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DOMAIN WALL CREEP IN PERMALLOY ELECTRODEPOSITED FILMS

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The paper deals with the behaviour of the process of reversal of magnetization by the domain wall creep on planary electrodeposited films of micron thickness.

I. INTRODUCTION

The reversal of magnetization of Ni—Fe thin films by the shift of domain walls starts at a certain critical field which in the H_L scale (the field component along the axis of easy magnetization) and H_T scale (the field component along the axis of hard magnetization) forms the critical curve of irreversible processes of the domain wall shift. If an alternating field with the amplitude H_T acts along the axis of hard magnetization, then a slow process of the reversal of magnetization due to the domain wall creep can be observed in the H_L field smaller than the critical field. This reversal of magnetization process has been dealt with in a number of papers [1—3]. Almost all of those papers are related to the domain wall creep of thin up to 4000 Å permalloy films obtained by vapour deposition in vacuum.

The domain wall creep is of practical importance also in the application of electrolytically deposited cylindrical films for calculation technique — as memor elements — since creep clears away the recorded information. At present it is not yet possible to observe directly the domain walls of cylindrical films of small diameters. That is why in our experimental study of the behaviour of the domain wall creep in planary electrodeposited permalloy films comparatively great thicknesses are investigated.

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II. EXPERIMENTAL PROCEDURE

Electrolytic coating was carried out in an electrolyte of the following composition:

1. nickel sulphate — $NiSO_4 \times 7H_2O$ 280 g/l,
2. iron sulphate — $FeSO_4 \times 7H_2O$ 10 g/l,
3. boric acid — H_3BO_3 25 g/l.

By means of this electrolyte composition films of 80 % Ni — 20 % Fe can be obtained [4]. The electrolyte temperature was 25 °C, the cathode current density 7 mA cm^{-2}. A nickel plate served as the anode. Films were deposited on circular copper pads of 20 mm in diameter. The pads were polished in a mechanical way on metallographic papers up to Nb 06 and finished in a chemical way on a piece of cloth with aluminium oxide by means of an electromagnetic polishing machine. The electrolytical deposition was performed in the magnetic field with the intensity of $H = 100$ Oe, formed by Helmholtz coils. The direction of the magnetic field coincided with the plane of the pad. Thus a series of Ni—Fe films of the thickness 0.6—2.4 μm, characterized by uniaxial anisotropy, were prepared. The thickness of the films was determined on the basis of Faraday's laws.

The curves of the dependence of the domain wall creep rate v on the magnitude of the static field H_L acting along the axis of easy magnetization were measured in the magnetooptic way [5]. The amplitude of the alternating current (50 Hz) field H_T was chosen as a parameter. From the data obtained curves of equal creep velocities were plotted in the H_L, H_T scale. Besides, the anisotropy field H_k [6], scanned hysteresis loops, static critical coercive force curves $H_c(\alpha)$ and the field of the domain wall start $H_{w.st.}$ [7] were measured by means of a magnetooptic hysteresis scope.

III. MEASUREMENT RESULTS

The onset film condition — demagnetized by the alternating field in the direction along the axis of easy magnetization with a small number of domain walls. Due to a decreased effect of the proper demagnetization of the sample field, the measurements of the domain wall creep rate were carried out only at a small shift of domain walls in the middle of the sample (240 μm at most). Thus the creep rate values measured are in the interval from 6 to 60 μm/sec.

The dependence of the domain wall creep rate v (for films of 0.8 μm and 2.4 μm thickness) on the magnitude of the magnetization field H_L is shown in Fig. 1 in the semilogarithmic scale. The thicker the film, the smaller is the field H_L in which the given rate is attained. The domain wall creep rate increases exponentially with the growth of the field H_L:

$$v = v_0 e^{\alpha(H_L - H_{w.st.})}, \quad (1)$$

where v_0 — represents the constant which has the character of the creep rate in the field $H_L = H_{w.st.}$, coefficient α is of the dimension (Oe^{-1}) and characterizes the steepness of the straight lines $\log v = f(H_L)_{H_T}$ (Fig. 1). The magnitude of α varies inversely to the square of the amplitude of the transverse field normalized to the anisotropy field $h_T = H_T/H_K$ (Fig. 2). Similar depencences $v(H_L)$ and $\alpha(1/h_T^2)$ were determined earlier by measurements on thin films of vapour deposition [8, 9] and in cylindrical permalloy films [10].

Of major practical importance is also the second creep characteristics — the curves of equal rates in the H_L, H_T scale. The easier the reversal of magnetization process is carried out by the creeping of the domain walls, the greater is the distance between these curves and the static critical curve of the domain wall start field.

Fig. 3 illustrates curves of equal rates for two films — a comparatively thin one ($d = 0.8$ μm) and a thick one ($d = 2.4$ μm). It illustrates also their corresponding critical curves of the start field $H_{w.st.}$. The threshold creep curves H_{cr} are shown by dash lines. These curves determine the minimum values of the fields H_L and H_T at which creeping only begins. While determining these

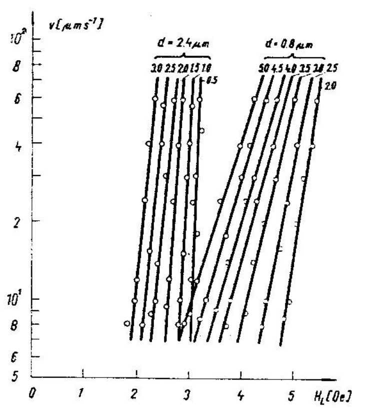

Fig. 1. Domain wall creep rate dependence on the static field H_L in films of the thickness $d = 0.8$ μm and $d = 2.4$ μm. The parameter being the amplitude of the alternating (50 Hz) field H_T (Oe).

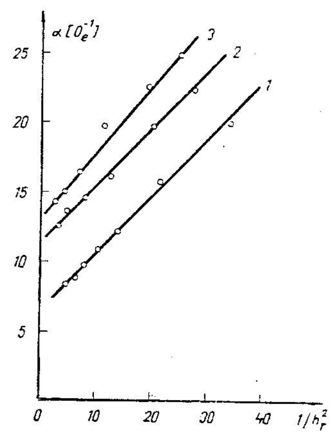

Fig. 2. The change of the coefficient α at the change of amplitude of the alternating field $h_T = H_T/H_K$. Thickness of layers: 1 — 0.8 μm; 2 — 1.5 μm; 3 — 2.4 μm.

fields the onset state is saturated. Then such field values of H_L, H_T are applied as to establish during 20 seconds (2000 pulses of H_T field) an alteration of the film magnetization by 5 % I_s, as a result of the growth of the domain nuclei from the boundaries of the film. The threshold curves limit the area of the working field H_L, H_T of the memory elements. In Fig. 3 it can be seen that for a thick film ($d = 2.4$ μm) the start field $H_{w.st.}$ is approximately twice smaller than for the film thickness $d = 0.8$ μm. At the same time, the stability zone of the recorded information decreased.

IV. EVALUATION OF EXPERIMENTAL RESULTS

Measurements of the domain wall creep rate in electrodeposited permalloy films of micron thickness have proved that laws similar to those for thin films of vapour deposition on glass are encountered here. In both cases the rate $v(H_L)$ changes according to the relation (1), however, the source of this exponential dependence so far has remaind inexplicable. The phenomenological theory of creep [11] is concerned only with very low rates (shift per pulse) at which relations presenting linear dependences for $v(H_T)$ and $v(H_L)$ have been obtained.

Of great interest is the study of the effect of the thickness of permalloy films on the creep characteristics. It is necessary to take into consideration that statical magnetic properties of electrodeposited films are substantially dependent on thickness. Fig. 4 shows the change of field of uniaxial anisotropy

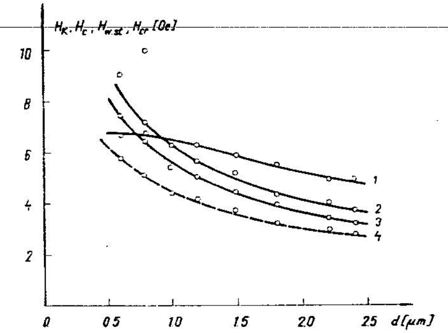

Fig. 3. Critical curves $H_{w,st.}$ (x) and curves of equal creep rates ($v = 10$; 40; 60 μm s^{-1}) for two films $d = 0.8$ μm and $d = 2.4$ μm. Threshold critical creep curves H_{cr} are shown by dashed lines.

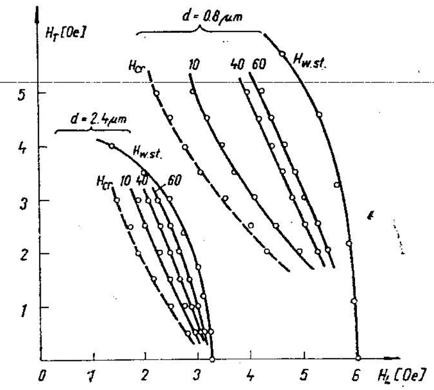

Fig. 4. The effect of film thickness on the anisotropy field H_k (1), coercive force H_c (2) domain wall start field $H_{w.st.}$ (3) and threshold creep H_{cr} (4).

H_K, coercive force H_c, start field H_{st} an the threshold creep field H_{cr} determined at the amplitude of $H_T = 0.1\ H_K$ in dependence on film thickness. It is evident that all quantities have a decreasing trend in accordance with the film thickness. The dependence of the threshold field H_{cr} on thickness is well illustrated by the shape of the curves $H_c(d)$ and $H_{w.st.}(d)$.

The shift of the domain walls in the range of small H_L, H_T fields in dependence on thickness of permalloy films can be explained by a strengthening effect of magnetostatic „magnitudes" on the curved domain wall [12]. The mechanisms of the domain wall creep connected with the change of the type of the domain wall (Bloch—Neel and Neel—Bloch) are not revealed in this case because creeping exists also in small fields H_T, at which the transitions mentioned above do not exist yet. The creep mechanism connected with the gyromagnetic behaviour of spins in Bloch walls [2] cannot play an important role either because the field H_T changes slowly.

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