + a_\lambda M_R M_{\mathrm{Fe}}\cos(\phi_R + \phi_{\mathrm{Fe}}). \tag{1}$$

The *first two terms describe the single-ion anisotropic magnetostriction* of the iron and rare-earth sublattices, and the last is the volume exchange magnetostriction due to the dependence of the exchange interaction between the sublattices on the interatomic distances; M_{Fe} and M_R are the magnetic moments of the iron and rare-earth sublattices, and θ_{Fe} and θ_R are the angles between the moment of the corresponding sublattices and the field. It must be emphasized that the exchange magnetostriction of the angular magnetic structure, unlike the exchange magnetostriction in the collinear state, is due not to the change of the magnetic moment of the rare-earth sublattice, but to its rotation relative to the magnetization of the iron sublattice (it is shown in [4] that M_R = const in the angular structure). In the calculation of the magnetostriction of the collinear structure, it is necessary to take into account the dependence of the constant of the single-ion anisotropy of the magnetostriction of the rare-earth sublattice λ_s^R on the magnetic moment, since M_R varies quite widely in the investigated field interval. When account is taken of these circumstances, the calculation of the magnetostriction by means of formula (1), using the relations for the magnetization of the collinear and angular structures from [4], is in good agreement with the results of our measurements. We note in conclusion that the magnetostriction of the collinear structure depends differently on the field above and below the compensation points, where $d\lambda/dH > 0$ and $d\lambda/dH < 0$, respectively (Fig. 1). The reversal of the sign of $d\lambda/dH$ is connected with the fact that application of the field increases the magnetic moment of the rare-earth sublattice when $T < \theta_c$ and decreases it when $T > \theta_c$ [11].

[1] S. V. Tyablikov, Metody kvantovoi teorii magnetizma (Methods of the Quantum Theory of Magnetism), Nauka, 1965.

[2] A. A. Gusev, Kristallografiya <u>4</u>, 695 (1959) [Sov. Phys. Crystallography <u>4</u>, 655 (1960)].

[3] A. A. Gusev and A. S. Pakhomov, Izv. AN SSSR ser. fiz. No. 11, 1327 (1961).

[4] A. Clark and E. Callen, J. Appl. Phys. <u>39</u>, 5972 (1968).

[5] K. P. Belov and S. A. Nikitina, Phys. Stat. Sol. <u>12</u>, 453 (1963).

[6] K. P. Belov, M. A. Belyanchikova, R. Z. Levitin, and S. A. Nikitin, Redkozemel'nye ferro- i antiferromagnetiki (Rare-earth Ferro- and Antiferromagnets), Nauka, 1965.

[7] N. F. Kharchenko, V. V. Eremenko, and L. I. Belyi, Zh. Eksp. Teor. Fiz. <u>26</u>, 869

(1968) [sic!].
[8] A. Clark, J. Rhyne, and E. Callen, J. Appl. Phys. 39, 573 (1968).
[9] K. P. Belov and L. P. Shlyakhina, Fiz. Tverd. Tela 11, 975 (1969) [Sov. Phys.-Solid State 11, (1969)].
[10] B. K. Ponomarev and R. Z. Levitin, PTE No. 3, 188 (1966).
[11] K. P. Belov, E. V. Talalaeva, L. I. Chernikova, and V. I. Ivanovskii, ZhETF Pis. Red. 7, 423 (1968) [JETP Lett. 7, 331 (1968)].

ELECTROMECHANICAL EFFECT IN METALS

O. A. Troitskii
Institute of Solid State Physics, USSR Academy of Sciences
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We have investigated the plastic deformation of metals under the influence of electric current pulses. Such investigations are of interest from the point of view of both the study of the electromechanical effect (influence of the electrons on the multiplication, motion, and interaction of dislocations) and the study of the jumplike deformation as one of the most characteristic manifestations of the inhomogeneity of plastic shear.

The experiments were made on single crystals of pure zinc (99.998% Zn) and doped zinc (2 x 10^{-2} % Cd), and on polycrystalline samples of zinc, cadmium tin, lead, and indium with purity not worse than 99.99%. Electric contacts connected to the discharge device were fused into the ends of the samples. Tests for tension and compression at a constant rate of 0.01 cm/min ($\sim$ 0.65%/min) were made with an Instron machine between insulated clamps. The load was determined accurate to 2 g. The samples used in the tension experiments were 15 mm long and 1 mm in diameter. The length and diameter in the compression experiments were 6 and 2.5 mm, respectively.

The employed current pulses had a duration $\sim 10^{-4}$ sec and a strength of 600 - 1800 A in the tension experiments and up to 4800 A in the compression experiments. The average current from pulse to pulse did not exceed 0.3 A. At room temperature, the heat rise of the metal did not exceed 12 - 16°. The samples were cooled with liquid nitrogen.

Figure 1 shows the characteristic tension diagrams of single-crystal zinc. Deformation jumps are seen beyond the elastic region; these increase in magnitude with increasing voltage on the terminals of the discharge source (a bank of electrolytic capacitors). The direction of the deformation jumps and their magnitude indicate an appreciable increment of the plastic deformation at the instant of passage of the current pulse. The places on the diagram at which the tension of the sample has been halted but the current pulses continues to be applied, show only small null jumps after a certain relaxation. The gradual approximately-exponential vanishing of the peaks after the cessation of the tension, and their instantaneous recovery when the tension of the samples is continued, indicate without a doubt that the observed deformation peaks are of dislocation origin.

Anomalously large peaks were observed in the region of the yield point (Fig. 1c). This fact, together with special experiments that have shown that the current pulses have no effect on the elastic part of the deformation curve, offers further evidence of the dislocation nature of the observed phenomenon.