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Abstract

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ON THE POLARITY OF DOMAIN BOUNDARIES IN THIN FERROMAGNETIC FILMS

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Introduction. In recent years much attention has been devoted to the study of thin ferromagnetic films ([1–10]).

The results of studying domain boundaries in thin ferromagnetic layers, as regards the question of their polarity, may be reduced to the following:

1. In relatively thick ferromagnetic films the change of the magnetization vector in the boundary layer is the same as in bulk crystals. For 180° adjacency, the magnetization vector in the boundary layer gradually changes by 180°, remaining the whole time in the plane of the boundary. Boundaries of this type, following the established terminology, we shall call **Bloch boundaries**.

2. In thinner ferromagnetic films the magnetization vector in a 180° boundary layer does not lie in the plane of this layer. The structure of such a boundary may be quite varied. For brevity we shall call this type of boundary **Néel boundaries**.

3. In some cases so-called double boundary layers, or doubled boundaries, are observed. Such a boundary is a system of two boundaries situated very close to one another. On both sides of such a boundary the magnetization is directed in the same way. When a field is applied against the magnetization thus directed, the boundary clearly splits in two, turning into a domain of reverse magnetization.

Experimental part. The polarity of domain boundaries was studied on thin ferromagnetic films obtained by thermal evaporation of an alloy of 17% Fe, 80% Ni, 3% Mo in a vacuum of $2 \cdot 10^{-5}$ mm Hg onto glass substrates heated to 350°. To create uniaxial anisotropy during the preparation of the films, a field of 100 oersteds was applied. The thickness of the films obtained was determined on a universal monochromator UM-2 by the method of lines of equal chromatic order ([11]). The study of domain boundaries was carried out by the powder-pattern method, using an MBI-6 microscope, on preliminarily demagnetized films.

Figure 1 presents the domain structure of a film 560 Å thick with characteristic double boundary layers. In the absence of a field these layers appear as almost straight, very thick lines. When a field normal to the plane of the film is applied, it is clearly revealed that the boundaries are indeed double, and that their polarities are opposite. Thus, in a field of −10 oersteds the upper boundary of such a double layer is revealed very sharply and distinctly, whereas the lower one is barely distinguishable; in a field of +10 oersteds, on the contrary, the upper boundary of the double layer is barely distinguishable, while the lower one is drawn sharply and distinctly. It is evident that the boundaries in the double layer in this case have opposite polarity and are Bloch-type boundaries.

Figure 2 presents the domain structure of a film 1450 Å thick. In the absence of a field the domain structure is almost planar-

Fig. 1. a $-H = -10$ oersted; b $-H = 0$; c $-H = 10$ oersted.

Scale: 0.1 mm

Fig. 2. a $-H = -220$ oersted; b $-H = 0$; c $-H = 220$ oersted.

Scale: 0.1 mm

Fig. 3. a $-H = -200$ oersted; b $-H = 0$; c $-H = 200$ oersted.

Scale: 0.05 mm

parallel domains with well-revealed thin boundaries. When a magnetic field of 220 oersteds normal to the film is applied, every other boundary is revealed very distinctly. When a field of the same strength directed exactly oppositely is applied, an analogous pattern is observed, with the only difference that the weakly expressed boundaries become sharply revealed, and vice versa. Thus the polarity of the boundaries alternates, which is not observed in massive ferromagnetic crystals. The regularity shown in Fig. 2 was found in a large number of ferromagnetic films. Evidently, in all these films the boundary layers were of the Bloch type.

Fig. 3 presents another case. In a film 480 Å thick, in the absence of a field the domain structure is revealed in the form of not very sharp boundaries running almost parallel to one another. When a magnetic field of 200 oersteds normal to the plane of the film is applied, the lines are revealed more distinctly, all to the same degree. When an exactly oppositely directed field of the same strength is applied, the pattern obtained is practically identical. Such a result can be obtained only if the boundary layer is not a Bloch-type boundary. Evidently the magnetization vector in such a boundary layer has a relatively small normal component, different at different points of the boundary, which can only be enhanced when such a comparatively large magnetic field, normal to the surface of the film, is applied. Observations of boundaries of this kind were also carried out repeatedly.

Conclusions. 1. In thin ferromagnetic films, doubled boundaries are Bloch boundaries of opposite polarity. This conclusion is in agreement with the theoretical investigations of Kaczer ([5]).

2. Bloch boundaries in thin ferromagnetic films have alternating polarity. It is quite possible that this fact has a purely historical cause. At the moment when a magnetization-reversal nucleus is formed, the boundaries delimiting it are quite similar to double layers and, consequently, must have opposite polarity. As the nucleus grows and is transformed into a domain, there is no reason for repolarization of boundaries that have already acquired a quite definite polarity. In a newly arising nucleus the boundaries may be formed under some influence of the already existing boundaries, which also predetermines the polarity of the new boundaries.
3. Néel boundaries have no sharply expressed polarity and, when a sufficiently strong magnetic field normal to the plane of the film is applied, are revealed more distinctly. Thus, by applying a magnetic field normal to the plane of the film, one can draw certain conclusions about the character of the boundary layers in it.

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