DOMAIN STRUCTURE OF DOUBLE LAYER SINGLE CRYSTAL FILMS OF IRON

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The domain structures of multilayered films consisting of mutually parallel single crystal (001) Fe layers and an LiF intermediate layer were studied by Lorentz microscopy. Magnetic flux transitions from layer to layer and formation of extraordinary domain walls were observed in systems with magnetic layers approximately equal in thickness. The effect of the adjacent layer on the 180° wall structure was observed.

The domain structures of double layer polycrystalline magnetic films were investigated rather thoroughly [1 – 2]. Interesting features were found in domain structures of the film systems with magnetic layers of approximately equal thicknesses. For example, the domain wall was shown to be able to deviate in an arbitrary way from the easy axis of the layer if an analogous wall in the other layer "accompanies" it. Such a behaviour of domain walls is accounted for by the compensation of arising magnetic charges. In our opinion it is more convenient to explain the deviations of double walls from easy axis directions on the basis of magnetic flux transitions from one layer to the other. Such transitions are most probable in the case of equal layer thicknesses and similar magnetic parameters of the materials. We shall use the latter model to describe domain structures of multilayered films consisting of mutually parallel (001) Fe layers of approximately equal thicknesses, separated by an LiF streak. In the present paper we will describe the domain structures of the systems in demagnetized states. The technique used for the preparation of such samples was described earlier [3].

Figure 1[1]) shows the most interesting section of the domain structure of an Fe 200 Å/LiF 100 Å/Fe 200 Å multilayered film. Basing on easy axis orientations and the formation mechanism of overfocused electron microscopy image of the film we can conclude that this section essentially presents the superposition of a 90° wall of the "upper" (conditionally) layer on the magnetic structure of the "lower" one. This wall seen as a dark stripe begins in the upper left corner of the figure, and in its center crosses the wall of the "lower" layer.

Probably due to this crossing of walls a double-contrast curve *A* was formed. The deviations of the 90° wall from the [110] direction (as well as that of the 180° wall from [100]) in single crystal Fe single-layer films are comparatively small because they give rise to the discontinuity of the magnetic flux component normal to the wall and consequently to magnetic charge on the wall. Therefore within the region of the

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[1]) For Fig. 1 see Appendix V (p. 590h).

loop-like wall with continuously changing direction no 90° (or other) turns of the magnetic flux occur and the wall itself may only represent the places of the transitions of flux from one layer to the other (without changing its direction). One can also arrive at the same conclusion starting from the distribution of the magnetization vector in the domains (fig. 1).

The formation of the curve section, that corresponds to the scheme of fig. 2a, arises from the electron scattering within the domain walls. The wall arrangement shown on this figure agrees with the observed contrast for loop-like curve.

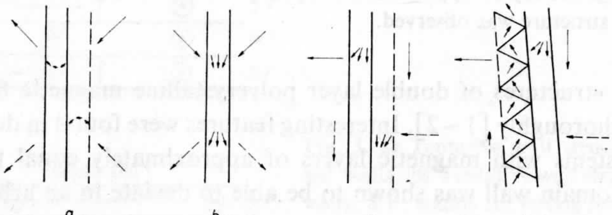

Fig. 2 . Structure scheme of the transition region of the magnetic fluxes from layer to layer.

In our opinion extraordinary domain neighbourhoods in the region of the double contrast curve (fig. 2b, c) may be explained by the above mentioned flux transitions. Loop-like curve sections corresponding to fig. 2b are very small. In other places of the film one can observe zig-zag lines of flux transition that exclude the situation shown in fig. 2b. In the case 2c the walls in the two layers are arranged side by side. If these walls were superimposed their image would not appear.

On fig. 1 a more complicated case of flux transition is denoted by the letter *B*. The transition line here consists of two 90° walls of different layers arranged side by side. There is some deviation of the line from the easy axis. The contrast of its image is not uniform. It has alternating dark and light transversal sections and one edge of the line is darker than the other one. On the basis of these features of the line *B* we can suppose that in one layer, say, in the "lower" one, there is a complex 90° wall, consisting of narrow triangles with different average spin directions (fig. 2d). As alternating triangle sections deflect electrons passing through them differently the electron intensity distribution under the wall (along it) will be alternating, too. At one side an ordinary 90° wall of the "upper" layer joins to this complex wall. Because of this one edge of line *B* is darker than the other one. The described structure of the region of flux transition was observed when the magnetization vectors of neighbouring domains of different layers had antiparallel orientations. In the case of parallel magnetization vectors flux transition was realized in a simpler situation (see fig. 2c). Such a difference is obviously connected with an exchange interaction between the layers. Because of this interaction the connection of different layer walls with nonparallel spins at the adjoining edges is energetically disadvantageous.

Figure 3 shows a detailed interpretation of the structure of the section denoted by A_1 in fig. 1. In fig. 3 a dot-and-dashed line denotes the place of another type of the flux transition. The flux of the "upper" layer passes here into the "lower" one with a 90° turn. Because of this the line of transition is obliged to pass (approximately) along the [110] direction of the system. It is seen from fig. 3 that not only magnetic fluxes can pass from layer to layer but domains walls are able to do the same.

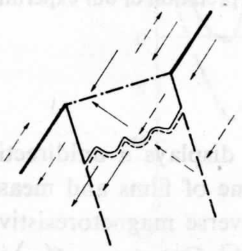

Fig. 3. Interpretation of the section denoted by "*A*" on fig. 1.

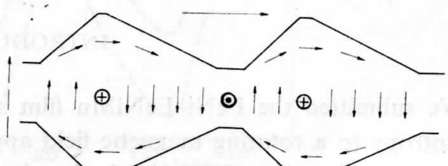

Fig. 4. The scheme of the 180° wall structure when the wall direction is perpendicular to the magnetization of the adjoining layer.

The close neighbourhood of an ordinary 180° wall with the second layer can substantially affect the internal structure of the wall. Figure 4 shows the scheme of a 180° wall structure denoted by *C* in fig. 1. The scheme is constructed on the basis of an analysis of the electron intensity distribution. It is seen that the Néel sections of different length are formed in the wall when the direction of the wall and that of the magnetization of the "upper" layer are mutually perpendicular.

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