Light-induced dynamic instability of the domain structure in $FeBO_3$: Ni

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Light-induced instability is observed in the domain structure of the crystal $FeBO_3$: Ni, observed in polarized light, in the form of propagating wave excitations in the spin system, whose parameters depend on the intensity and wavelength of the light, external magnetic field, and temperature.

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Iron borate belongs to the class of photosensitive crystals whose magnetic properties change under illumination. The investigations of the influence of light on the magnetic susceptibility[1] and magnetoacoustic resonant frequency[2] in this crystal were interpreted as decrease in the magnetocrystalline anisotropy in the direction of the ferromagnetic moment. At the same time, the behavior of the domain structure of the crystal under these conditions remained unclear. In this letter we attempt to resolve this problem using direct observations.

The specimen studied consisted of single crystals of $FeBO_3$ with a small admixture of Ni (less than 0.1%), introduced in order to increase the photosensitivity.[3] The single-crystalline plates were 40 μm thick and had linear dimensions of 1–1.5 mm; the plane of the plates coincided with the basal plane of the crystal. The specimens were placed in cryostat on the coolant conduit whose temperature was regulated within the range 78–350 K. The image of the crystal was recorded in low-intensity polarized light either visually or on photographic film with the help of the optical system. The exciting radiation from incandescent lamps focused on the specimen with intensity 10^{-3} W/cm^2.

1. At a temperature of $T = 78$ K the observed domain structures (DS) differed little from the DS at room temperature and were consistent with the description of domains in these crystals given by Scott[4] (Fig. 1a). When the illumination was switched on, some of the walls of the observed DS experienced jumps and moved over appreciable distances (Fig. 1b). In addition, the appearance of substructures in the form of thin bands with different constrasts were recorded on the same photograph. The bands represent a moving lattice with constant spacing and different directions of motion. The velocity of the bands is tens of microns per second and increases with increasing intensity of the exciting optical radiation. The direction of motion is perpendicular to the band structure and can reverse in a specific direction for no apparent reason. There are no discontinuities in the substructure accompanying these changes: It moves as a unit. The sources and sinks of the moving bands are the walls of macrodomains and surface defects of the crystal. The magnitude of the spacing of the moving lattice differs slightly in different areas of the specimen and on the average consti-

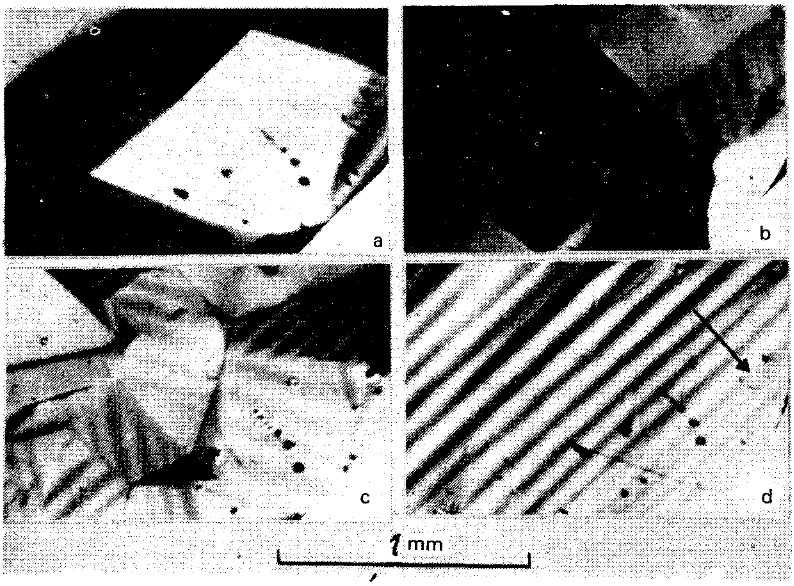

FIG. 1. Development of domain structure in the crystal $FeBO_3$: Ni under illumination. (a–c) Without an external magnetic field; (d) with a field $H = 8$ Oe applied in the direction indicated by the arrow.

tutes several tens of microns. By changing the azimuth of the polarizer relative to the crystallographic C_2 symmetry axis, it was established that the contrast redistributes between three systems of bands, in which the directions of motion are oriented relative to each other at 60 or 120°. Figure 1c shows all three systems of moving bands. When a filter is introduced into the exciting light flux, cutting off the near IR region, the motoin of both the band substructure and of the walls of the macrodomains ceased. At the same time, the resulting distribution of DS remained static and could be conserved during the experiment (8 h). By separating out the different sections of the emission spectrum of the incandescent lamp with the help of light filters, it was established that the spectral region 0.8–1 μm was most effective in exciting the dynamics of the induced substructure.[1)] When a magnetic field is applied to the basal plane simultaneously with the "active" illumination, the domain walls of the macrostructure are displaced with the enlargement of domains magnetized along the field and development of a system of bands whose direction of motion is close to the direction of the field. When this field is rotated in the basal plane, there is a smooth transition from one moving system to another. Figure 1d shows a photograph of the photoinduced dynamic structure in a magnetic field $H = 8$ Oe, oriented perpendicular to the moving bands (along the arrows). With further increase in the magnetic field, the spacing of the moving lattice increases slightly and the contrast between bands decreases. In fields $H \approx 60$ Oe, the specimen becomes uniform in contrast. If the field is subsequently decreased, first we see a band substructure, which in moving fills the entire surface of the specimen, and then we see the usual DS in the small fields. When the active illumination is switched on in $H = 0$, the motion of the substructure ceases and saturation of the specimen to a homogeneous state occurs in much lower fields $H \approx 20$ Oe.

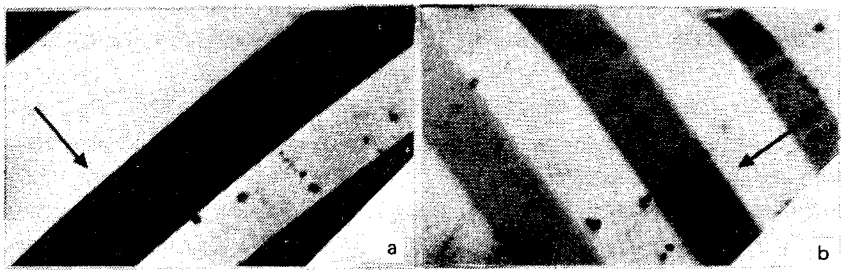

FIG. 2. Photograph of the domain structure forming after illumination of a specimen in saturating magnetic fields. The orientation of the magnetic fields at the same time of illumination is shown by the arrow in each photograph.

When the temperature of the specimen increases, the light-induced dynamics of DS exists up to temperatures $T \approx 130$ K and with further increase in temperature the static band structures, created by the active illumination at $T = 78$ K, disappear.

2. In order to clarify the problem of the direction of the easy axis of light-induced magnetic anisotropy in this crystal, we performed the following experiment. The specimen was saturated in a magnetic field $H = 100$ Oe and illuminated with white light for several minutes. After switching on the illumination, the magnetic field was removed and the DS subsequently formed was observed. The results are shown in Fig. 2. This figure shows a photograph of the DS formed after illumination in mutually perpendicular fields, whose orientations are indicated by arrows. In contrast to the DS shown in Fig. 1(a), the domains in this case are produced in the form of macrobands, which in both cases are oriented perpendicular to the magnetic field applied at the time of illumination. From an analysis of the changes in the magnetooptical contrast in the domains formed under different inclinations of the specimen relative to the direction of propagation of the visualizing light, it follows that the ferromagnetic moment in the domains is oriented parallel to the direction of the axes of the bands, i.e., normal to the magnetic field applied at the time of illumination.

3. Thus, by direct observations under illumination of the crystal $FeBO_3$: Ni, we observed the instability of the domain structure and the appearance of wave excitations in the form of moving bands of different contrast. Since the external magnetic field affects the parameters of the dynamic band substructure, it can apparently be viewed as a light-induced wave process in a spin system of weakly ferromagnetic $FeBO_3$: Ni. The formation of DS in the form of parallel macrobands after illumination in the saturated state indicates that an uniaxial magnetic anisotropy, whose easy axis in contrast to other photosensitive crystals is induced in a direction perpendicular to the external magnetic field applied at the time of illumination, is induced in the specimen. Therefore, under continuous illumination of the crystal, a magnetic-anisotropy field, which is always oriented normal to the ferromagnetic moment and which creates a rotational moment in the spin system, is induced. The instability arising in this manner is realized in the form of long-wavelength excitations in the spin system.

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1) A peak in the photosensitivity of the change in the magnetic susceptibility is located in this region.

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