Noncollinearity of sublattices and existence of a domain structure in $Dy_3Fe_5O_{12}$ near the magnetic-compensation point in strong magnetization fields

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We report experimental observation of a domain structure in $Dy_3Fe_5O_{12}$ in strong magnetization fields near the magnetic-compensation point. We show that in a definite temperature range the domain structure that exists in weak magnetization fields vanishes when the field is increased, and then reappears in sufficiently strong fields.

It was shown in[1–5] that in antiferromagnets and ferrimagnets that admit of flipping or turning of the sublattices, a domain structure connected with the existence of metastable or degenerate energy states can appear in sufficiently strong magnetic fields. The appearance of domain structures of this kind was experimentally registered in some antiferromagnets by indirect methods, namely by determining the antiferromagnetic resonance frequencies in dihydrate of copper chloride,[6,8] and by measuring the absorption of ultrasound in hematite.[7,9] The authors of[10], analyzing the results of experiments on magnetooptical investigation of the compensation in $Gd_3Fe_5O_{12}$, have reached the conclusion that the results cannot be attributed solely to the rotation of the magnetization vector as a whole.

We report in this paper the first experimental observation of a domain structure at sufficiently strong magnetic fields in dysprosium iron garnets near the magnetic compensation point $T_c = 230.2\,°K$. The domains were observed visually by a magnetooptical method (by the Faraday effect) at a wavelength 1.15 μ. The employed sample was a plane-parallel plate 0.86 mm thick, cut in the (110) plane; the magnetization field and the wave vector of the light were parallel to the normal to the plate ([110] axis). Photographs of the domain structure at different values of the magnetization, obtained at 299.2 and 229.5 °K, are shown in Fig. 1. In weak magnetization fields we encounter the "usual" domain structure (Fig. 1a) that is observed at any temperature. At $T = 229.2\,°K$, this domain structure vanishes with increasing field (Fig. 1b) but then, with further increase of the field, the domain structure appears anew (Fig. 1c). At temperatures closer to the compensation point (e.g., at $T = 229.5\,°K$), the existence of domains was observed in the entire range of magnetic fields at our disposal, from 0 to 15 kOe (Figs. 1d and 1f). At temperatures slightly exceeding the compensation point, e.g., at $T = 230.9\,°K$, the domain structure existed in weak magnetization fields, vanished in intermediate fields, and again appeared in strong fields. At $|T - T_c| \gtrsim 1\,°K$, the magnetic fields at our disposal were not sufficient to produce a domain structure. [Judging

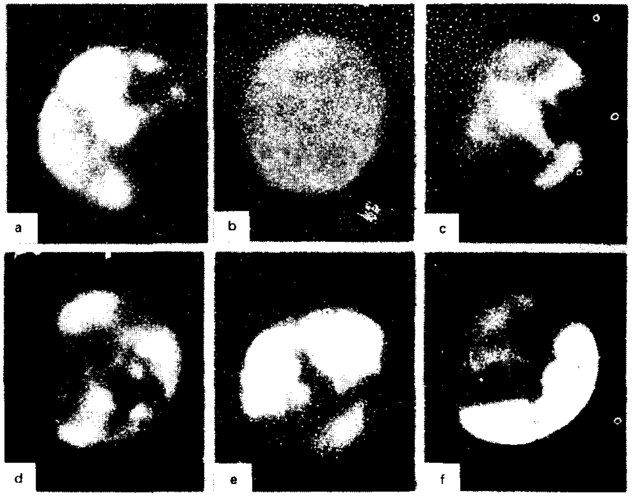

FIG. 1. Photograph of the domain structure in a $Dy_3Fe_5O_{12}$ plate 0.86 mm thick with ten-fold magnification: a, b, c—$T = 229.2\,°K$, $H = 50$ Oe, 10 kOe, 15 kOe; d, e, f—$T = 229.5\,°K$, $H = 5$ kOe, 10 kOe, 15 kOe.

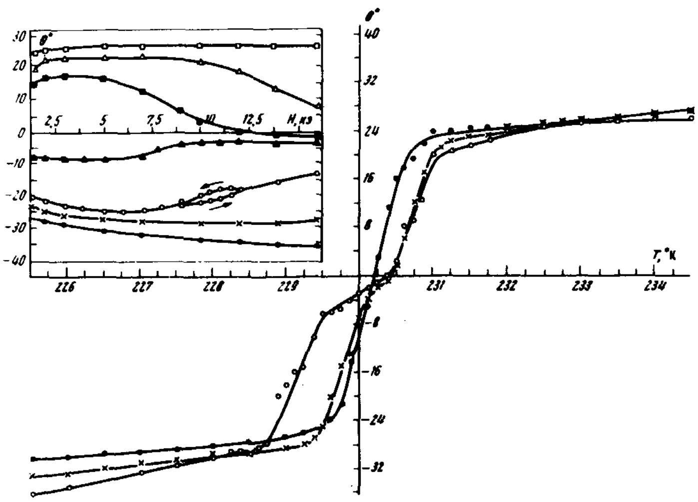

FIG. 2. Temperature dependence of the Faraday effect in a $Dy_3Fe_5O_{12}$ plate 0.86 mm thick: ●—5 kOe, ×—10 kOe, ○—15 kOe. The nsert shows isotherms of the Faraday effect: ●—225 °K, ×—229 °K, ○—229.5 °K, Δ—230 °K, □—230.5 °K, Δ—231 °K, □—235 °K.

from the $(H-T)$ phase diagrams for cubic ferromagnets, the domain structure can be produced in sufficiently strong fields at arbitrary $0<T<T_{Cu}$, where T_{Cu} is the Curie point; the produced domain structure will exist up to sublattice-collapse fields $\sim 10^6$ Oe [5]).

The transition of the ferrimagnet into a noncollinear phase is evidenced by the plots of the temperature dependence of the Faraday effect, shown in Fig. 2. (The plots are shown only for strong fields, when the temperature hysteresis loop existing in weak fields has "collapsed."[5,12,13]) In the general case, the temperature dependence shows breaks at four points. It appears that the outermost points correspond to a transition from the colinear to the noncolinear phase, followed by a rotation in the $(1\bar{1}0)$ plane towards the $[111]$ axis (state I) or towards the $[11\bar{1}]$ axis (state II), while the intermediate breaks corresponds roughly speaking to a reorientation of the noncollinear sublattices from the $(1\bar{1}0)$ plane to the $(\bar{1}12)$ plane (state III—rotation in the direction of the $[1\bar{1}1]$ axis, state IV—rotation in the direction of the $[\bar{1}1\bar{1}]$ axis), or in the $(1\bar{1}2)$ plane (state V—rotation in the direction of the $[\bar{1}11]$ axis and state VI—rotation in the $[1\bar{1}\bar{1}]$ axis). It is easy to understand that states I and II are degenerate in energy, as are also states III, IV, V, and VI. The appearance of states degenerate in energy on going over to the noncollinear phase and the finite transverse dimensions of the samples are indeed the cause of the stratification of the samples into domains. [5] We note that the projection of the ferromagnetic vector on the magnetization field is the same for all domains; only the transverse components of the ferromagnetic vector differ in direction.

The transition of the ferrimagnet into a noncollinear phase is confirmed also by the Faraday-effect isotherms shown in the insert of Fig. 2. We see that when the compensation point is approached a distortion is observed in the shapes of the curves in the region of the paraprocess on the strong-field side, accompanied by hysteresis phenomena (the hysteresis is shown here only for $T=229.5$ °K). The course of the Faraday-effect isotherms agrees fully with the course of the magnetostriction isotherms in $Dy_3Fe_5O_{12}$. [14] Hysteresis phenomena were observed also on the temperature dependence of the Faraday effect in the region of sublattice rotation (not shown in Fig. 2).

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