DOMAIN STRUCTURE WALL ON THE SURFACE OF A FERROMAGNET

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A magneto-optical method was used to study the distribution of the magnetization in a 180° Bloch wall emerging to the surface. The wall is broadened on the surface by approximately four times (to 0.7 – 0.8 μ), the normal component of the magnetization is greatly decreased, and the surface layer of the wall breaks up into subdomains of the Neel type with alternating polarity.

A magneto-optical method for the study of domain walls was proposed in [1], and the dynamic signal from an oscillating domain wall was obtained in [2]. Further improvements in the magneto-optical setup, with a resolution in the micron range, made it possible to register reliably linear and quadratic magneto-optical effects due to different magnetization components in the surface layer of the domain wall, and to establish as a result the far from trivial structure of a 180° domain wall on the surface of an iron single crystal.

The operating principle of the magneto-optical setup with micron resolution consists in recording the change of the intensity of the light arriving at the focal plane of a microscope from a micron-sized surface area of the investigated sample [3]. The experiments described below were performed with the photomultiplier entrance slit set to a value corresponding to an

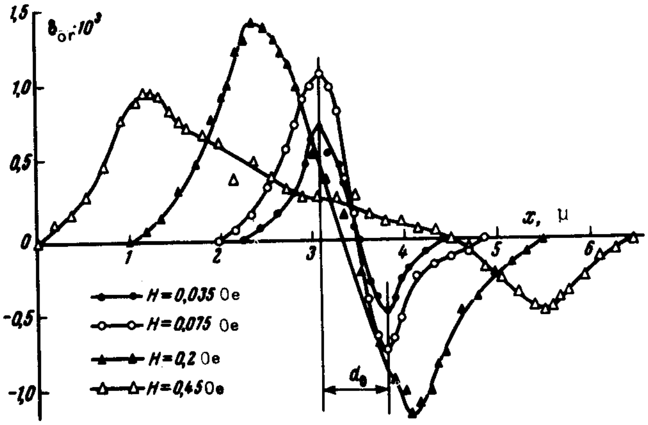

Fig. 1

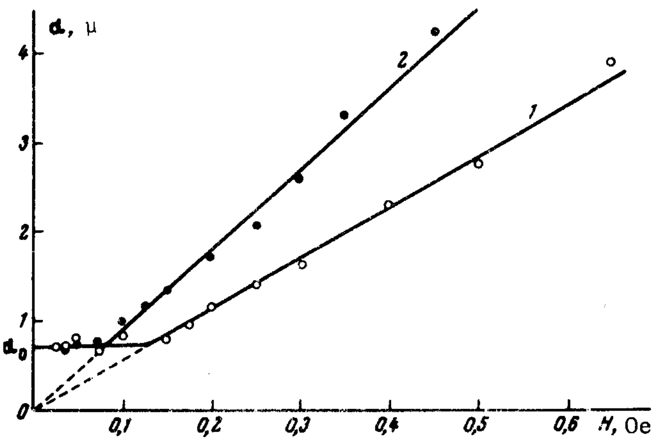

Fig. 2

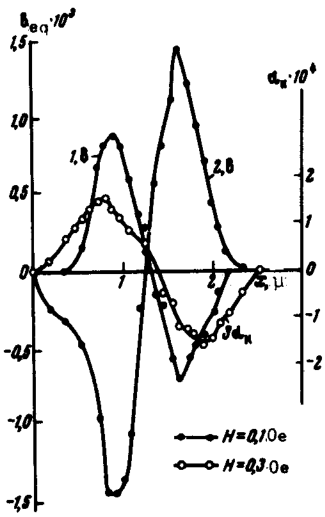

Fig. 3

illuminated surface strip measuring 0.03×3 μ and parallel to the domain wall. The measured magneto-optical effect corresponds to the change of the magnetization of this illuminated section of the surface, a change due to the periodic oscillations of the wall in the external magnetic field. By shifting from one magneto-optical effect to another, say by varying the sample orientation, the plane of incidence of the light, or the angle of incidence, or else by introducing an analyzer, we can determine in principle the contributions of different magnetization components. Appreciable information is obtained also by varying the amplitude of the wall swings. The measurements were performed both on bulky single crystals of silicon iron and on whisker crystals.

Figure 1 shows plots of the variation of the reflected-light intensity when the photomultiplier slit is moved in the focal plane of the microscope in a direction transverse to the wall, at a fixed amplitude of the wall swings. The trivial effect due to incidence of the image of alternating domains was eliminated by symmetrizing the light beam emerging from the lens. The equatorial Kerr effect from the domain vanished in this case because each light beam with "positive" incidence angle was accompanied by a beam with "negative" angle, and the equatorial effect is odd in terms of the incidence angle. On the other hand, an effect that does not vanish in this case and is recorded on the curves of Fig. 1 is the orientational magneto-optical effect [4], which is quadratic in the magnetization and is even in the incidence angle the variation in the reflected-light intensity. At low amplitudes of the wall swings, the interval d between the positive and negative maxima does not depend on the amplitude of the magnetizing field H, and we interpret the appearance of these maxima as a differential effect due to the regions of maximum magnetization variation in the domain-wall layer, and the interval d_0 as the effective width of the domain wall. Figure 2 shows plots of d(H) for different sections of the boundary and for its two orientations, "transverse" (1) and "longitudinal" (2), for which the equatorial and meridional Kerr effects from the domains are observed respectively when an oblique-illumination prism is introduced. The curves of Fig. 1 correspond to case (2) of Fig. 2. Since in case [2] of longitudinal wall orientation only a meridional effect is observed from the domains, it becomes possible, when the analyzer is moved away, to eliminate the domain effect even under oblique illumination, and to observe this equatorial effect, which is odd in the magnetization, from the transverse component of the magnetization in the domain-wall volume. Figure 3 shows plots of the equatorial effect from the boundary in this case, and a reversal of the sign of the equatorial effect is observed on moving along the wall (curves 1 and 2), thus evidencing a reversal in the polarity of the wall, i.e., formation of subdomains in the domain wall itself. From the measurement results we can estimate the order of magnitude of the transverse (Neel) component of the magnetization in the surface layer of the wall. The maximum value of the equatorial effect from the domains amounts to 9.6×10^{-3}. It should be decreased by 25% because the signal has a rectangular rather than sinusoidal waveform, and by double this amount because in the domain effect we are dealing with an approximately double reversal of the magnetization owing to the continuous rotation of the magnetization vector in the domain wall. Thus, the maximum expected cross section for pure Neel surface layer might be approximately 2×10^{-3}. The obtained values are quite close, albeit smaller, of the order of 1.5×10^{-3} (Fig. 3, curve 2). In the case of a pure Bloch wall, there should be no transverse component at all, and the normal component should reach a maximum. The fact that the normal component in the surface layer of the wall decreases sharply follows from measurements of the polar Kerr effect α_K from the wall, which are shown by curve 3 of Fig. 3. The maximum value of α_K is smaller by approximately one order of magnitude than the value expected for iron [5], thus confirming the statement made above.

Thus, the wall broadens approximately by four times on approaching the surface. In measurements on different samples we obtained for d_0 values from 0.6 to 0.8 μ, whereas the maximum theoretical width of a 180° Bloch wall in iron is 0.16 μ [6]. The normal magnetization component is sharply decreased in this case, and an appreciable transverse component appears. The surface variation of the wall structure is asymmetrical, for the mean value of the transverse component would vanish in the case of a symmetric structure. The closest to the indicated picture is the model calculated by Hubert [7] for the wall structure on the surface of a thick ferromagnetic film. In this model the wall broadens on approaching the surface, rather than become narrower as predicted in other calculations. Although this wall broadening amounts only to several times ten per cent, the theory predicts a theoretical increase of the wall width on the surface with increasing film thickness.

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