360° dynamic domain wall in ferrite garnet films

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The formation of a dynamic 360° domain wall has been observed in uniaxial ferromagnetics. This wall forms during the convergence of two 180° domain walls for which the magnetization rotates in the same direction as the domain wall is crossed during a pulsed magnetization reversal of ferrite garnet films from the saturated state.

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High-speed photography[1,2] has revealed 360° domain walls in ferrite garnet films of various compositions. The possible formation of such walls in uniaxial ferromagnetic materials to which an external magnetic field was applied along the easy axis

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had been predicted by Shirobokov.[3] A 360° domain wall may form as two 180° domain walls move toward each other; the magnetic moment vector must rotate in *the same direction* when these 180° domain walls are crossed (for brevity, we shall assume that the walls have the same rotation direction), for otherwise there would be a complete magnetization reversal of the ferromagnet. A 360° wall does not form upon a quasistatic change in the external field, since the energetically less preferred magnetic phase is displaced long before the two 180° walls converge. Furthermore, as a rule, an extended 360° wall does not form in the dynamic convergence of 180° walls, since the domain walls are usually an alternation of Bloch regions with opposite rotation directions.[4] In particular, this circumstance is responsible for the rupture of stripe domains[1,2]: When parts of the walls with opposite rotation directions meet, the domains are ruptured, while if the rotation directions are the same a region of a 360° wall forms.

It has been found possible to arrange the convergence of two 180° domain walls *with identical rotation directions during the pulsed magnetization reversal of ferrite* garnet films from the saturated state.[1] The pulsed field H_p was applied in the direction antiparallel to the constant magnetic field (the bias field) H_B. The magnetization *reversal began with the nucleation of regions of the opposite magnetization at in*homogeneities of the film, and then these nucleation regions increased in size. After the H_p pulse, of length τ_p, the dimensions of the reverse-magnetization regions began to decrease. At certain values of H_p and H_B, however, nucleation regions of the opposite magnetization in turn appeared within these regions; the rotation directions turned out to be the same at the two 180° walls (the outer and inner ones). When these walls met, a 360° wall formed.

We studied ferrite garnet films of the compositions $(Y, Bi)_3(Fe, Ga)_5O_{12}$, $(Y, Sm)_3(Fe, Ga)_5O_{12}$, and $(Y, Sm, Lu, Ca)_3(Fe, Ga)_5O_{12}$. Nucleation regions of the *reverse magnetization were observed to form at inhomogeneities of various types, in*cluding inclusions and scratches.

Figure 1 shows some photographs of dynamic domains (at the top), which were visualized by means of the Faraday effect, in various stages of the pulsed magnetization reversal in a $(Y, Bi)_3(Fe, Ga)_5O_{12}$ film. Also shown in this figure are the distribution of magnetic moments in the cross section of the film (at the center of the figure) and the dependence of the angle between the easy axis and the direction of the magnetic moment at the center of the film on the coordinate along the normal to the domain wall (at the bottom). Figure 1c shows an image of a 360° domain wall.

The lifetime of the 360° wall, which was assumed to be equal to the time interval (τ) between the end of the field pulse and the time of total disruption of the 360° wall, depended on the bias field. Figure 2 shows a typical $\tau(H_B)$ dependence, found with $H_p = 178$ Oe and $\tau_p = 0.4$ μs for an $(Y, Sm)_3(Fe, Ga)_5O_{12}$ film with $h = 4.7$ μm, $l = 0.53$ μm, $4\pi M_s = 234$ G, and $H_k = 1470$ Oe. Two mechanisms leading to the rupture of the 360° wall were observed. At $H_B = 140$–150 Oe, for the particular sample, the rupture occurred through a magnetization reversal over the film thickness; at $H_B = 108$–140 Oe, the rupture occurred through the formation of a rupture of the 360° wall (at one or several places) and the expansion of the rupture region along the wall. At $H_B = 107$ Oe, the 360° wall became stable and would persist for an arbitrar-

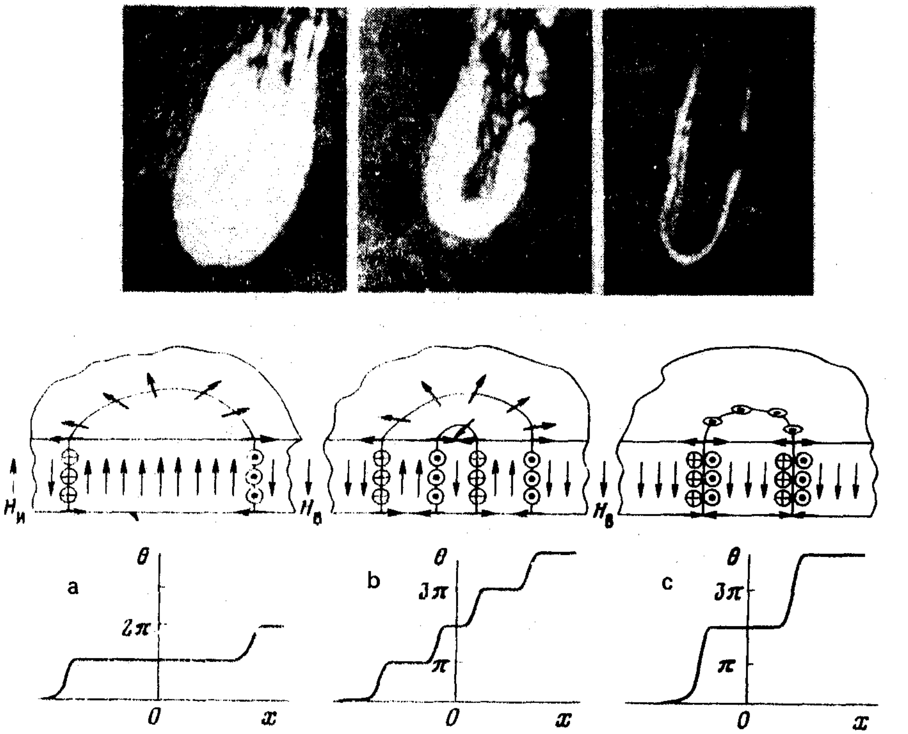

FIG. 1. Top–Photographs of dynamic domains; center–distribution of the magnetic moments over the film cross section; bottom–the $\theta(x)$ dependence at various times after the application of a field pulse 0.4 μs long. (a) $t = 0.4$ μs; (b) 0.6 μs; (c) 1.5 μs.

ily long time. Its width increased with decreasing H_B; the minimum width did not exceed the resolution of the microscope. The expansion velocity of the ruptured region along the 360° wall was 46 m/s, approximately equal to the expansion velocity of stripe domains under the same conditions.

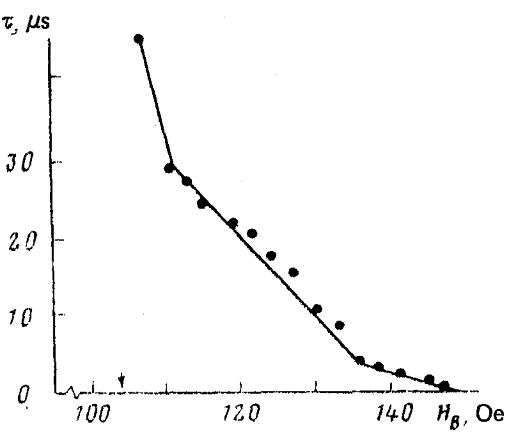

FIG. 2. The dependence $\tau(H_B)$ at $H_p = 178$ Oe and $\tau_p = 0.4$ μs. The arrow shows that value of H_B at which the 360° domain wall becomes stable.

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