Dynamics of domain structures in iron-garnet films

L. P. Ivanov, A. S. Logginov, V. V. Radnoshkin, and R. V. Telesnin

Moscow State University
(Submitted April 25, 1976)
Pis'ma Zh. Eksp. Teor. Fiz. **23**, No. 11, 627–631 (5 June 1976)

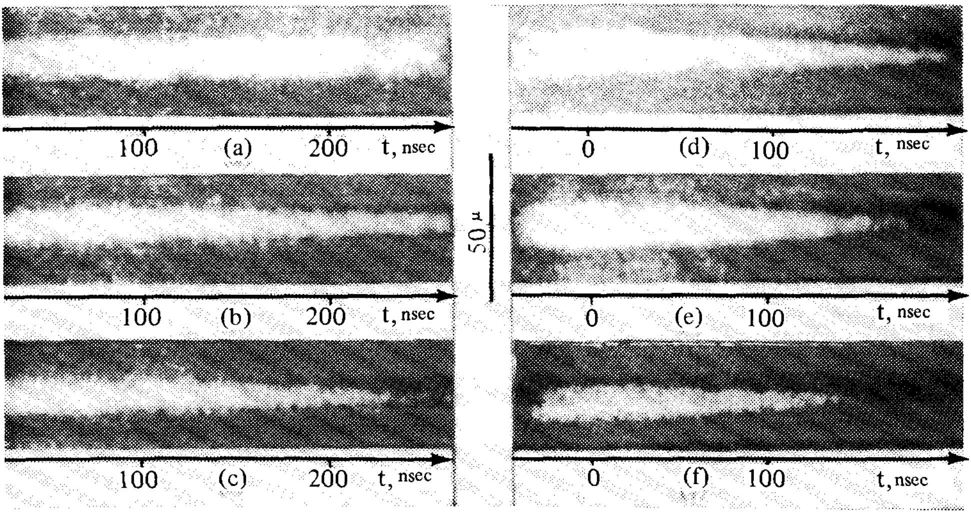
We investigated the behavior of domain structures in iron-garnet films under the influence of a pulsed magnetic field, by directly observing the dynamic domains with the aid of a magneto-optical setup using an image converter and a semiconductor injection laser.

PACS numbers: 75.60.Fk, 75.70.+j, 07.45.+r

Dynamic domains in iron-garnet films are registered as a rule by high-spee photography.[1–3] The changes produced in the investigated objects by the heat of the laser radiation can be avoided by using an image converter with brightness intensification.[4]

We have investigated the behavior of the domain structures in iron-garnet films in pulsed magnetic fields by directly observing the dynamic domain via the Faraday effect. By using as the illumination source a semiconductor injection laser with a double heterojunction based on GaAs—GaAlAs, operating at a wavelength $\sim 0.9\ \mu$, we were able to regulate easily the duration of the optical pulse in the range 5—500 nsec by varying the length of the laser pump pulse. The image of the domain structures was focused on the photocathode of the image converter. We used an image converter with an enhancement of the brightness (by a factor 10^5) and with a system for deflecting the electron beam This made it possible not only to obtain photographs of the dynamic domains by light from a single laser pulse of 10—20 nsec duration and power not larger than 10 W, but also, in contrast to[1–4], to register time scans of the images c one-dimensional objects, for example, of the diameters of cylindrical magneti domains (CMD). The one-dimensional image was cut out with the aid of a slit placed in the focal plane. The time scan of this image was obtained by applyin a sawtooth voltage on the deflecting plates of the image converter. To decreas the noise level, the image converter was operated only for a time interval slightly longer than the duration of the optical pulse. The pulses of the magnetic field, the laser pump current, and the sawtooth voltage were strictly synchronized with one another. Their relative time position was varied with the aid of delay lines. The pulsed magnetic field was produced by a 20-turn coil having a 2 mm diameter and located near the surface of the film.

When random and nonrepeating processes are investigated, the procedure yields data on the initial domain structure, its configuration at some instant o time during the time of action of the magnetizing pulse or after its terminatio and the resultant domain structure. In the investigation of the behavior of CMI in a homogeneous pulsed magnetic field, registration of the time scans of the CMD image makes it possible to determine, by applying only a single field pulse, the dependence of the CMD diameter on the time and, by the same



IG. 1. Time scans of CMD image under the action of pulsed fields with dif-
rent amplitudes: a) $H_p = 0$, b) 200 Oe, c) 400 Oe, d) 600 Oe, e) 800 Oe,
1000 Oe. The bias field is ~100 Oe.

ken, the radial velocity V of the CMD walls, whereas the procedure of[3] elds only the CMD diameter at a certain instant of time.

When a magnetic-field pulse of amplitude 100—1000 Oe is applied, the CMD ameter varies linearly with time. The velocity V increases with increasing ılsed field, with a differential mobility 1—5 cm sec^{-1} Oe^{-1}. Figure 1 shows ıotographs of the time scans of the CMD image in a film of composition $_{1.0}Gd_{1.1}Yb_{0.6}Bi_{0.3}Ga_{0.15}Al_{0.7}Fe_{4.15}O_{12}$ (thickness $h = 20\ \mu$, saturation magnetiza- on $4\pi M_S = 175$ G, CMD collapse field $H_0 = 126$ Oe) following application of agnetic-field pulses of varying amplitude at the instant of time $t = 0$.

In the investigation of the pulsed magnetization process, the initial domain ructure was produced by slowly decreasing the constant bias magnetic field plied perpendicular to the film plane, from a value exceeding the collapse eld down to zero. The pulsed magnetization begins with motion of the domain alls, in which sections moving with different velocities alternate. The differ- ce between the velocities of the "slow" and "fast" sections leads to formation discontinuities of the "inconveniently" magnetized domains. If the action of e magnetization-reversing pulse stops prior to the complete reversal of the agnetizations of the regions produced after the breaking of the domains, then eir dimensions begin to increase, as a result of which a CMD lattice is oduced. Figure 2 shows photographs that illustrate the formation of a CMD ttice in a film of composition $Y_{1.2}Gd_{1.1}Yb_{0.3}Bi_{0.4}Al_{0.7}Fe_{4.3}O_{12}$ ($h = 15\ \mu$, $4\pi M_S$ 190 G, $H_0 = 141$ Oe). The configurations of the initial and resultant domain ructures coincide only at sufficiently low amplitudes and durations of the agnetization-reversing pulse, when no breaking of the domains takes place.

An investigation of the reversal of the magnetization of iron-garnet films

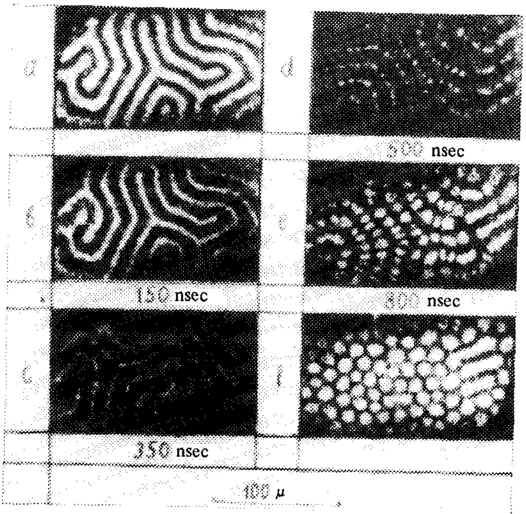


FIG. 2. Initial (a), dynamic (b—e), and resultant (f) domain structures produced by a magnetization-reversing pulse of amplitude $H_p \approx 500$ Oe and duration $\tau_p \approx 400$ nsec. The numbers indicate the instants of registration of dynamic domains relative to the application of the field pulse.

from the saturated state under the influence of a remagnetizing pulse applied antiparallel to the bias field H_b has shown that the formation of nuclei of reverse magnetization takes place on various types of inhomogeneities. The number n of nucleus-formation centers, at a given value of H_b, increases with increasing amplitude of the magnetization-reversing pulse H_p, and also when the sample is heated. A decrease of H_b also increases the number n. Under identical conditions, the number and locations of the centers of nucleus formation remained constant as a rule when the magnetization-reversal cycles were repeated.

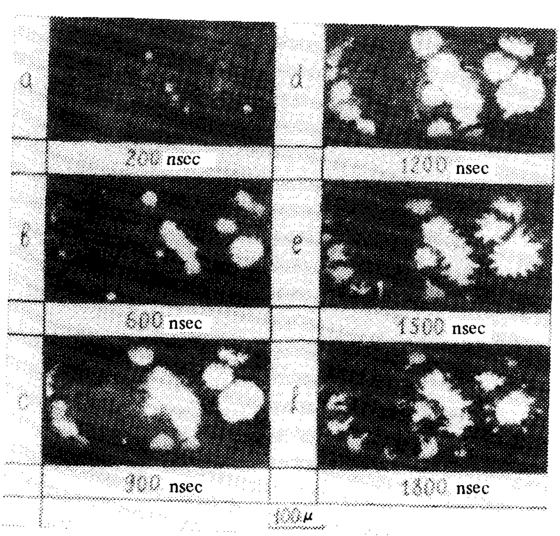


FIG. 3. Dynamic domains at various instants of time relative to the instant of application of a magnetic-field pulse of amplitude $H_p \approx 800$ Oe and duration $\tau_p \approx 1$ μsec. The bias field is 160 Oe.

The appearance of inverse-magnetization nuclei took place at a certain time $\tau_3 \sim 10^{-7}$ sec after the application of the magnetic-field pulse, and these nuclei did not appear simultaneously at the different nucleus-formation centers. The value of τ_3 decreased with increasing amplitude H_p. Once the nuclei appeared, the dimensions of the reverse-magnetization regions increased and the regions were merged. If the action of the pulsed field is stopped before complete remagnetization of the sample takes place, then "starlike" dynamic domains, similar to those observed in experiments[1,2] with strip and cylindrical magnetic domains, appear a certain time after the termination of the pulse. Figure 3 shows photographs illustrating the nucleus-formation process in the same sample as in Fig. 2.

1. G. J. Zimmer, T. M. Morris, and F. B. Humphrey, IEEE Trans. Magn. **MAG-10**, 651 (1974).
2. L. Gal, G. J. Zimmer, and F. B. Humphrey, Phys. Status Solidi [a] **30**, 561 (1975).
3. G. J. Zimmer, L. Gal, K. Vural, and F. B. Humphrey, J. Appl. Phys. **46**, 4976 (1975).
4. G. P. Vella-Coleiro, F. B. Hagedorn, and S. L. Blank, Appl. Phys. Lett. **26**, 69 (1975).