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The features of Barkhausen jumps in multilayer ferromagnetic films with crossed easy axes of magnetization

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Abstract

The Barkhausen jumps (BJs) of multilayer magnetoresistive stripes with crossed easy axes of magnetization (EAs) in ferromagnetic layers have been studied. Switching a stripe in the threshold field H_t is shown to be made by one or two BJs. A change in magnetoresistance $\Delta\rho/\rho$ corresponding to a big BJ is as great as $\sim 1.5\%$. The results of defining BJ parameters are: forms of individual BJs, duration and probability of BJ appearance in the preset field range are presented. The displacement speed of the domain boundary of reverse magnetization in the process of BJs reaching 300 m/s was evaluated.

1. Introduction

Three-layer films containing two ferromagnetic layers of $Ni_{65}Fe_{17}Co_{18}$ separated by a non-magnetic Ta interlayer are the subject of investigation in the present paper. Easy axes of magnetization (EAs) in the magnetic layers are crossed and form an angle of 90°. Specimens are made in the form of narrow stripes whose long side is parallel to the bisector of the angle between the EAs.

According to previous investigations [1], the multilayer film stripes with crossed EAs possess a number of distinct features. Each ferromagnetic layer remains a single domain in the wide field range. The behaviour of the domain structure determines the dependence of magnetoresistance $\Delta\rho/\rho$ on the external field H_L applied along the whole stripe length. A smooth change in $\Delta\rho/\rho$ corresponding to the reversible rotation of magnetization in ferromagnetic layers occurs in the wide field range from $+H_s$ (the saturation field) to the negative threshold field $-H_t$. Over the area of H_t one can observe a sharp change in $\Delta\rho/\rho$ which is $\sim 1.5\%$ for a given specimen. It is caused by rapid displacement of the reverse domain top throughout the whole specimen.

The experimental data suggest that the films with crossed EAs are bistable, i.e. they have two stable magnetic states separated by a potential barrier. Since a transfer from one state to the other occurs in a field $H_t \gg H_c$ (H_c is the coercive force of a ferromagnetic material), one can suppose the switching of stripes by one BJ over the area of H_t. The present investigation was initiated to check for this supposition and to study the features of BJs in detail.

Investigation tests were stripes with length of 3 mm and width $b = 5$, 10, 20, 50, 100 and 200 μm. The thickness of the two ferromagnetic layers are alike and amount to $h_1 = h_2 = 70$ nm. The interlayer thickness was chosen to be 10–20 nm. The preparation conditions of specimens and their parameters were presented in Ref. [1].

Registering the BJs was made by two methods: the traditional one for magnetic materials with the use of a search induction coil as well as the unusual method of measuring magnetoresistance change $\Delta\rho/\rho$ in the film remagnetization proposed by us. The true configurations of BJs are registered by the second method, the duration of jumps is defined with an error of not more than 10^{-7} s.

2. Experimental results and discussion

The remagnetization of films with crossed EAs was shown to be made by one or two BJs. The jumps appear when the value of the external field is $H_L \simeq H_t$. This result was obtained both by the induction and the magnetoresistive methods of registering BJs. The typical oscillogram of an individual BJ registered by the magnetoresistive method is shown in Fig. 1. In this case the duration τ of a BJ was 10 μs. The remagnetization by one BJ indicates that the reverse domain moves on the specimen defects practically without delay when $H_L \simeq H_t$.

Close to H_t fluctuations of ΔH, at field values at

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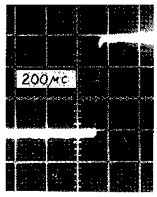

Fig. 1. Oscillogram of BJ for a 20 μm wide stripe.

which BJs appear, were observed. The maximum shift of BJs throughout the field corresponds to 0.1–0.2 A/cm.

Fig. 2 shows the results of the experimental research at a frequency ν of an individual BJ appearing in the preset field (the number of information accumulation cycles $N = 64$). Fig. 2(a) corresponds to the magnetoresistive method of registering BJs. Though in this case the field range in which the BJs appear is on the order of ± 0.04 kA/m, the greater part of BJs ($\sim 70\%$) is grouped in the range of $\Delta H \simeq \pm 0.01$ kA/m around H_m (H_m is the most probable value of the field of BJs appearing) in the subsequent remagnetization cycles. Induction measurements (Fig. 2(b)) showed similar results. Qualitatively similar dependences were observed on the specimens with width b from 5 to 200 μm. With an increase in b the value H_m decreased monotonically in accordance with the behaviour of H_t.

Also fluctuations of the duration τ from cycle to cycle of remagnetization were revealed. The tendency toward an

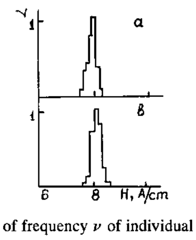

Fig. 2. Dependence of frequency ν of individual BJ appearance on external field H_L, $b = 50$ μm.

increase in the fluctuations of τ was observed, as b increased. Thus, for stripes of 5–10 μm wide, the value τ varied within 10–20 μs, in the specimens 200 μm wide the fluctuations reached 20–70 μs.

Since the signal level is proportional to the length of the remagnetized section of a specimen, using the magnetoresistive method of registering BJs, one can define the speed of boundary displacement between the direct and the reverse domains from the oscillograms. In this case the possibility of defining not only the average $\overline{V}$ but also the instantaneous speed V of the boundary is essential. Considering that a BJ corresponds to the remagnetized stripe length ($l = 3$ mm), we estimated the average boundary speed $\overline{V}$. In the specimens studied the value of $\overline{V}$ was 40–300 m/s, somewhat decreasing with increasing b. A decrease in $\overline{V}$ is likely to be connected with a drop in the difference between the nucleation formation field H_t of the critical size and the value of H_c.

3. Conclusion

The Barkhausen jumps (BJs) have been studied in the remagnetization process of narrow stripes of multilayer films with crossed EAs. The stripes were found to be switched by one or two big jumps close to the critical field H_t. In this case a change in the magnetoresistance is as high as $\sim 1.5\%$. Field fluctuations of an individual BJ appearance from cycle to cycle of remagnetization of 0.1–0.2 A/cm for a major part of the BJ have been observed. Using the magnetoresistive method for registering BJs made it possible to define the duration τ of a jump directly from the individual BJs and to estimate the values of the average and instantaneous speeds of the reverse domain growth $\overline{V}$ and V, respectively. The value τ varied in the range from 10 to ~ 70 μs, which gives 40–300 m/s for $\overline{V}$.

Reference

[1] V.N. Samofalov, L.I. Lukashenko, Fizica Metallov i Metalloved. 75(5) (1993) 47.