Motion of dynamic domain walls

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We have investigated, for the first time, the velocity of 180° dynamic domain walls produced by pulsed reversal of the magnetization of magnetic films. We observed that the velocity of these walls in films of thickness from 500 to 1200 Å exceeds by 1.5 to 5 times the velocity of the equilibrium walls.

A study of the motion of dynamic domain walls produced in the course of pulsed reversal of the magnetization of ferromagnetic materials is one of the main problems of ferromagnetism and is of great scientific and applied significance. A special place in the solution of this problem is occupied by thin magnetic films. The purpose of the present study was to investigate the speed of 180° dynamic domain walls produced when the magnetization of uniaxial permalloy films is reversed. Investigations of this kind were never discussed in the literature before. On the other hand, the extensive information in the literature (see, e.g.,[1-7]) concerning the mobility of 180° domain walls was obtained by the following procedure: the film was transformed into the multidomain state in one way or another, and displacement of the walls under the influence of a series of pulses of known duration was measured. In these experiments, the structure of the wall, at least in the initial and final states, was at equilibrium, and this raises a question of the applicability of the obtained result to the description of nonequilibrium processes of pulsed magnetization reversal.

FIG. 1. Dynamic domains produced by pulsed reversal of film magnetization. The easy axis of the film is vertical. The horizontal lines show the pickup loop and its reflection in the film. The numbers indicate the instant of strobing relative to the start of the magnetization-reversal pulse (in microseconds). The film parameters are indicated in the caption of Fig. 2. $H_{rev} = 1.3$ Oe.

To observe the dynamic domains, we used a stroboscopic magneto-optical setup with a time resolution of 15 nsec.[8] The film magnetization was reversed by pulses of duration up to 60 μsec, rise time 7 nsec, and flat-top unevenness 1–2%; the repetition frequency was

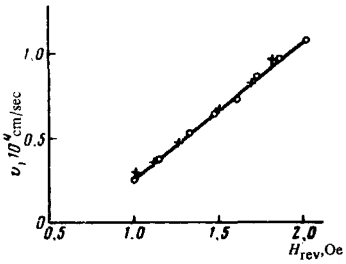

FIG. 2. Domain-wall speed v against the magnetization-reversing field H_{rev}, Oe. The curves were obtained with the aid of stroboscopic procedure (×) and the usual procedure (○). Film parameters: thickness 2500 Å, coersive force 0.9 Oe, effective anisotropy field 2.4 Oe.

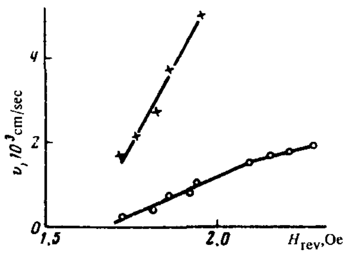

FIG. 3. Domain-wall speed v against the magnetization-reversing field H_{rev}, obtained with the aid of stroboscopic (×) and usual (○) procedure. Film parameters: thickness 720 Å, coersive force 1.8 Oe, effective anisotropy field 2.8 Oe.

0.5 kHz. Depending on the intensity of the magnetization-reversal field H_{rev}, the 180° walls of interest to us are produced at 10–40 μsec after the application of the pulse. The speed of these walls was measured by observing their instantaneous position for 20–30 μsec after formation. The process of formation and motion of the dynamic walls is illustrated in Fig. 1. We chose for the measurements the most linear section of the wall. For the domains shown in Fig. 1, a wall with suitable profile was produced 10 to 15 μsec after application of the magnetization-reversal pulse in the lower-right quarter of the film. The results were compared with the wall speed as measured by the usual procedure employed by others. Equilibrium walls were obtained by applying to the sample a single pulse of 20–30 μsec duration. The wall motion was produced by multiple application of pulses of 0.1–1 μsec duration. When the two indicated procedures were used, particular care was taken to have the investigated walls pass through the same sections of the film. The use of the same magnetization-reversal setup has made it possible to eliminate, when the results were compared, the influence of errors due to the inaccurate orientation of the sample and inaccurate measurement of the magnetic field.

We investigated the motion of domain walls in 15 films obtained by thermal precipitation of Permalloy of composition 79% Ni, 4% Mo, 17% Fe, and 83% Ni, 17% Fe. Conditions most favorable for the study of the wall mobility were produced in the indicated films, namely, the walls were straight enough, were produced far from the edge of the film, their profile did not change significantly during the course of motion,[9] etc. According to the results, the films can be divided into two groups. The first includes films of thickness $d < 500$–600 Å and $d > 1000$–1200 Å. In these films, in the field interval investigated by us, the wall speeds measured by the indicated procedures agreed within the limits of experimental error (see Fig. 2). This shows that both in sufficiently thick and in very thin films the structures of the dynamic and equilibrium walls do not differ greatly, at least from the point of view of the losses that cause them to slow down.

On the other hand, in films with thickness 600 Å $< d$ $<$ 1200 Å, the speed of the dynamic walls exceeds by 1.5 to 5 times the speed of walls as measured with the aid of the usual procedure (see Fig. 3). As is well known,[2,3] this thickness interval corresponds to the minimum of the wall mobility as measured with the aid of this procedure. The appearance of this minimum is attributed to the structure of the equilibrium films,[4–7] namely, walls with transverse bonds are produced in this thickness interval, and the density of the transverse bridges is maximal in the region of the minimum. Thus, the appearance of bridges leads to an additional deceleration of the domain walls. The differences between the results obtained with comparable procedures indicates that the structure of the nonequilibrium dynamic domain walls in films of thickness 600 Å $< d$ $<$ 1200 Å differs appreciably from the structure of the equilibrium walls. It is possible that the density of the bridges on the dynamic walls is much smaller than on the equilibrium walls, or else no such bridges are produced at all in the course of magnetization reversal.

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