Journal of Optoelectronics and Advanced Materials Vol. 6, No. 3, September 2004, p. 931 - 934

ANALYSIS OF BIAXIAL ANISOTROPY IN FERRITE-GARNET FILMS WITH IN-PLANE MAGNETIZATION USING PULSE INDUCTIVE EQUIPMENT

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A method of studying biaxial anisotropy in ferrite-garnet films with in-plane magnetization is considered. To ensure the maximum reliability in a comparison between the pulse properties of a film and its anisotropy the latter is investigated by means of a pulse inductive apparatus. For the identification of the anisotropy axes the dependence of the shape of the 180°-pulse reversal signal on the direction of the switching field is analyzed. The value of the effective anisotropy field, was measured by the method of free magnetization oscillations.

(Received April 26, 2004; accepted June 22, 2004)

Keywords: Biaxial anisotropy, Ferrite-garnet films with in-plane magnetization, Free magnetization oscillations

1. Introduction

Anisotropy is one of the factors that affect the behavior of magnets in magnetic field pulses. Thus, the value of the effective anisotropy field and the direction of the external switching field relative to anisotropy axes determine the form of the pulse switching curve representing the dependence of the magnetization reversal rate on the pulse field intensity. To ensure the maximum reliability in a comparison between the pulse properties of a magnet and its anisotropy the same measuring equipment should be used. However, in the papers related to this problem [1-4], the investigation of magnets with unaxial anisotropy (permalloy and soft amorphous films) has been not considered in depth. Here the possibility of studying biaxial anisotropy in ferrite-garnet (FG) films with in-plane magnetization is discussed. As already known, such films are applied to the solution of some technical problems, in particular, for making high speed optical modulators [5,6]. In such films, alongside with in-plane anisotropy (with an effective anisotropy field $H_{K_1} \leq 1\,\mathrm{kOe}$ [7,8]), the biaxial anisotropy [9] does appear. Quantitative information on the effective field of biaxial anisotropy H_{K_2} is absent.

2. Experimental equipment

Reference pulse induction installation [10,11] was used. The explored FG film was positioned in a strip line. This line and used sources of current pulses have allowed to gain pulses of a magnetic field H_P with amplitude up to 65 Oe at rise time 3-4 nanoseconds and up to 30 Oe at rise time 0.3 nanoseconds. Frequency repetition of the pulses was 1.2 kHz. For recording the change of a magnetization a longitudinal pickup loop was used, which plane was perpendicular to the field pulse H_P. The induced voltage in the pickup loop was detected by a sampling scope. The sampled signals were subjected to an electronic noise subtracter.

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3. Indentification of the anisotropy axes

For the indentification of the anisotropy axes the regime of the 180° magnetization reversal was used. An initial state of a technical saturation of FG films was achieved by applying a constant bias magnetic field H_b in the film plane. The reversal process was exited by applying the field pulse H_P, which direction was opposite to the bias field. The dependence of the reversal signal shape on the film orientation relative to the field H_P was investigated.

It has been found that if the amplitude of the total field $H_S = H_P - H_b$ is sufficiently high (≥ 50 - 60 Oe) and a film is rather homogeneous, the four directions are clearly defined. These four directions lie in the film plane and the signals for these directions have maximum duration (~ 8-12 ns). A transition from one of these directions to another is achieved by the rotation of the film on the angle close to 90°. For homogeneous films this transition is not followed by appreciable change of the signal shape. Fig. 1 shows the signals corresponding to the four possible directions of the field H_P, for which the signals duration is maximum. Oscillograms are obtained for the film with the following data: FG composition - $(LuBi)_3(FeGa)_5O_{12}$, thickness - 2.75 μm, field of technical saturation - 2.7 Oe, saturation magnetization - 16 Gs. The analysis of hysteresis loop of the film has shown that the discussed directions are collinear to two easy axes [9].

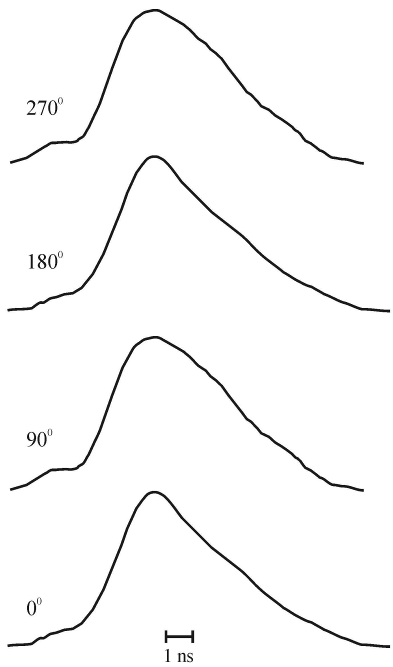

Fig. 1. The signals of magnetization reversal relevant to four possible directions of a field H_S along the easy axes H_S = 56 Oe.

For more precise orientation of field H_S along any easy axis in FG films, we have addressed to the experience of investigation of permalloy films [10,12] and used a dependence of the signal shape on a magnetic field $H_\perp$, perpendicular to the easy axis. After applying the field $H_\perp$ (~ 2-3 Oe) the signal shape sufficiently changes and the signal duration decreases (see Fig. 2, signal 1 and signal 2). If the film is homogeneous, and the field H_S is collinear to one of easy axes, the change of the field $H_\perp$ direction on 180° is not followed by any change of the signals (see Fig. 2, signal 2 and signal 3). However, if the film is essentially inhomogeneous this condition is not developed at any orientation of the field H_S. Thus, with the help of the described method it is possible to estimate the inhomogeneity of FG films. Our experiments shows that the required orientation of the field H_S and one of the easy axes for homogeneous FG films can be carried out with an accuracy of ~ 0.5-1.0°.

4. Measurement of the effective field of biaxial anisotropy

In order to measure the values of an effective field of biaxial anisotropy we have applied a method of the free magnetization oscillations, which was used earlier for measuring a field of an unaxial anisotropy in permalloy films [1,2]. We have showed that the free magnetization oscillations are easily generated in FG films under action of the magnetic field pulse applied in their plane [11]. It has been also found that Landau-Lifshits damping constant $\lambda<2\times10^6$ Hz . In these conditions

$$f^2 = \frac{\gamma^2}{4\pi^2}\cdot m\cdot\left(H_{K_2} + H_b\right), \quad (1)$$

where f is free oscillation frequency,

$$m = 4\pi M_S + H_{K_1}, \quad (1a)$$

γ - gyromagnetic ratio, H_{K_1} - effective in-plane anisotropy field, H_{K_2} - effective field of biaxial anisotropy, H_b - planar bias field applied to along one of the easy axes.

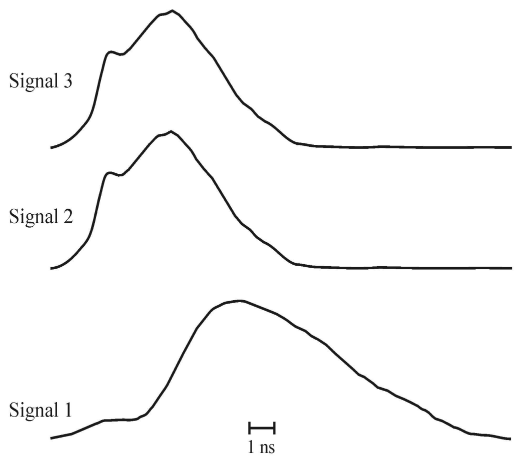

Fig. 2. The signals of magnetization reversal, received in presence of a field H_S = 56 Oe, directional along an easy axis. The signal 1 is received at field $H_\perp$ = 0, and signals 2 and 3 – at two opposite directions of a field $H_\perp$ = 3.2 Oe.

Free magnetization oscillations are initiated by applying the field pulse $H_S\ (\le 3-7\,\mathrm{Oe})$, perpendicular to the bias field H_b. A value of the anisotropy field H_{K_2} can be obtained from the dependence of the oscillation frequency square on the field H_b. The example of the experimental dependence is shown in Fig. 3. The experimental points are measured, accordingly, for two geometries, i.e. the field H_b was applied in first case along one axis, and in the second case - along another, perpendicular to first one. Fig. 3 shows that all these points are well approximated by one straight line. This result shows, that the investigated FG film really is biaxial and influence of unaxial anisotropy in this film does not appear. Prolonging the approximation straight line up to crossing with an X-axis, we find that for the sample under study $H_{K_2} = 50 \pm 6$ Oe. Also, we found out that for others investigated FG films H_{K_2} is situated in limits 35-55 Oe.

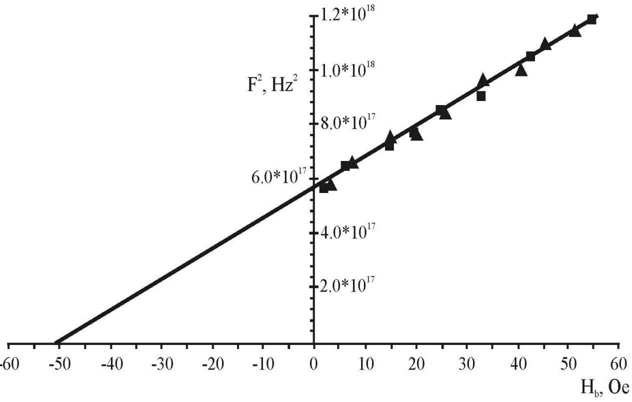

Fig. 3. Frequency square, F^2, versus bias field H_b. Triangles and quadrates represent results obtained for two geometries discussed in the text.

Using the value of H_{K_2} the coefficient m in (1) can be determined. So, from the data presented in Fig. 3 follows, that $m = 1.2 \pm 0.2$ kOe. Using above mentioned value of M_S (which has been found by use of vibrating sample magnetometer; VSM of Princeton Measurement Corp.), we got the value of $H_{K_1} = 1.0 \pm 0.2$ kOe.

5. Conclusion

Extension of the pulse inductive method's investigation of magnetic anisotropy in thin permalloy films on the case of ferrit-garnet films with in-plane magnetization is rather fruitful and allows to obtain data not only on the biaxial anisotropy, but also on in-plane anisotropy.

References

[1] P. Wolf, Z. Physik, **160**, 310 (1960).
[2] Y. Suezawa, F. B. Humphrey, IEEE Trans. Magn., **MAG-8**, 319 (1972).
[3] K. U. Stein, Z. Angew, Phys. **20**, 36 (1965).
[4] A. S. Kashintzev, O. S. Kolotov, V. A. Pogozhev, Pribory i Tekhnika Eksperimenta, №3, 191 (1992).
[5] R. Wolfe, V. J. Fratello, M. McGlashan-Powell, J. Appl. Phys. **63**, p.3099 (1988).
[6] M. McGlashan-Powell, R. Wolfe, J. F. Dillon, L. C. Fratello, J. Appl. Phys. **66**, 3342 (1989).
[7] E. N. Il'yicheva, U. A. Durasova, A. V. Klushina, O. S. Kolotov, V. V. Randoshkin Zavodskaya Laboratoria. Diagnostika materialov **67**, №7, 27 (2001).
[8] L. E. Helseth, E. I. Il'yashemko, M. Bazilijevich, T. H. Johansen, J. Appl. Phys. **92**, 1 (2002).
[9] E. N. Il'yicheva, U. A. Durasova, O. S. Kolotov, V. V. Randoshkin, M. U. Gusev, U. V. Kozlov, N. S. Neustroev, Zavodskaya Laboratoria. Diagnostika materialov **68**, №12, 44 (2002).
[10] O. S. Kolotov, V. A. Pogozhev, R. V. Telesnin, Methods and Apparatus for Investigation of Pulse Properties of Thin Magnetic Films (in Russian), Moscow State University Press, Moscow (1970).
[11] E. N. Il'yicheva, E. I. Il'yashenko, O. S. Kolotov, A. V. Matyunin, V. V. Smirnov, Fiz. Tverd. Tela **45**, 1037 (2003).
[12] A. S. Kashintzev, O. S. Kolotov, V. A. Pogozhev, Fiz. Met. Metalloved. **64**, 891 (1987).