Local concentration of effective mass of domain walls in iron-garnet films

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The kinetics of the motion of local sections of a domain wall in an iron-garnet film was investigated by comparing high-speed photographs of the dynamic configuration of a cylindrical magnetic domain. The appearance of sections with effective-mass densities that differ by one order of magnitude was observed for the first time.

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To determine more accurately the mechanism whereby a cylindrical magnetic domain (CMD) changes from a statistically stable circular or elliptical shape to the "smudged" dynamic configuration observed in the course of a sufficiently rapid radial expansion or collapse,[1,2] a study was made of the local motion of different sections of the wall on the periphery of the domain. The CMD set in and grew under the influence of a pulsed magnetization-reversing pulse H_p perpendicular to the surface of the sample. The field $H_p = 650$ Oe was produced by applying current pulses of amplitude ~7 A and duration $\tau_p \approx 400$ nsec with rise times ~50 nsec in a flat coil of 2 mm diameter, located near the surface of the sample. The initial magnetic moment of the reversed region was restored by a dc bias field $H_b = 170$ Oe. The positions of the walls of the growing and relaxing domain were determined by successive photography of the dynamic configuration of the CMD with a magneto-optical setup using a UMI-93 electron-optical converter to increase the brightness of the image.[2] The illumination source was an injection laser with a double heterojunction based on GaAs—GaAlAs, operating at a wavelength ~0.9 μ. The duration of the light pulse, 15 nsec, made it possible to record the dynamics of the variation of the CMD configuration with a sufficiently high resolution. The temporal position of the light pulse relative to the start of the magnetization-reversing pulse was established with the aid of a delay line. The samples were iron-garnet films of the system $(YGdYbBi)_3(FeAlGa)_5O_{12}$, obtained by liquid-phase epitaxy on single-crystal plates of gadolinium-gallium garnet. The inclusion of bismuth in the films made it possible to increase by almost one order of magnitude their optical Q factor and ensured a sufficiently high contrast of the high-speed photographs of the dynamic configuration of the CMD. By way of example, Fig. 1 shows photographs of CMD at different values of τ_d (τ_d is the time of the delay between the start of the light pulse and the start of the magnetization-reversing pulse).

A comparison of the photographs of the dynamic configuration of the CMD at different instants of time has made it possible to obtain the time dependence of the distance R of individual sections of the domain boundary from its center, as shown in Fig. 2. Each point on the plot is the result of averaging the measurements of the wall position for three segments of the CMD periphery that

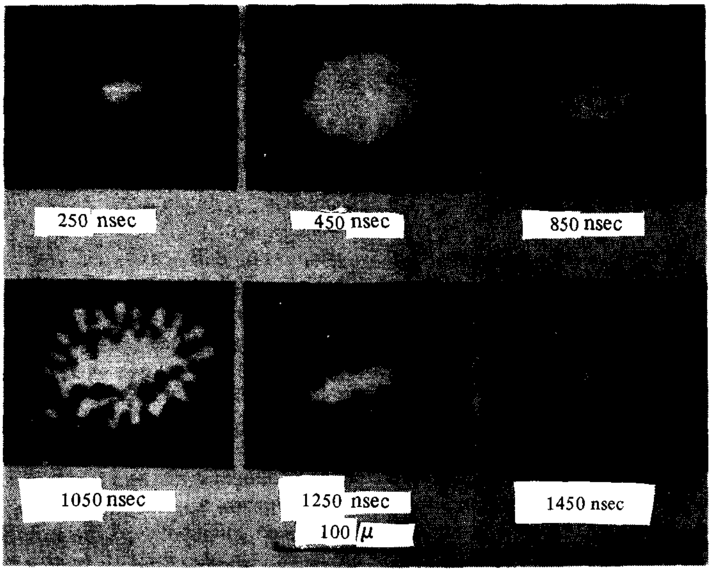

FIG. 1. Photographs of the dynamic configuration of CMD at different instants of time τ_d after the start of the action of the magnetization-reversing pulse of amplitude $H_p = 650$ Oe and duration $\tau_p \approx 400$ nsec. The bias field was 170 Oe.

were different but behaved similarly. The vertical lines show the scatter of the obtained values.

An analysis of the experimental data reveals that from the instant when the domain is produced up to the instant τ_p when the magnetization-reversing pulse terminates the different sections of the CMD wall move radially from the center with approximately the same velocity in all directions (curve 1 of Fig. 2). It is seen that the process of the radial expansion proceeds with a certain constant velocity, on which rather noticeable oscillations are superimposed starting with $t \gtrsim 200$ nsec.

After the termination of the H_p pulse, the main part of the wall begins to move under the influence of H_b towards the center of the domain (curve 2 of Fig. 2). At certain points of the wall, however, with an average density 0.2 point per micron of the CMD perimeter, the motion from the center of the wall continues also after the end of the H_p pulse (curve 3). A noticeable return of the resultant stubs to the center of the CMD begins only after 0.7—0.8 μsec. This different behavior of the individual sections of the domain wall notwithstanding, the CMD acts as a unit the entire time. Only at $t \geq 1.6$ μsec does the contrast of the magneto-optical image of the bridges between the stubs and the main body of the decreasing CMD disappear and the remnants of the stubs and the principal part of the CMD relax separately. Using for an analysis of the obtained experimental data the known equation of motion of a domain wall:

$$m\frac{d^2R}{dt^2} + \beta\frac{dR}{dt} + cR = 2M_S H_p \qquad (1)$$

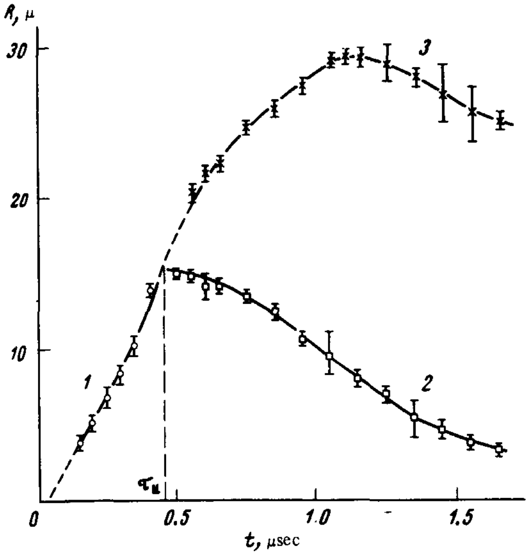

FIG. 2. Time dependence of the distances of the individual sections of the domain wall from its center.

(m is the effective mass, β is the coefficient of viscous damping, c is the coefficient of the quasielastic restoring force, and M_s is the saturation magnetization) and estimating β from the expression of the steady-state velocity of the wall of the expanding domain in the interval $0 < t < 0.45$ μsec

$$V = \frac{2M_S}{\beta} H_p, \tag{2}$$

we can show that the behavior of the wall sections that continue their radial translational motion after the end of the H_p pulse are described with sufficient accuracy in the interval $0.5\ \mu\text{sec} \le t \le 1.5\ \mu\text{sec}$ by expression (1) with the parameters values $m = 1\times10^{-6}$ g/cm^2, $\beta = 3.6$ g cm^{-2} sec^{-1}, and $c = 5\times10^6$ g cm^{-2} sec^{-2}. For all the sections of the domain wall which begin to move towards the CMD center after H_p is turned off, the estimates yield $m = 1\times10^{-7}$ g/cm^2, which is the cause of the predominantly viscous character of their behavior at constant β and c.

The appearance of sections with increased values of the effective mass can apparently be attributed to the local domain-wall structure changes during the course of the motion (see, e.g., [3]).

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