Generation of ring domains and the formation of a dynamic grating of ring domains in an iron garnet film

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The formation of a dynamic grating of ring domains as a result of the functioning of a local domain source in an alternating magnetic field is observed in an iron garnet film. The dynamic characteristics of the domain source and quantitative parameters of the ring domains grating are determined. © *1995 American Institute of Physics.*

It is known[1] that in iron garnet films with perpendicular anisotropy a self-organization of a system of magnetic domains takes place under the influence of an external magnetic field. Stable regular dynamic domain structures (DDSs) of various configurations are formed in a region of an Anger state (AS). At the same time a self-generation of the periodic processes of appearance/disappearance of DDSs with a certain geometry takes place. The frequencies of these processes are at least three orders of magnitude smaller than the pump frequency f. Systems of spiral and concentric ring domains[1,2] and gratings of magnetic bubbles (cylindrical magnetic domains) and mixed gratings[3] are typical kinds of ordered DDSs. In Refs. 3 and 4 DDSs of the leading center type in the form of concentric ring domains, slowly expanding from the center were revealed and studied. The center is connected with some local defect, on which magnetic bubbles of opposite polarities arise and expand periodically. Thus the defect proves to be a source of dynamic domains under suitable pumping conditions. In the present paper we are reporting a new kind of domain source and a new type of ordered DDS.

We investigated a liquid-phase-epitaxy (111) iron garnet film of the composition $(YBi)_3(FeGa)_5O_{12}$ with thickness 2 μm and static saturation field $H_S=50$ Oe. A sample of 5 mm in size was placed in a coil with an inner diameter of 6 mm. An alternating spatially uniform field $H(t)=H_0 \sin 2\pi f t$ was oriented along the normal to the film, i.e., along the easy magnetization axis. The field was applied continuously during a run; only the frequencies f and amplitudes H_0 were varied. The temperature of the films was kept at about 27 °C. The domain structure was observed through a microscope by using the Faraday magnetooptical effect and was photographed with an exposure time $t=1$ ms.

In the initial state the film has an irregular domain structure with arbitrary shapes of the domains, as the magnetic compensation temperature of this sample is near room temperature. After demagnetization in a field with $f=50$ Hz the structure looks like a serpentine (labyrinthine) one but with broken domain walls. A mobile serpentine structure with smooth boundaries is formed under the influence of a field with $f\sim10^4$ Hz and $H_0=15$–30 Oe. The domain width $d=50$ μm.

Different domain sources are functioning in the film in the region $f=20$–140 kHz,

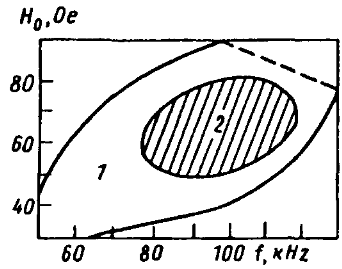


FIG. 1. The gain-frequency regions in which the source of the ring domains functions (*1*) and in which a stable grating of ringlets exists (2).

H_0=30–90 Oe. Among the domain sources is a leading center, which generates concentric ring domains. The diameter of the outermost ring may reach 1 mm. These domain sources connected with local defects release various domains (concentric rings,[4] magnetic bubbles either singly or in whole groups,[5] separate ring domains). As f and H_0 are varied, conditions favorable for intensive functioning of one among them are created. A domain source generating small ring domains one after another is active at values of f and H_0 corresponding to the gain-frequency region *1* in Fig. 1. The diameters of these domains are far smaller than the diameters of the rings of the leading center. We therefore call them ringlets. DDSs photographed on the same sample at different H_0 and f are shown in Fig. 2. Figure 2a corresponds to the edge of the (H_0-f) existence region of the ringlets and Fig. 2b corresponds to its middle part. The first ring domains in the chaotic DDS (Fig. 2a) are observed near the bottom border of region *1* in Fig. 1, where this domain source starts functioning. The intensity of ringlet generation from this domain source increases with increasing H_0 at f=80–100 kHz. The other domain sources are suppressed. As a result, a stable grating of ringlets (Fig. 2b) is formed in the film at values of f and H_0 corresponding to the shaded region *2* in Fig. 1. Such dynamic gratings of ring domains (GRDs) are observed here for the first time.[1)] The domain source exists for an

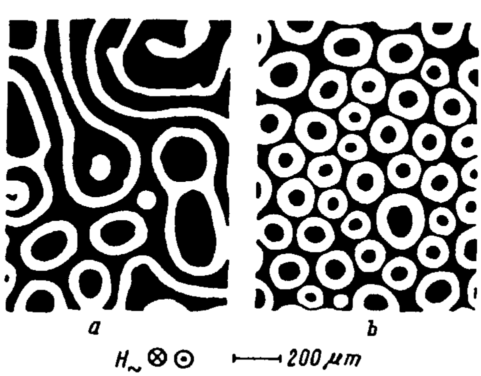
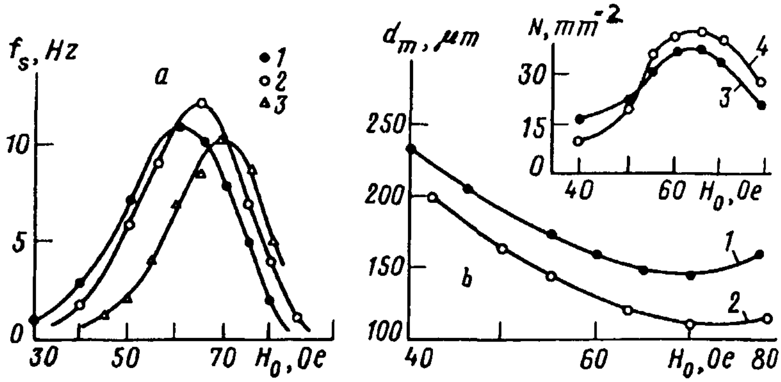


FIG. 2. Photos of the domain structure in alternating field at values of H_0 and f, respectively: (a) 38 Oe, 60 kHz; (b) 60 Oe, 100 kHz.



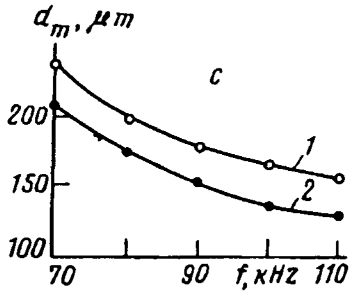


FIG. 3. The parameters of the domain source and grating of ringlets: (a) natural frequency f_s of generation of ringlets as a function of the amplitudes H_0 at the different fixed pump frequencies f=90 (●), 100 (○), and 110 kHz (△); (b) the average diameter d_m of ringlets versus amplitude H_0 at different pump frequencies f: 80 (*1*) and 100 kHz (*2*), and their number N per 1 mm^2 as a function of the external field amplitude H_0 at f=90 (*3*) and 100 kHz; (*4*); (c) the average diameter d_m of the ringlets versus pumping frequencies f for different fixed amplitudes H_0=50 (*1*) and 60 Oe (*2*).

arbitrarily long time if a suitable alternating magnetic field is applied. This domain source stops functioning gradually at H_0 and f corresponding to the top borders of the (H_0–f) region *1* in Fig. 1. The remaining ringlets are elongated and torn.

The domain sources have natural frequencies f_s. These frequencies are much smaller than the pump frequencies f.[3] The intensity of ringlet generation changes depending on H_0 and f. Figure 3a exhibits the nonmonotonic dependencies $f_s(H_0)$. The domain source stops functioning at amplitudes which are lower or higher than the critical values of H_0. The most intense generation of ringlets occurs at H_0 and f corresponding to the middle of region *2* in Fig. 1. One can also see that the maximum of the $f_s(H_0)$ curve is displaced towards greater amplitudes with increasing f.

We have chosen the mean value (for 20–100 domains) of the outer diameter d_m of the ringlets and their number N per unit (1 mm^2) of sample area as quantitative parameters of the GRD. The dependences $d_m(H_0)$ for f=const and $d_m(f)$ for H_0=const are shown in Fig. 3b and 3c, respectively. One can see that the average diameter of the ring domains decreases monotonically with growth of H_0 and f, i.e., a dynamic "grinding" of the DDS takes place. Such an effect was observed earlier for another DDS.[2] The number of ringlets per unit of sample area depends nonmonotonically on H_0 (curves *3,4* in Fig. 3b). At first N increases with growth of H_0, when the ringlet grating is forming and condensing. Then N decreases with further growth of H_0, and the destruction of the grating takes place. Apparently, a delay of the onset and growth of magnetization-reversal nuclei and the dependence of their form on the defect configuration are responsible for the effects described above.

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[1)]Static gratings of ring domains were first observed for garnet crystals in Ref. 6 and recently for iron garnet films in Ref. 3.

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