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Domain Wall Creeping in Thin Permalloy Films

In permalloy films, for a given dc magnetic field in the hard direction, there exists a threshold field in the easy direction at which rapid motion of the domain walls suddenly begins. A plot of this critical field amplitude as a function of the hard-direction dc field is known as the *critical curve* for wall motion,[1] and it is generally assumed that no wall motion takes place when the applied field vector is within this curve.

This note reports the results of an investigation in which it was found that under the influence of an ac, rather than a dc, field in the hard direction and a dc field in the easy direction, domain walls begin to creep even though the vectorial sum of the ac and dc fields lies well within the critical curve.

Domain wall creeping in thin Ni-Fe films has previously been reported by Olmen and Mitchell[2] and in Ni films by Hellenthal.[3] In these cases, however, no ac field was applied, and explanations later given ascribed these instances of creeping to thermal fluctuation effects.[4,5]

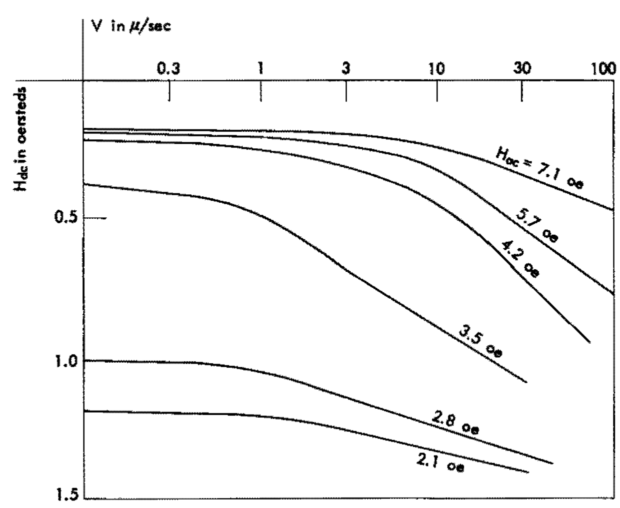
We have observed creeping in many films of different thicknesses and compositions. All films were prepared by vacuum evaporation at 10^{-5} mm Hg onto a heated glass substrate in the presence of an applied magnetic field.

Measurements were made by observing the domain walls through a microscope using the Kerr magneto-optic effect. The apparatus was aligned so that the earth's magnetic field lay in the hard direction. The 50 cps ac field and the dc field were applied by two orthogonal pairs of solenoidal coils in the hard and easy directions, respectively. In all cases the domain walls were made to traverse the same 58-micron-wide segment near the center of the 1 cm^2 film. Although an effort was made to work with half the film magnetized in each direction, in order to minimize stray fields due to poles at the edges of the film, only the wall under observation could be fixed, and, as the other walls moved about, the stray field at the observation point changed gradually during the course of the experiment. In order to compensate for this unknown dc component, therefore, the creeping velocities to the left and to the right were both measured as the dc field was varied at a constant ac field. After both resulting curves had been plotted, they were shifted equal amounts, one up and the other down until they coincided, and the resulting curve was taken as the true one.

Measurements of the creep velocity as a function of the dc field in the easy direction for different ac fields in the hard direction are given for a representative film in Fig. 1. This film was evaporated from a 74–26 Ni-Fe melt, is 1260 A thick as measured by the Tolansky method, and has H_c = 1.58 oe and H_k = 13.0 oe.

Figure 2 shows the same data plotted as curves of constant velocity in the applied field plane for comparison with the critical curve for wall motion. The same pattern is typical of all thick films: for ac fields with peak values below a certain value, creeping occurs only when the dc field is quite close to the critical field. Above this ac field value, rapid creeping is observed for quite small dc fields. Indeed, the stray fields in the film alone are sufficient to cause creeping when a large ac field is applied. On the other hand, in contrast to the results of Olmen and Mitchell, no

Figure 1 **Velocity of domain walls in a permalloy film as a function of a dc field in the easy direction, with a 50 cps sinusoidal field in the hard direction.** *Values given for H_{ac} are peak values.*



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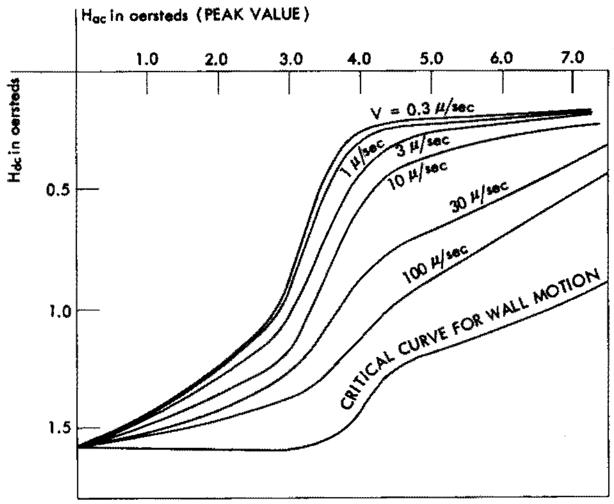

Figure 2 **Curves of constant creep velocity in the applied field plane.** *The "critical curve" for wall motion is also shown.*

creeping was observed over a 12-hour period when a dc field equal to 0.95 H_c was applied in the easy direction and care was taken to isolate the film from all ac fields.

The consistent appearance of the knee of the curve near $H_{ac} \approx 0.3H_k$, where, as shown in our observations of Bitter patterns, transitions from Bloch to Néel walls occur, suggests strongly that such transitions may play an important role in the creeping process. Other effects which could be significant are wall width changes, Bloch line movements, or changes in the magnetization distribution within the walls.

The magnitude of the creep velocity appears to be temperature-dependent, but this relationship has yet to be fully investigated. It may be closely related to the dependence of the critical field for wall motion itself upon temperature, as reported by Segmüller.[6]

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