Domain structure of yttrium iron garnet single crystals

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The optical polarization method and the powder technique are used to investigate the domain and actual atomic-crystalline structures of bulk crystals of yttrium iron garnet. The crystallographic orientation and structure of Bloch walls are studied experimentally. It is established that as a rule, 180-degree boundaries do not have the form of a plane-parallel transition layer, but are bent in the surface regions and at the locations of the Néel lines that separate the subdomains of opposite polarity in a boundary. The experimental data obtained are compared with the results of calculations based on the theory of Landau and Lifshitz. It is shown that the crystallographic orientation of the boundaries corresponds to that predicted theoretically; but the effective width of a wall, measured experimentally, greatly exceeds that found theoretically. It is established that internal stresses due to defects of the crystal lattice may determine not only the mode of division of the crystal into domains, but also the nature of the separation of the boundaries into subdomains of opposite polarity and the behavior of the magnetization in them. It is discovered that under the action of the stresses, Bloch walls broaden, changing to domains of a new magnetic phase. It is shown that the boundaries assume the role of places of nucleation of new domains during reorganizaion of the domain structure under the action not only of stresses, but also of a magnetic field or of illumination of the crystal with visible and near infrared radiation.

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The fundamental principles of the theory of the formation of domain structure in ferromagnets were established in the papers of Landau and Lifshitz.[1,2] Their subsequent development was directed principally toward the calculation of the effect of the specimen surfaces on the shape of the closure domains and the structure of the domain boundaries. It was shown that the magnetic surface charges due to Bloch walls may cause them to divide into sections of opposite polarities[3,4] and may change the behavior of the magnetization near the surface,[5] that for very thin crystals Bloch walls are replaced by Néel walls,[6] etc.

But real crystals possess, besides the surface, a rich spectrum of other defects of the crystal lattice; and these, as is well known,[7,8] influence in a radical manner the magnetization processes of ferromagnets. The study of their influence on the laws of formation of domain structure is only beginning to unfold.

Direct experimental investigation[9,10] of the interaction of dislocations with moving domain boundaries in single crystals of yttrium-iron garnet (YIG) revealed a disagreement between the experimental data and the predictions of the theory,[8] not only in the values of the coercive force but also in the way in which a Bloch wall surmounts a potential barrier due to dislocation-produced microstresses. The theoretical treatment[8] of the effect of dislocations on the displacement of domain boundaries is valid for an idealized situation (an infinite crystal, containing no other defects besides the dislocation and the wall). The observed discrepancies with experiment may be determined by peculiarities, not taken into account in[8], in the structure of the domain boundaries, resulting from the effect of internal stresses, impurities, and the surface. But so far no detailed study has been made[1)] of the characteristics of the domain structure of YIG single crystals and of their correspondence to the theories that have been developed. This is surprising, since the ferromagnetic dielectric YIG is transparent for visible and near infrared radiation and therefore, in contrast to metals, on which an enormous number of investigations have been made to test the basic assumptions of the theories,[1,2] offers the possibility of direct study of the configuration of the domain boundaries and of the distribution of the magnetization in them, not only in the surface layers, but also within the volume of a bulk crystal, for which experimental information is practically nonexistent.

In the present paper, an optical polarization method and powder technique were used to investigate the nature of the domain structure of YIG single crystals, grown from solution in the melt, as it depends on the distribution of growth bands, stresses, and dislocations in them, and to study the crystallographic orientation, form, and width of various Bloch walls and the behavior of the magnetization in them. The experimental data are compared with the predictions of the theories in relation to the most important characteristics of the domain structure.

EXPERIMENTAL METHOD

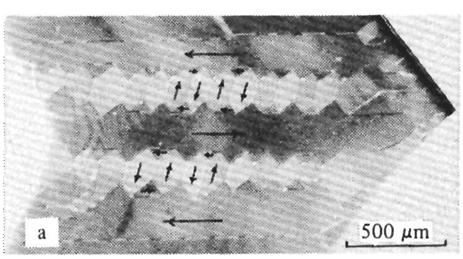
Single-crystal YIG plates of various orientations, polished mechanically and then chemically, were studied in a polarizing microscope. A detailed description of the method is given in[9]. Regions having magnetization components parallel to the direction of propagation of the light were revealed by virtue of the Faraday effect ("Faraday" domains). They showed appreciably more contrast than those analyzed by means of the Cotton–Mouton effect ("Cotton" domains), with magnetization ($\mathbf{M}_s$) lying in the plane perpendicular to the light beam. The structure of domains at the surface of the plates was investigated with powder figures observed in transmitted light.

For study of the behavior of the domain structure in the field of elastic stresses, the YIG plates were cemented to a glass substrate, which was subjected to the effect of four-point or symmetric bending. The symmetric bending was accomplished by use of a circular fulcrum and a circular die.

RESULTS AND THEIR DISCUSSION

1. *Structure of domain configurations.* Figure 1a shows a typical picture of the domain structure of a single-crystal (110) YIG plate (thickness 35 μm) in polarized light. The main volume of the specimen is occupied by Cotton domains of regular form, with magnetization vectors lying along the allowed easy axes of the type $\langle 111\rangle$. But it is to be noticed that the domain structure is not realized in the form of 180-degree neighborhoods of a single type, with closure of the magnetic flux only at the edges of the plates as predicted for an ideal ferromagnet. The appearance of such peculiarities leads to an increase of the energy of the crystal, as compared with that expected theoretically for a defect-free crystal, by the amount of the energy of the additional boundaries and of the incompatible magnetostrictive deformations. The advantageousness of their occurrence is determined by the internal stresses that act in the material in consequence of the nonuniform distribution of impurities. Figure 1b shows a picture of the stresses, revealed by virtue of the piezo-optical effect, in a specimen magnetized to saturation. It reflects the stratification in the impurity distribution that inevitably occurs in the crystallization process.

A growing crystal forces an impurity back into the melt. Its content near a phase interface increases, and as a result there is attained a concentrational supercooling and crystallization of a layer enriched with point defects. This process repeats many times. The microstratification in the impurity distribution is detected in selective chemical etching (Fig. 2) and serves as a source of internal stresses: the mean interatomic distances in layers with different impurity content are different. As a result, compressed and expanded layers alternate in the crystal along the crystallization direction.



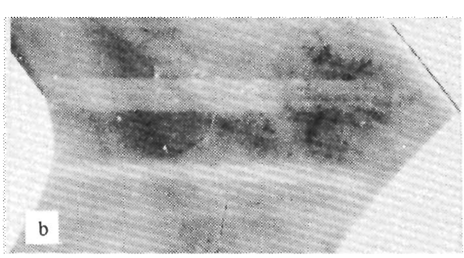


FIG. 1. Domain structure (a) and internal stresses (b) in a plate of YIG.

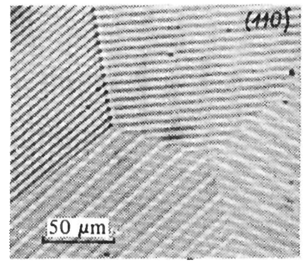


FIG. 2. Growth bands, revealed by chemical selective etching on the surface of a (110) plate of YIG, reflecting sectorial growth of the crystal.

The stratification shown in Fig. 1b is determined by a macroscopically inhomogeneous distribution of impurities caused by random variations of the temperature field, of the convection currents, etc. It is clearly evident that domains with selected (not dictated by conditions at the surface) directions of $\mathbf{M}_s$ are located in sections with a definite type of stresses from the growth bands. In the light regions, tensile stresses act along the bands; and since the magnetostriction constants in YIG are negative, in a (110) plate one of the $\langle 111\rangle$ axes of easy magnetization is realized that lies close to the normal to the direction of tension. In a number of cases, there may also occur in specimens[13] Faraday domains that are accompanied by closure domains located not on the ends of the crystal, with minimum area, but close to the surface. It is obvious that for a defect-free plate, such a variant is not in thermodynamic equilibrium. The examples presented show the erroneousness of the conclusion of some authors,[14] who have denied the influence of growth bands on the magnetic anisotropy of YIG and have attributed the occurrence of induced anisotropy to an ordered arrangement of defects in growth sectors.

An important source of destruction of the uniformity of the domain structure is dislocations. Arising during the crystallization process, they are as a rule distributed nonuniformly throughout the volume of a crystal grown from solution in the melt. In parts with a large density of dislocations, the character of the domain structure is determined principally by them.[13]

The situation described shows that in garnets grown from solution in the melt, it is practically impossible to carry out a test of the dependence of the domain width on the crystal dimensions, since the formation of the domain structure depends not only on the external shape of the specimens but also on imperfections of their crystal lattice.

The structure of the domains at the edges of the YIG plates, for given structure in the volume, is determined in large measure by the conditions of magnetic flux closure near the surface. In YIG crystals it is possible to observe both the forms of closure considered in the theory and also ones not described in the literature. In specimens with a sharp edge, it can be accomplished (Fig. 3; see also[15]) by stratification of the basic domains through the thickness and cyclic transfer of magnetic flux through Faraday domains. Magnetic flux closure according to this scheme is realized only in

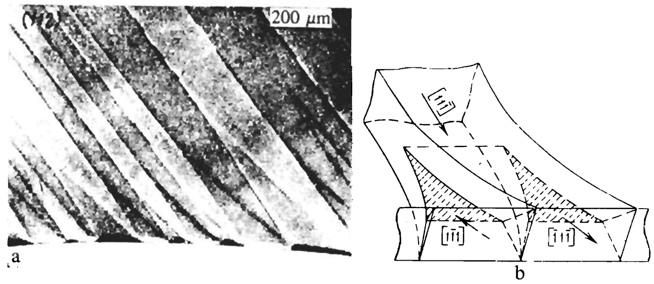


FIG. 3. Form in polarized light (a) and model (b) of closure domains at the edge of a plane-parallel (112) plate.

plates whose thickness does not exceed a certain critical dimension, at which formation of domains of other forms becomes more advantageous. At the edges of specimens polished to a wedge, there appears the tendency toward branching of domains predicted in[2,16] (Fig. 4).

2. *Domain boundaries*. Until now, experimental study of the structure of domain walls has been chiefly carried out either on thick specimens of opaque ferromagnets, where the structure of boundaries on the surface was investigated by the powder method and by the magneto-optic Kerr effect, [17] or on thin films, where the boundary differs essentially from the Bloch walls in bulk crystals. [7] We made an attempt to carry out a test of the basic assumptions of the theory in its application to domain boundaries within the volume of thick plates of YIG. The domain walls were investigated on the basis of an analysis of the intensity of the Faraday effect for light transmitted along the plane of the boundary. The place of exit of the transitional layer at the surface of the plates was recorded by the powder technique. The thickness of the plates investigated was from 30 to 1000 μm.

YIG single crystals have a magnetic symmetry similar to the symmetry of nickel. The boundaries most often encountered in YIG plates and most convenient for magneto-optical investigation are 180-, 109-, and 71-degree boundaries separating Cotton domains. For the specimen thicknesses indicated, these walls should be of the Bloch type. The calculation of the spin distribution in the boundaries and the search for the most advantageous distribution within the volume of YIG were carried out by use of the theoretical model of[1], specialized for application to single crystals of Ni. [18,19] In order to satisfy the basic condition—conservation of the value of the component of the vector $\mathbf{M}_s$ normal to the plane of the boundary—it is supposed in this model that the turning of $\mathbf{M}_s$ within the transitional layer occurs in such a way that it can be described as the motion of generators of a cone whose axis is perpendicular to the plane of the wall. Under these conditions, the distribution of $\mathbf{M}_s$ and the energy γ of the boundary can be described by the expressions

$$z=\sin\theta\int_0^{\varphi}(A/\Phi)^{1/2}\,d\varphi \qquad (1)$$

and

$$\gamma=2\sin\theta\int_{\varphi_1}^{\varphi_2}(A\Phi)^{1/2}\,d\varphi. \qquad (2)$$

Here the z direction is along the axis of the cone; θ is the angle between the vector $\mathbf{M}_s$ and the normal to the plane of the wall (its value doubled is the angle of the cone); φ is the angle between the projection of the vector $\mathbf{M}_s$ on the cone base and the chosen initial direction (the x axis); φ_1 and φ_2 are the values of φ in adjacent domains; $A=0.34\cdot10^{-6}$ erg/cm[20] is the exchange-interaction constant; and $\Phi=K_0+K_1(\alpha_1^2\alpha_2^2+\alpha_2^2\alpha_3^2+\alpha_1^2\alpha_3^2)$ is the crystallographic magnetic-anisotropy energy, where $K_0=|K_1|/3$, $K_1=-6.7\cdot10^3$. [21] The dependence of the direction cosines α_i of the vector $\mathbf{M}_s$ on the angles θ and φ for various boundaries is expressed in terms of appropriate trigonometric functions. [19]

For 180-degree boundaries, magnetostrictive deformations were taken into account by addition to the expression for Φ of a term $(9/2)c_{44}\lambda_{111}^2\cos^2\varphi$, [18] where $c_{44}=7.64\cdot10^{11}$ dyn/cm^2 [22] and $\lambda_{111}=-2.4\cdot10^{-6}$. [23]

To find the energetically advantageous position of the boundaries in the crystal, the value of γ was calculated as a function of the angle ψ of rotation of the boundaries about the line of intersection of the plane of the wall with the surface of the plate—the y axis ($\psi=0$ when the plane of the boundary coincides with the plane of the plate). Allowance for the change of area of the boundary when it departed from the normal to the plane of the plate by various angles (ψ) was made by multiplying the expression (2) by the value of $(1/\sin\psi)$. In the case of a 180-degree boundary, the functions $z(\varphi,\psi)$ and $\gamma(\psi)$ were obtained from (1) and (2) by integration by quadratures[18]; the calculation of these quantities for 109- and 71-degree boundaries was done by machine calculation. The results of the calculation are given in Figs. 5 and 6.

It is seen that in YIG plates cut parallel to a (110) plane, 71-degree boundaries should be inclined to the (110) plane at an angle $\psi=50°$ to $70°$ and 109-degree boundaries at $\psi\approx80°$, and 180-degree boundaries should practically coincide with the normal to the plane of the plate. The calculations made for a 180-degree boundary, separating Cotton domains in a (112) plate, showed furthermore that in this case the advantageous position of the boundary is $\psi=90°$ (curve 3).

For experimental test of these calculations, YIG

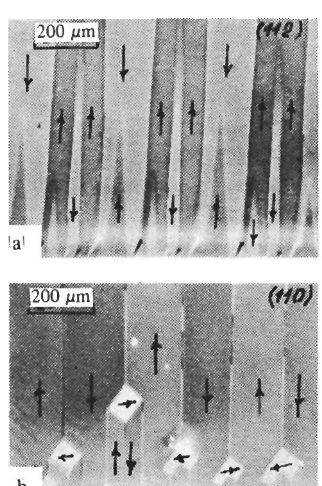


FIG. 4. Closure domains at wedge-shaped edges of (112) plates (a) and (110) plates (b).

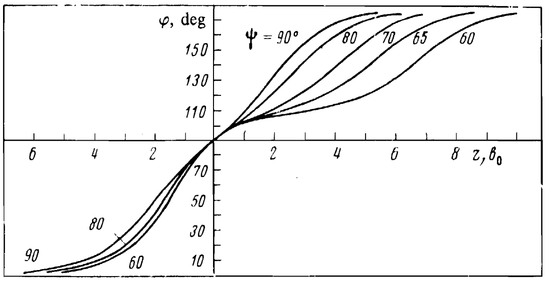


FIG. 5. Magnetization distribution in a 180-degree boundary, calculated on the basis of (1) with allowance for the angle (ψ) of inclination of the boundary with respect to the surface of a (110) plate; $b_0 = (A/K_1)^{1/2}$.

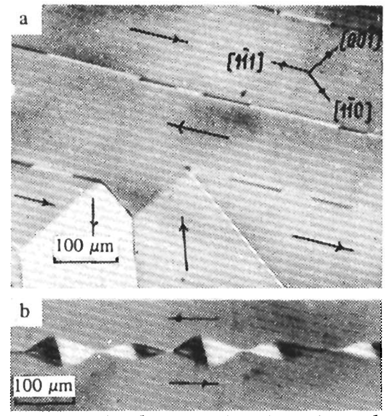


FIG. 7. a, domain structure in a plate of YIG, revealed in polarized light. b, formation of domains of a new magnetic phase at Néel lines of a 180-degree boundary, caused by nonuniform internal stresses. Nicols uncrossed.

plates were placed in a glycerine medium between spherical segments of a Fedorov stage, and the image of the boundaries in a polarizing optical microscope was studied at various inclinations of the crystal around a line corresponding to the y axis (chosen above for each type of boundary). The typical form of these boundaries in polarized light, with nicols slightly uncrossed, is shown in Fig. 7a. Each type of boundary has its own characteristic features: a 71-degree boundary is imaged in the form of a band of nonuniform intensity, parallel to direction [001]; a 109-degree boundary is visible in the form of a contrasting strip of uniform thickness and intensity (white or black, depending on the direction of rotation of the analyzer from the position corresponding to crossed nicols), located along direction [1$\bar{1}$0]; a 180-degree boundary, as distinguished from a 109-degree, consists of segments of alternating color and nonuniform thickness. Observation of these boundaries in different directions and study of powder deposits on the plate surfaces made it possible to explain these peculiarities.

71-degree boundaries are always inclined to the plate surface by an angle $\psi \approx 55°$ to $62°$, corresponding to the minimum calculated values of $\gamma(\psi)$. (In Fig. 6 the experimentally observed range of values of ψ for the boundaries is marked by the scales placed over curves 2 and 3.) In transillumination of a (110) plate in the direction perpendicular to its surface, the inclination of a 71-degree boundary leads to the result that the light beam crosses sections of the crystal with different orientations of the optical indicatrix, corresponding to different directions of $\mathbf{M}_s$ in adjacent domains. This causes the appearance of contrast in the form of a band whose width is equal to the projection of the boundary. It is the appreciable inclination of the 71-degree walls, and not a Néel type of distribution of $\mathbf{M}_s$ in them, as was supposed in[12], that causes the absence of sharp Faraday contrast in the image of these boundaries. When the light is propagated along the plane of a 71-degree boundary, a large rotation of its plane of polarization is observed (Fig. 8); this is evidence of a Bloch-type rotation of $\mathbf{M}_s$ in the boundary.

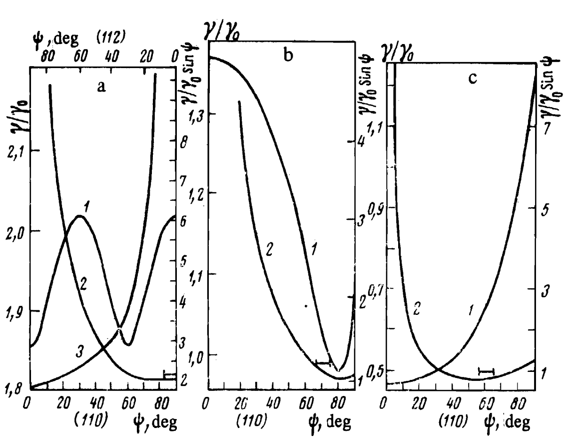


FIG. 6. Orientational dependence of the energy (γ) of 180-degree (a), 109-degree (b), and 71-degree (c) Bloch walls (in units $\gamma_0 = (AK_1)^{1/2}$), calculated on the basis of (2) for infinite YIG crystals (1), for (110) plates (2), and for (112) plates (3). The scale (|—|) indicates the experimentally observed range of values of ψ, describing the actual arrangement of boundaries in a crystal.

The position of 109-degree boundaries in (110) plates also corresponds to the values, $\psi \approx 80°$ to $75°$, obtained in the calculations. The bright intensity of their color is explained by the presence of a component of $\mathbf{M}_s$ parallel to the direction of propagation of the light. The presence of color uniform in sense in 71- and 109-degree boundaries is a demonstration of the fact that on departure of these boundaries from the (1$\bar{1}$0) or (001) plane, respectively, rotation of the vector $\mathbf{M}_s$ along the cone becomes nonequivalent for "right" and "left" directions of rotation. (An analogous situation was predicted for 90-degree boundaries in iron.[24]) Observation of both types of rotation simultaneously is possible only in 109-degree boundaries not in thermodynamic equilibrium, arranged parallel to a (001) plane.

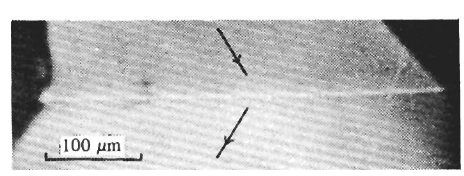


FIG. 8. Form of a 71-degree boundary in polarized light, when its plane coincides with the direction of the light beam. Nicols crossed.

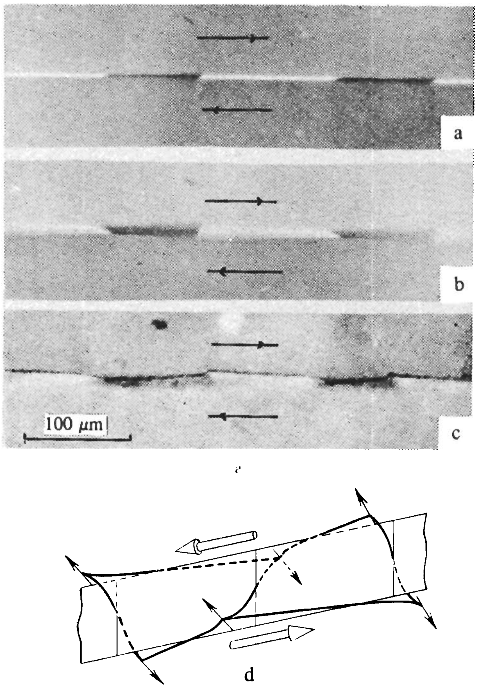


FIG. 9. Image of a 180-degree boundary in polarized light when its plane is parallel to the direction of observation (a) or inclined to the light beam (b, c). The exits of the boundary at one surface of the plate in Fig. 9c coincide with the traces of a powder suspension. Nicols uncrossed. d, model of the observed boundary.

The structure of 180-degree boundaries proved the most interesting. Their nonuniform image, both with respect to the sign of the Faraday component of $\mathbf{M}_s$ and with respect to thickness, indicates a complicated distribution of $\mathbf{M}_s$ in the boundary, not only in the direction perpendicular to the wall but also along the other two coordinates. Figure 9 shows how the image of a 180-degree boundary in polarized light varies with different inclinations of the plate. It is seen that the boundary is characterized by maximum intensity of the Faraday effect when it is examined in the [100] direction (Fig. 9a). On inclination of the boundary about the direction $[1\bar{1}1]$, parallel to the y axis, its image broadens, and simultaneously the intensity of the color weakens. During this, as is seen in Fig. 9b, the edge of the narrower sections of the boundary image "shines" more brightly than the boundary as a whole. On inclination of the boundary in the other direction, the narrow sections broaden and the broad become narrower. An example of powder deposits at places of exit of a 180-degree boundary to the surface of the specimen is shown in Fig. 9c.

On the basis of such experiments, the shape of the 180-degree boundary "surface" was constructed; a fragment of it is shown in Fig. 9d. From it it is seen that the sections of the boundary in which there occurs a change of the direction of rotation of $\mathbf{M}_s$, and which are sometimes called Néel[4] or Bloch[3] lines, are lines of complicated configuration, which do not coincide with direction [110] and do not lie in plane (112), with respect to which the boundary in the surface regions of the specimen is inclined in one or the other direction. A 180-degree boundary in YIG plates cut along plane (112) is also imaged in a manner similar to that described above. The difference consists only in the fact that in this case the "basal plane" of the 180-degree boundary is the plane (110).

For experimental determination of the distribution of $\mathbf{M}_s$ in a boundary and of the wall width, only 180-degree boundaries were used, because the width of their image is greatest as compared with 71- and 109-degree boundaries. The sections of Bloch walls studied were those farthest removed from Néel lines. The sections of boundaries under study were set strictly along the direction of observation and were photographed on film in polarized light. The negative image of the boundary was measured photometrically on an "MF-4" microphotometer.

Figure 10 shows one of these experimental curves, reflecting the distribution through the thickness of the boundaries, i.e., in the direction of the z axis, of the intensity of the Faraday effect. Also given here is the theoretical curve 2 calculated on the basis of the function $z(\varphi)$ of Fig. 5. It is seen that the experimentally determined width of the boundary exceeds the theoretical by about three times. This discrepancy cannot be explained by the effect of diffraction of light at the boundary. An objective with aperture $A_0 = 0.85$ and light with wavelength $\lambda = 0.55$ μm were used in the experiment. Therefore the optical resolution of the microscope, $\lambda/A_0 = 0.65$ μm, is sufficient for analysis of objects of size ≈ 2 μm.

The data presented attest to the fact that although the 180-degree boundaries in the (110) and (112) YIG plates investigated are indeed arranged approximately along {112} and {110} planes, respectively, as the theory predicts (Fig. 6), nevertheless their structure cannot be described as a plane transitional layer with uniform (along the layer) distribution of $\mathbf{M}_s$. The experiment gives qualitative corroborations of the predictions of the theories[3,4] regarding the nature of the influence of the surface on the structure of Bloch walls. The stray fields that occur in sections of the boundaries that intersect the crystal surface determine their division into subdomains of opposite polarities. Experimental verification of the predictions of the theory[4] with respect to the relation of the periodicity parameter of the boundary structure to the thickness of the crystal does not seem possible, because the arrangement of the Néel lines is significantly influenced by the real atomic-crystalline structure of the material.

The possibility of significant twisting of the boundaries, like that shown in Fig. 9d, in a region of Néel lines near the surface, was treated in[3] as a means of

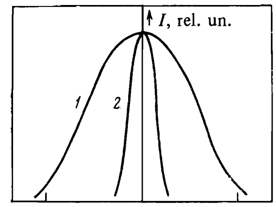


FIG. 10. Intensity distribution of the Faraday effect in a 180-degree boundary in the direction perpendicular to its plane: (1), measured; (2), calculated theoretically from the data of Fig. 5.

additional neutralization of the magnetic stray fields that occur in sections of exit of the walls to the surface of the crystal.

In the light of the results obtained, it seems probable that the interaction between dislocations and a Bloch wall, observed in[19], at distances exceeding the width of the wall image, is determined by peculiarities of structure of the boundaries in the surface layers of the specimen; this structure may change still further in the field of dislocation-caused microstresses. In Fig. 11 it is seen that the intensity of transillumination of a "domain" that connects a dislocation with a 180-degree boundary is appreciably less than would be expected if it penetrated the whole depth of the crystal (it corresponds approximately to the intensity of color of the boundary).

The method used did not permit a study of the magnetization distribution in the surface layers; this would provide a possibility of testing whether YIG single crystals exemplify the method proposed in[5] for decrease of the magnetostatic energy of a wall, by change of the type of rotation of $\mathbf{M}_s$ in the boundary from the Bloch type in the bulk of the ferromagnet to the Néel type at the surface. In this case the effective thickness of the transitional layer broadens at the surface. Some corroborations of the model[5] have been obtained by use of the magneto-optical Kerr effect[17] on iron and hematite crystals.

It is obvious that the appreciable discrepancy observed in our experiments between theoretical estimates and experimental data for the thickness of Bloch walls in the bulk of the specimen cannot be explained solely by the effect of the surface on the function $z(\varphi)$. It seems to us that the principal cause of the disagreement between curves 1 and 2 in Fig. 10 may be the effect of internal stresses on the state of the domain boundaries.

Investigation of a large number of 180-degree Bloch walls revealed an appreciable spread in the measured values of boundary thicknesses—from 2 to 10 μm (Fig. 10 gives the $z(\varphi)$ curve for the narrowest boundary). In many cases, in a region where nonuniform stresses act, there occurs a gradual widening of the wall, formation at the boundary of domains of a new magnetic phase.

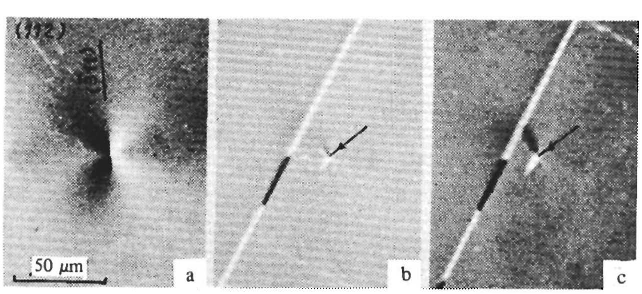


FIG. 11. Formation of a domain of a new magnetic phase between an edge dislocation and a 180-degree boundary in a plate of YIG. a, Birefringence rosette around the dislocation in the specimen magnetized to saturation; nicols crossed. b, crystal demagnetized; position of the dislocation shown by the arrow. c, boundary pushed toward the dislocation by a magnetic field. Nicols uncrossed in b and c.

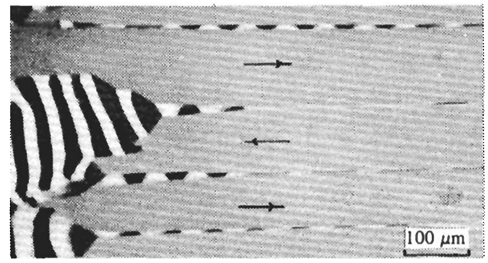


FIG. 12. Transformation of 180-degree Bloch walls to domains of a new phase under the action of uniaxial tensile stresses acting parallel to the vectors $\mathbf{M}_s$, which lie in the plane of the plate. Nicols uncrossed.

This happens especially easily and frequently in sections where Néel lines are located (Fig. 7b). The decisive role of stresses in the formation of anomalously wide boundaries shows up most graphically in the experiments described below, in which a crystal was deformed by external forces for the specific purpose of producing a definite stress field in it.

3. *Effect of external stresses on the domain structure of* YIG. Figure 12 shows the change of domain structure of a (112) plate under the influence of tensile stresses acting along the direction $[11\bar{1}]$ in its plane. It is seen that the stresses produce a gradual reorganization of the Cotton domain structure (gray regions of the crystal) into a Faraday (black-white regions). The 180-degree boundaries between Cotton domains assume the role of regions of nucleation of domains of a new magnetic phase: gradually broadening, segments of Bloch walls of opposite polarity are transformed to Faraday domains. Diminution of the stresses leads to the reverse reorganization of the domain structure, which concludes with transformation of the Faraday domains to segments of 180-degree boundaries between Cotton domains.

With symmetric extension of (111) plates, domains of a 180-degree neighborhood with $\mathbf{M}_s$ at an angle $\sim 29^\circ$ to the plane of the plate (Fig. 13a) are transformed to 180-

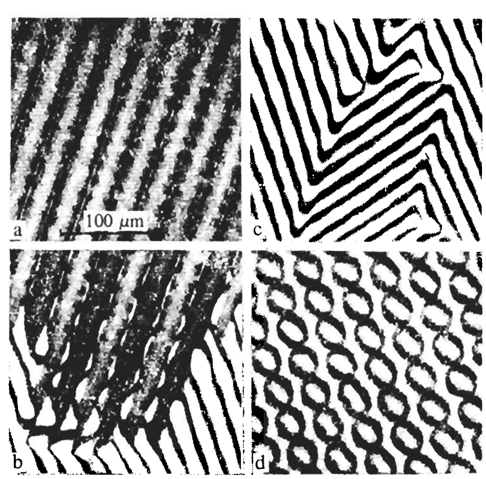


FIG. 13. Change of domain structure in a (111) plate under the action of a centrally symmetric tension. The stresses increase from a to d. The CMD appeared under the action of a magnetic field normal to the plane of the plate.

degree domains with magnetization vectors perpendicular to the plane of the specimen. Just as in the case described above, the reorganization begins by formation of domains of a new phase in sections of the original Bloch walls. At a certain value of the deformations, in fields close to the saturating fields, from this structure are formed cylindrical magnetic domains (CMD). At first they are localized in separate sections of the crystal, but at large stresses they occupy its whole area (Fig. 13d).

As is well known,[25] a structure with domains of cylindrical shape is formed in crystals with uniaxial anisotropy—orthoferrites and dilute garnets, which are used for the production of new electronic-computer memory elements. The CMD lattice shown in Fig. 13d is distinguished by a peculiarity: it possesses closure domains. Their appearance is evidence that the level of the applied stresses does not yet insure satisfaction of the condition for existence of open CMD structures ($K > 2\pi M_s^2$).

The data described convincingly attest to the very strong influence of stresses on the magnetization distribution in Bloch walls. In the example shown in Fig. 12, the thickness of a 180-degree boundary changes continuously from $\sim 2\ \mu$m to values at which it is transformed to two (71- and 109-degree) boundaries, separated by a full-fledged domain (its size is of the order of the plate thickness).

The formation and growth of domains of a new phase in sections of boundaries occurs not only under the influence of stresses, but also under other forms of action on the crystal—an external magnetic field, intense illumination by visible and near infrared radiation. In all cases the most mobile elements of the domain structure, the primary responders to a change of conditions, are the sections with the largest magnetic inhomogeneity: Néel lines, junctions of boundaries of different type

CONCLUSION

Thus in the present research a direct experimental proof has been obtained of the important influence of internal stresses, due to defects of the crystal lattice, on the structure of Bloch walls in single-crystals of ferromagnetic YIG. The decisive role of internal stresses in the formation of magnetization processes of ferromagnets has already been known for a long time. But the only factors considered were the changes in the character of the domain distribution caused by the additional magnetoelastic energy and the necessity for the boundaries to surmount a potential barrier due to the internal stress field. The investigation made has shown that they can also lead to a significant readjustment of the behavior of the magnetization within a Bloch wall. It has been shown that boundaries assume the role of effective sources of nucleation of domains of a new magnetic phase during reorganization of the domain structure (by a gradual development of a Bloch wall into a domain). This theoretically unstudied mode of remagnetization of a crystal is apparently not specific to YIG alone: the majority of theoretical predictions with respect to the characteristics of domain structure are in qualitative, and in some cases in quantitative, agreement with the experimental data described. The unique possibilities provided by YIG for direct study of the domain structure in bulk crystals have merely facilitated the explanation of the peculiarities noted.

1)In a number of communications[11,12] there is a merely qualitative description of certain pecularities of its domain structure.

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