THE INVESTIGATION OF MAGNETIC ANISOTROPY OF "EASY PLANE" TYPE AND THE DISTRIBUTION OF MAGNETIZATION IN THE EPITAXIAL GARNET FILMS WITH THE (100) SUBSTRATE ORIENTATION

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An epitaxial films $(BiLu)_3(FeGa)_5O_{12}$ and $(BiTm)_3(FeGa)_5O_{12}$ with anisotropy of "easy plane", grown up on the (100) gallium-gadolinium garnet substrate, were investigated. We revealed the presence of biaxial in-plane anisotropy of the films coinciding with directions [110] and [100] of film crystallographic axes. From the critical-transition curves through the demagnetized condition the angles θ_0 ($1\text{-}5^0$) of "easy plane" inclination from the plane of film were determined. The requirements for the parameters of the ferrite-garnet films with the "easy plane" anisotropy for improving of magneto-optical imaging applications are discussed.

1. Introduction

Now interesting application of opportunities Bi-containing ferrite-garnet films with an anisotropy such as "easy plane" are investigated. The combination of major amount of Faraday rotation and a small of a magnetization in such films allows to solve many practical problems of integrated optics, to use them for visualization of magnetic fields distribution of different magnetic media and superconductors, diagnostics of defects in metal materials, examinations of features of dynamic magnetization behavior [1].

For this purpose detailed studies of problems, as an "easy plane" deviation from a plane of film, presence of an anisotropy in a plane of film, influence of plane fields on sensitivity of a film to the action of normal external field components are necessary.

2. Experimental

The main experimental method is based on a magnetooptical Faraday effect. The measuring equipment allowed to carry out measurements of the angle of Faraday rotation F under the field H_Z, perpendicular to the plane of the film. The hysteresis loops is recorded and the domain structure [2] is observed. In these measurements a light beam was oriented perpendicular to the plane of a film.

There were explored two Bi-containing ferrite-garnet films of composition $(BiLu)_3(FeGa)_5(O)_{12}$ and $(BiTm)_3$ $(FeGa)_5(O)_{12}$, grown by LPE method on GGG substrates with orientation [100]. During LPE process the constant anisotropy K_U is negative. In this case the vector $\mathbf{M_s}$ has in-plane orientation and the hard axis is perpendicular to the plane of film. Thus

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$$\cos\beta = \frac{H_Z}{H_K} = \frac{M_Z}{M_S} = \frac{F}{F_S}, \tag{1}$$

where β is the angle between vector $\mathbf{M_s}$ and the normal to the plane of the film.

Thus, the angle of Faraday rotation F should depends linearly on the field H_Z up to $H_Z = H_K$. Actually, the linear relation takes place only in a particular interval of field H_Z (in this case $\cos\beta_m \sim 0.7$ and $\beta_m \sim 45°$). The value of the anisotropy field H_{K_1} can be determined by calculating

$\cos\beta = \dfrac{F}{F_S}$ from the linear part of the function $F(H_Z)$.

3. Results

The observed domain structure in a residual magnetization state exhibits weak contrast and represents the macrodomains separated by direct walls with angles between them 90° and 135°, that corresponds to reference axes of [100] and [110] of a plane (100) of cubic crystals. For $K_U < 0$ axis [100] is a hard direction, and the axis [100] - the intermediate easy direction.

The presence of the anisotropy in the plane of the film is evidenced from azimuthal dependence of the shape of transverse hysteresis loops M_Z (H_X). At some azimuth angles φ the loop looks like in Fig. 1a. The amplitude of the signal in the state of saturation by field $\pm H_X$ is identical (points 1 and 2 correspond to the demagnetized state). This loop is iterated approximately through 90° and corresponds to easy axis [110]. In this case the change of M_X - components direction do not cause a change of M_Z - component sign. At a small deviation from easy axis ($\pm2°$) (Fig. 1b, c) the shape of a loop changes, and allows to locate the orientation of easy axis with a high accuracy. At $\varphi = \pm 45°$ the loop is rectangular, in the state of saturation M_Z - components are opposite.
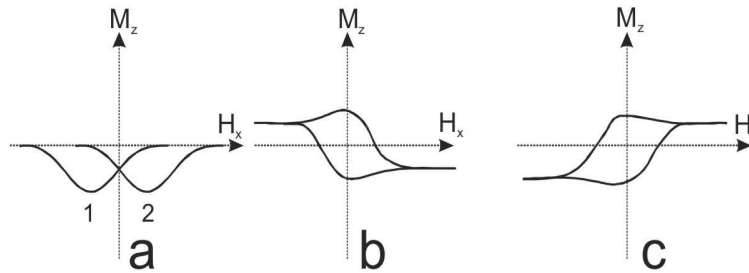

Fig. 1. Transverse hysteresis loops $M_Z(H_X)$ for the sample №. 8 (Table 1) a: $\varphi = 0$,
b: $\varphi = + 2^o$, c: $\varphi = - 2^o$ (at $H_{o_x} = 7.5$ Oe).

There was examined the transition process caused by magnetic fields, parallel to the plane of the film [3] on samples №2 and №3 (see Table 1). It has been found, that the character of the given processes depends on the direction of these fields. On the other hand there were found the two directions of easy and hard axes, which coincide enough accurately with the directions, revealed by magnetooptical method.

The study of the frequency dependence of the free oscillations induced by an impulse of the plane field on the strength of the constant adjusting the magnetic field [4], has allowed to find the in-plane anisotropy field H_{K_2} in the same films as 40.0 ± 0.4 Oe.

The constant field $H_Z \ll H_{K_1}$ determines the shift of the transverse hysteresis loops along the field H_X. Thus, the loop along the easy axis changes its shape (Fig. 2). There are two M_Z unipolar loops divided by horizontal step, relevant to state (Fig. 2a, b). Transition from

demagnetized state in a one-domain state is easily checked (Fig. 2 c,d). For hard axis case this transition occurs at the field H_{C_x} .

Table 1.

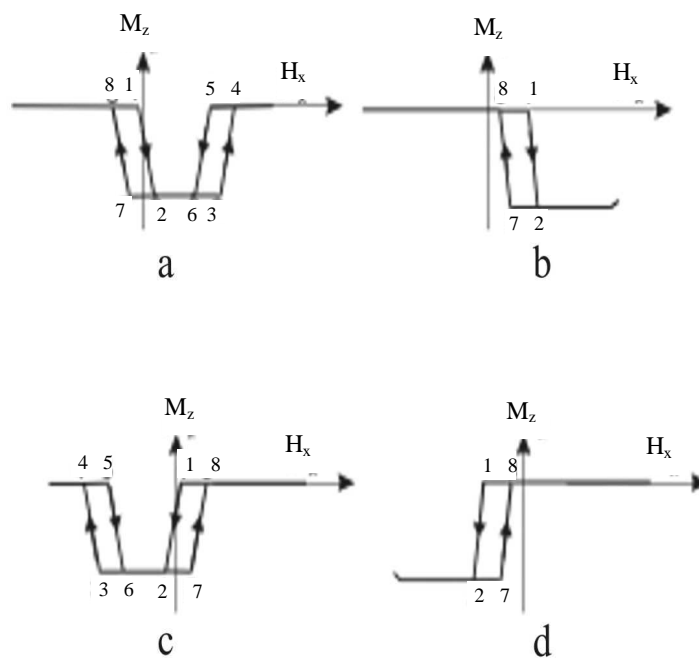| Sample №	RE	h, [mkm]	F_S, [grad]	θ_0, [grad]	H_{K_1}, [Oe]	$\cos \beta_m$
1.	Lu	1.0	1.0	-	500	1.0
2.	Lu	4.0	4.8	4.67	580	0.75
3.	Lu	1.8	1.5	3.17	430	0.99
4.	Lu	3.9	4.0	1.3	500	0.90
5.	Lu	2.3	2.25	1.3	440	0.80
6.	Lu	2.0	2.0	-	700	0.75
7.	Lu	6.0	6.0	1.77	820	0.83
8.	Tm	4.8	4.6	2.83	700	0.60
9.	Tm	4.0	3.6	7.0	630	0.70
10.	Tm, Lu	3.0	2.8	4.5	400	0.60
11.	Tm	4.2	4.1	5.1	600	0.60

Fig. 2. Influence of the field H_Z on transverse hysteresis loop given on Fig. 1a: a) at $H_Z = + 60$ Oe, b) at $H_Z = + 70$ Oe, c) at $H_Z = - 60$ Oe, d) at $H_Z = - 70$ Oe. Sample № 8. Numerals show the sequence of change of the signal of magnetization reversal.

The fields H_Z and $H_{X_{lim}}$ form the critical curve of transition through demagnetized state (Fig. 3). The processes of transition are interlinked in shifting the domain walls at constant angle θ_0 of vector $\mathbf{M_S}$ deviation from the plane of the film.

In this case the pressure P on the domain wall is:

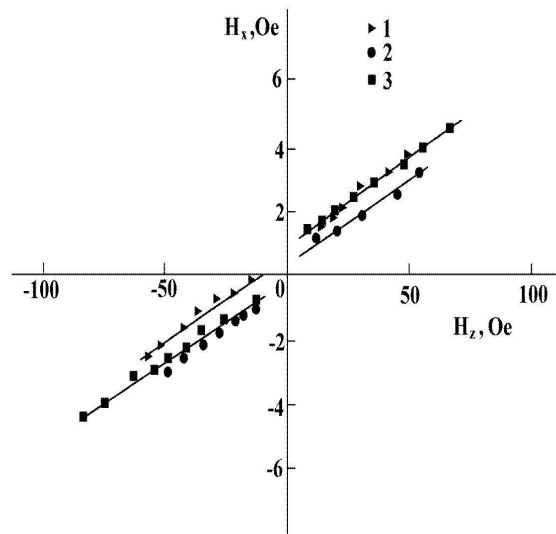$$P = 2M_XH_X + 2M_ZH_Z = 0; \quad \text{where} \quad \frac{M_Z}{M_X} = \frac{H_X}{H_Z} = \text{tg}\theta_0 .$$

Fig. 3. Critical curves $H_{Cx} = f(H_Z)$ for the sample №7 (Table 1), $\varphi = 45^o$ (curves 1 and 2) and $\varphi = 0$ (curves 3), $\theta_0 = (1.77\pm0.12)^o$.

4. Conclusion

The presence of biaxial in plane anisotropy in the $(BiLu_3)(FeGa)_5O_{12}$ and $(BiTm)_3(FeGa)_5O_{12}$ along the directions [110] and [100] was demonstrated.

References

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