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Domain-Wall Motion by Néel–Quasi-Néel Wall Pairs in Two-Layer Ni–Fe Alloy Films

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Over the past several years, considerable controversy has developed concerning domain-wall motion in laminated films. Mobility measurements were first reported by Patton and Humphrey[1] for wall motion in films with from two to five magnetic layers separated by 100 Å of SiO which were the same as for single-layer films. Following this initial report, Middlehoek and Wild[2] published mobility determinations which were almost an order of magnitude greater than the earlier results. In an attempt to clarify this situation, mobility measurements have now been made for two of Middlehoek and Wild's double films, each with 400-Å Ni–Fe layers (≈80% Ni) separated by 100 Å of SiO, using the quasistatic technique reported previously.[1,3,4] The present mobility values are less than one-third the values reported by Middlehoek and Wild. As discussed previously,[4] differences in the experimental technique must account for the different mobility determinations for similar films from the same laboratory. The purpose of the present communication is to point out two interesting aspects of these latest observations.

Domain configurations in two-layer films which exhibited lines of intermittent wall sections were first observed by Middelhoek.[5]

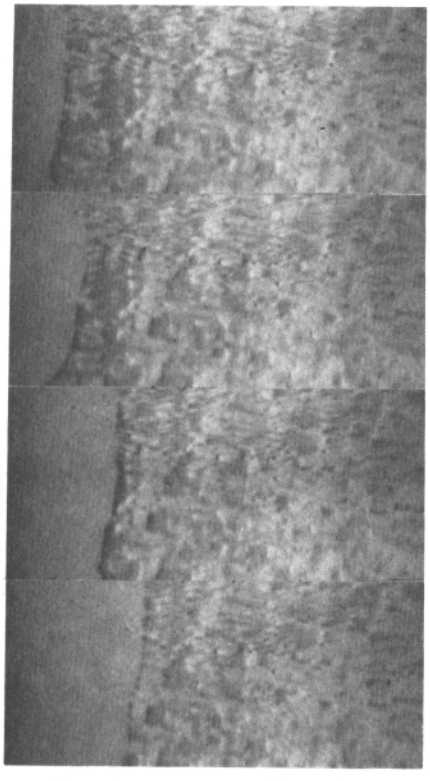

FIG. 1. Kerr-effect observations of the wall configurations and displacements obtained after successive application of several easy-axis-field pulse sequences. Each pulse sequence was identical, consisting of ten 0.72-Oe pulses, 1.4 μsec long. The easy axis and the field direction are vertical.

He proposed that the Néel wall in one layer (separating antiparallel domains) induces a so-called quasi-Néel wall in the other layer with the domains on both sides of the quasi wall magnetized parallel. The domain-wall structure shown in Fig. 1 consists of a Néel–quasi-Néel wall pair in which the Neél and quasi-Néel sections interchange layers along the length of the wall. The light–dark boundary is intermittent along the length of the wall because the sections corresponding to quasi walls do not separate antiparallel domains and do not appear as the usual light–dark boundary seen in Kerr observations.

Wall-mobility determinations were made by pulsing the films with small ($H \gtrapprox H_c$) easy-axis field pulses of long duration (10–50 μsec) and observing domain-wall positions using the Kerr magneto-optic effect. In Fig. 1, a series of domain-wall photographs is shown. Wall positions are shown after successive applications of a sequence of 10 easy-axis field pulses. In spite of the large changes in the distribution of Néel sections and quasi-Néel sections along the length of the wall as it moves and the highly intermittent nature of the total structure, the walls are very straight and their displacements are quite uniform under the easy-axis field pulses. Wall velocities, as determined from the wall displacements, number of pulses, and pulse lengths, were found to vary linearly with the easy-axis field amplitude. The wall mobility was extracted as the slope of the velocity-vs-field curve. For these two films provided by Middelhoek and Wild, a wall mobility of 1.2 (± 0.3) $\times 10^4$ cm/sec·Oe was obtained.

In the usual calculation,[3] mobility is obtained by equating the rate at which the film structure loses energy through the growth of domains along the field direction to the rate at which the domain wall dissipates energy by its motion. In the layer containing the quasi wall, both domains are magnetized parallel, and no energy reduction (for this layer) is accomplished by the wall motion. The motion of the quasi wall, however, does dissipate energy, since the spins within the wall are in motion. By adapting previous calculations to this situation, it can be shown that the wall mobility for a Néel–quasi-Néel wall pair should be exactly half that expected for two juxtaposed 180° Néel walls (each separating antiparallel domains), assuming both magnetic layers are identical. Lorentz microscopy static wall shape measurements have been made by Feldtkeller *et al.*[6] for double films with 350-Å Ni–Fe layers separated by 100 Å of SiO. These measurements were for locked 180° Néel wall pairs, but can also be taken as representative for Néel–quasi-Néel wall pairs on the basis of magnetostatic energy considerations. Using these wall shape data and a Landau–Lifshitz damping parameter $\alpha = 0.014$, the theoretical mobility for a Néel–quasi-Néel wall pair is 1.2×10^4 cm/sec·Oe. The damping parameter was chosen on the basis of extensive mobility measurements for single layers.[3] The theoretical value of 1.2×10^4 cm/sec·Oe is in excellent agreement with the measurements discussed above.

The two important results of this investigation are: (1) The wall motion for which the present measurements were made was not for locked Néel walls (two parallel 180° Néel walls juxtaposed in adjacent magnetic layers) as reported on previously, but for a Néel–quasi-Néel wall pair. (2) The results are consistent with available static wall shape information and a phenomenological Landau–Lifshitz damping parameter $\alpha = 0.014$ which has been shown to be characteristic of wall motion in single layers.[3]

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