Direction investigation of the influence of the dynamic change of the Bloch-wall structure on its mobility

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The dependence of the velocity of an 180° Bloch wall in yttrium-iron-garnet single crystals on the state of its structure and on the value of the magnetizing field is measured. It is established experimentally that the motion of the Bloch lines leads to an increase of the viscous friction of the entire wall.

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A study of the domain-wall mobility in magnetically ordered crystals is of fundamental interest not solely because it determines the most important macroscopic characteristics of the magnetization of ferromagnets.[1] The research of the last decade[2] has demonstrated the possibility of using a single magnetic-structure element (a domain or even a section of a domain wall) as a carrier of information in various memory systems for computers, thereby uncovering prospects for microminiaturization of systems for information reduction and revolutionizing the changes in the corresponding branches of technology. The high speed of such new memory elements is determined directly by the mobility of the domain walls. This was precisely the stimulus for the great increase in the scope and depth of the research on subtle features of the structure of domain walls and mechanisms that limit their velocity. As a result, a number of singularities have been observed in the motion of Bloch walls and have so far found no explanation. One of the most interesting (and debatable from the point of view of its origin) is the nonlinear dependence[3] of the velocity v of the domain wall on the magnetizing field H, the cause of a considerable decrease of mobility with increasing H, of the appearance of "rigid" domains that affect adversely the quality of the memory elements. To explain this dependence, in particular, a hypothesis was advanced[4] that the decisive role in the increased resistance to wall motion is played by a dynamic transformation of its structure, determined by the motion of the Bloch lines. However, no direct experimental proof of the validity of this hypothesis has been obtained so far. The point is that an overwhelming majority of the investigations of the Bloch-wall mobility consisted of magneto-optical measurements on ferrite films with uniaxial anisotropy, such films are promising from the point of view of practical applications, but it is impossible to study in them simultaneously the structure of the Bloch wall because of serious methodological difficulties.

It was shown in[5] that in real yttrium iron garnet crystals the thickness of the 180° wall inside the volume of the crystal is sufficient not only for polarization-optical observation of its subdivision into subdomains, but also for the study of the evolution of the magnetization in the wall. This has made it possible to investigate experimentally in these crystals the dependence of the domain-wall velocity both on the magnetizing field and on the behavior of the Bloch lines in the wall.

The experiments described in the present article were performed on plates ~60 μm thick, bounded by {112} planes. To increase the measurement accuracy, the samples were made in the form of long parallelepipeds elongated along ⟨111⟩ and having a single 180° Bloch wall that separates two domains magnetized in the plane of the plate. In such a sample, the motion of the

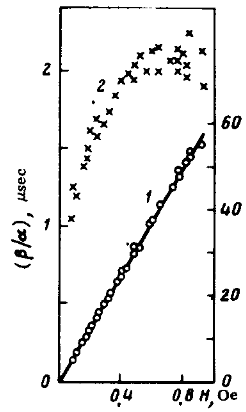

FIG. 1. Plots of X_0 (1) and of β/α (2) against the magnetizing fields H. $v=X_0/(\beta/\alpha)$.

wall did not change the wall area S and was accompanied by an increase in the demagnetizing force $F=\alpha X$ in direct proportion to the displacement X of the wall ($\alpha=$const, curve 1 of Fig. 1). The viscous-friction coefficient β was obtained from the law of motion of the wall under the influence of the pulsed magnetic field H: $X=X_0[1-\exp(-\alpha t/\beta)]$. Here $X_0=2M_0HS/\alpha$, M_0 is the saturation magnetization and t is the time of displacement of the wall. The displacement of the wall with time

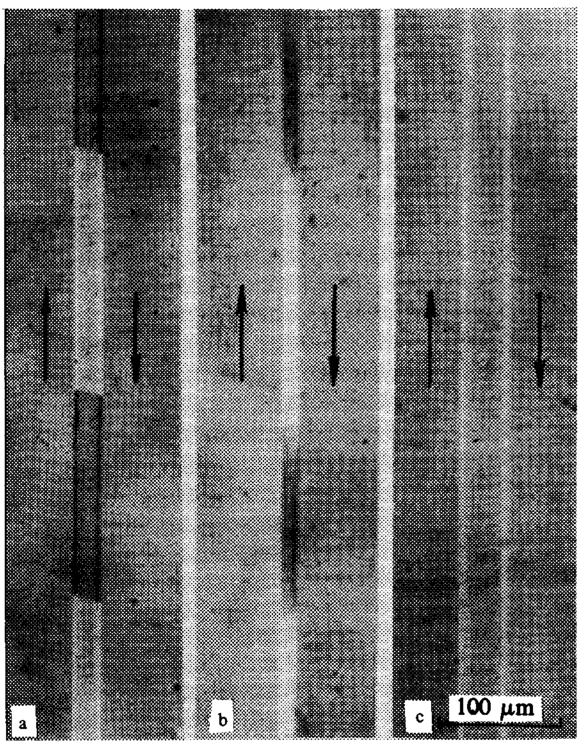

FIG. 2. Photograph, in polarized light, of Bloch wall oscillating in an alternating magnetic field: a) $v<1\times10^{-3}$; b) $v=6$; c) $v<15$ m/sec.

was determined from measurements of the intensity of plane-polarized light passing through the crystal under conditions when the plate was slightly inclined to the observation direction, and the Nicol prisms of the microscope were slightly uncrossed. The value of v for each H was determined as the ratio $X_0/(\beta/\alpha)$.[6]

The dependence of the wall velocity on the magnetizing field turned out to be noninear in practically the entire investigated interval of H. With increasing H, an increase takes place in β (Fig. 1, curve 2), meaning also in the intensity of the dissipative processes that limit the domain-wall mobility. Figure 2 shows photographs, in polarized light, of a 180° Bloch wall moving at different velocities. This wall consists of subdomains that manifest themselves in the form of black and white sections. At their junction points, where the direction of spin relaxation is reversed, are located the Bloch lines. The wall vibrates under the influence of the alternating magnetic field, and this is the cause of the double image. At small values of v, the structure of the wall remains practically unchanged [Fig. 2(a)]. With increasing wall velocity, a smearing takes place [Figs. 2(b) and 2(c)] of the transmission region between the "black" and "white" subdomains, thus evidencing a successive increase of the amplitude of the oscillation and of the velocity of the Bloch lines. The resultant additional energy scattering by the moving wall with increasing v determines the growth of β, in qualitative agreement with[4].

It should be noted that the dynamic changes of the structure of the Bloch wall begin at relatively small wall velocities. The reason may be that, as shown by experiment, the motion of the Bloch lines, and particularly their generation and annihilation, depends not only on the wall velocity but also on the real structure of the crystal (especially on the presence of dislocations).

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[1]S.V. Vonsovskiĭ, Magnetizm (Magnetism), Nauka, 1971.
[2]V.G. Bar'yakhtar, V.V. Gann, Yu.I. Gorobets, G.A. Smolenskii, and B.N. Filippov, Usp. Fiz. Nauk **121**, 593 (1977) [Sov. Phys. Usp. **20**, 298 (1977)].
[3]V.N. Dudorov, V. Randoshkin, and R.V. Telesnin, Usp. Fiz. Nauk **122**, 253 (1977) [Sov. Phys. Usp. **20**, 505 (1977)].
[4]J.C. Slonczewski, J. Appl. Phys. **44**, 1759 (1973).
[5]V.K. Vlasko-Vlasov, L.M. Dedukh, and V.I. Nikitenko, Zh. Eksp. Teor. Fiz. **71**, 2291 (1976) [Sov. Phys. JETP **44**, 1208 (1976)].
[6]J.A. Setchik, W.D. Doyle, and G.K. Goldberg, J. Appl. Phys. **42**, 1272 (1971).
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