Resonant generation of Bloch lines

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(Submitted 25 June 1980; resubmitted 19 August 1980)
Pis'ma Zh. Eksp. Teor. Fiz. **32**, No. 6, 402–404 (20 September 1980)

An abrupt increase in the density of Bloch lines at a 180° domain boundary was observed in an yttrium ferrogarnet single crystal due to the action of a weak, variable magnetic field, which was directed perpendicularly to the wafer surface and to the magnetization in the domains at certain field amplitudes and frequencies.

PACS numbers: 75.60.Ch

It was shown[1] long ago that a crystal, which has been divided into domains under the influence of a magnetostatic field caused by surface magnetic charges, corresponds to the ground state of a ferromagnetic material. The properties of domain boundaries determine to a large extent, and sometimes entirely, the magnetization of an object in constant and variable magnetic fields, its spin-wave spectrum, etc. A large number of papers[2] has been devoted to theoretical and experimental study of the laws governing the rearrangement of a domain structure and the mobility of domain boundaries.

Much more recently, attention has been focused on the fact that the domain boundaries can be divided into subdomains for the same reason.[3] As a result the Bloch lines, which separate part of the wall with oppositely directed spins at the boundary and which must influence the properties of the domain boundaries and of the entire crystal, can be an element of the domain structure of a crystal in the majority of cases. In recent years, theorists have used Bloch lines to explain many important characteristics of Bloch walls (their mobility, limiting displacement velocity, etc.) which cannot be explained in terms of the one-dimensional model of a domain boundary.[4] Experimental study of the properties of Bloch lines, however, is in its initial stage: the first papers,[5,6] in which methods were developed for measuring the dynamic characteristics, were published this year.

The conditions for excitation of the displacement resonance of Bloch lines in a 180° domain boundary in an yttrium ferrogarnet by a weak, variable magnetic field oriented perpendicularly to the specimen surface and to the magnetization in the adjacent domains, were satisfied in Ref. 6. This made it possible to obtain information about the mass and mobility of the Bloch lines in a wall. In a subsequent study of this effect over a wider range of variation of the amplitude and frequency of the external field, we discovered a new resonant generation of Bloch lines, which was not predicted theoretically. This opens the possibility of varying the substructure of a domain boundary in a controlled manner and studying many of its basic characteristics. This paper is devoted to a brief description of this effect.

"Vertical" Bloch lines oriented perpendicularly to the (112) surface of a 35-μm-thick, single-crystal wafer were identified through uncrossed Nicol prisms of a polarization microscope as a sharp boundary separating dark and light subdomains in a wall, which are characterized by opposite spin directions. As a result of application of a sinusoidal, variable magnetic field with an amplitude $H_0 = 0.01$ Oe in the frequency range ν 50–500 kHz, we observed[6] resonant oscillations of the Bloch lines in the form

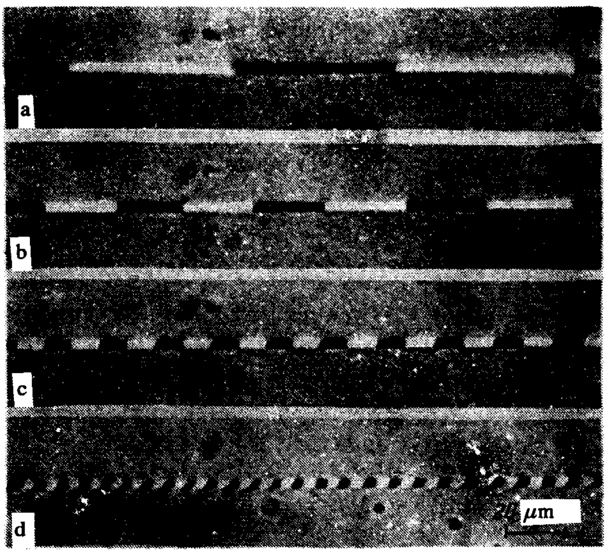

FIG. 1. Structure of domain boundary in a variable field ($H_0 = 0.06$ Oe) at frequencies: (a) $0.5 < \nu < 5.6$ MHz, (b) $5.6 < \nu < 7$ MHz, (c) $7 < \nu < 9$ MHz, and (d) $9 < \nu < 12$ MHz.

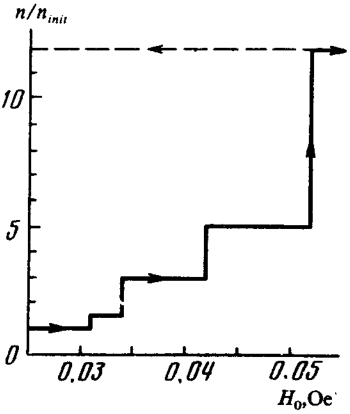

FIG. 2. Dependence of the relative density (n) of Bloch lines at the boundary on the amplitude of the variable magnetic field. $\nu = 11$ MHz and n_{init} is the original density of Bloch lines at $H_0 = 0$. The solid line corresponds to the variation of n/n_{init} as H_0 is increased; the dashed line corresponds to decreasing H_0.

of a loss of contrast in the transition region between the subdomains. As a result of a subsequent increase of ν, the amplitude of their displacement decreased to values that could not be resolved by the microscope. By further increasing ν, however, we observed sudden changes in the density of the vertical Bloch lines at the boundary at certain, H_0-dependent critical frequencies (Figs. 1a–1d). A resonant generation of Bloch lines, which occurred several times in the frequency range up to 12.5 MHz, decreased the size of the subdomain to such extent that it became approximately equal to the thickness of a Bloch wall (~ 2 μm). The structure with a high density of the Bloch lines remained after the external field was removed.

Similar abrupt changes of the substructure of a domain boundary were observed when the frequency remained constant and the amplitude of the external magnetic field was increased (Fig. 2). At lower ν values a resonant formation of Bloch lines resulted in a more abrupt increase (fourfold to sixfold) of their density than that in Fig. 2, after one jump that occurred at larger H_0.

Frequently, the generation of subdomains did not begin simultaneously along the entire wall, but rather in sections of the crystal that contained the defects or those located in region of the maximum gradient of the external field, which was produced, as in Ref. 6, by two 1.1-mm-diam, wire loops. In addition to an increase in the density of Bloch lines, we could see a displacement of all the subdomains. In some intervals of ν and H_0 the induced oscillations of the Bloch lines that preceded the rearrangement of the wall substructure were so large that the fine structure of the boundary image could not be resolved. In many cases a resonant displacement of the Bloch lines induced oscillation of the entire wall.

An abrupt increase of the subdomain density at the boundary may be caused by thermally activated generation and subsequent growth in the external magnetic field of new Bloch lines that limit the subdomain nucleation center. At a certain field amplitude and frequency its size is equal to the wafer thickness. The sections of the Bloch line parallel to the surface emerge from it, the only the "vertical" Bloch lines, which are responsible for a stable increase in the density of subdomains, remain in the crystal. A large number of resonant frequencies and fields apparently corresponds to the formation of nucleation centers in the nonuniform potential contour of a crystal near the defects and in a system of surface spins.

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Translated by Eugene R. Heath
Edited by S. J. Amoretty