

Study of Magnetic Non-Uniformities in Yttrium-Iron Garnet by the Measuring Method of Magneto-Optical Susceptibility

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Abstract

Study of magnetic non-uniformities in yttrium-iron garnet by the measuring in method of magneto-optical susceptibility in laser beam with the wave length of $\lambda = 1.15\mu\text{m}$.

1. Introduction

It is known that iron-garnets (FG) transparent in I R and visible region of spectrum are broadly applied in functional magnetoelectronics, optomicroelectronics [1, 2] and integral magneto-optics [3]. Materials with strip-domain structure are of particular interest for technical application for thermomagnetic information record in magneto-optical (MO) storage devices [4] and for creation of light beam deflectors. One of the problems closely connected with the practical application of FG is the problem of the magnetic non-uniformities nature in these materials. Main sources of magnetic non-uniformities are deformations of the crystal lattice, caused by the growth anisotropy, defects, dislocations etc. [6, 7]. Application of FG in technique placed greater demand on their magnetic uniformity.

Thus the development of sensitive methods for observation and study of magnetic non-uniformities nature is one of the important applied problems of the physics of magnetic phenomena.

Experimental Device and Measurement Methods

For magnetic non-uniformities study the value of dynamic magneto-optic susceptibility (MOS) was measured. For the measurement of dynamic MOS the differential device was used which was previously described in [5]. In this device the modulation of the stationary magnetic field of the electromagnet with the frequency $f = 71\text{Hz}$ is being created by the additional coil. The angle between a polarizer and analyzer was 45 degrees. The laser beam with wave length of $\lambda = 1.15\mu\text{m}$ was focused on the surface of the sample being studied to spot diameter of $50\mu\text{m}$. For absorption of the laser noise the photodetectors were switched through balance schemes. The scanning of the magnetic field was carried out by special block, designed on the basis of the generator sawtooth voltage and power amplifier which provided quasi-static change of the magnetic field with scanning interval from 10 sec. to 60 min. The value of the external magnetic field was controlled by a PHEM 602.117 A type Hall sensor. The directions of the external magnetic field H and variable field were collinear between each other and perpendicular to plate plane.

For the exclusion of the magnetization primary process effect, the external magnetic field applied to the sample was first brought to 1500 Oe and, then by quasi-static reduction of the field value, the measurements of MOS field dependences were carried out. The application of such measurement methods provide the good reproduction of results and to reliably determine MOS features.

Experiment and Discussion

1. Experiment

Monocrystals of yttrium iron garnet (YIG) with various background and thickness were prepared as the samples investigated

$$a) Y_3Fe_5O_{12}, d = 50\mu\text{m}, H = 16Oe;$$

$$b) Y_3Fe_5O_{12}, d = 55\mu\text{m}, H = 250Oe : \quad \text{in the plane (110).}$$

MOS curves for YIG are given in the Figure. Results of measurements show, that depending on the degree of magnetic non-uniformity of the sample, don't change for various light wavelengths. Thus the most characteristic curves of investigated samples were given at the wave length $\lambda = 1.15\mu\text{m}$.

As it can be seen in the Figure (a), one well revealed maximums at $H = 1000Oe$, and broadly at $H = 500Oe$ and $700Oe$ being observed. It should be noted that the maximum at $H = 1000Oe$ is observed in all investigated samples. In Figure (b) for other YIG three well resolved maximums were noticed at fields of $500Oe$, $700Oe$ and $950Oe$ and a small deflection at $1100Oe$. The maximum being observed in all samples at $H = 1000Oe$ is sample shifted to the region of smallest fields, i.e. $950Oe$.

2. Discussion

In work [8] it was shown that various mechanisms of magneto-optic effects correspond

to various plots of magnetization in the region of domain walls movement. In the region of domain walls movement magnetization is determined by domain structure reconstruction, which can be carried out by the domain walls shift and turn of magnetic moments in domain. This process is very sensitive to defects in crystal [9-11]. Depending on the character of domain walls fixing on available defects the domain walls shift speed and magnetic moments turn in domains takes place in various ways.

Magneto optic susceptibility has the following form [8]

$$\chi^{MO} = 4Am_S S \cos^2(Q/\alpha),$$

where A is the magneto optic coefficient; S -total domain walls length Q - angle between directions M in the domain and magnetic field; m_S -saturation magnetization; α -average curvatures for potential pits for domain walls, produced as a result of crystalline structure destoration.

Thus in the region of domain walls movement magnetization change takes place due to the volume increase of energy effective and decrease of the volume of energy uneffective domain with the increase of the external magnetic region value. In this case, $\alpha = 1$ and $\chi^{MO} = \text{const}$ if the crystal is defective ($\alpha = 1$) then with the change of external magnetic field H magnetization occurs abruptly and particularities are being observed on the χ^{MO} curves. The availability of defects in crystal forms metastable domain regions and, at the edge of their fixation, the magnetization speed changes. To reveal features connected with the crystal defects in the region of domain walls movement, the following conditions are implemented: firstly, for determination of these features, the laser beam diameter is minimized, i.e. closer to the domain sizes; secondly, the condition $h \ll H_C$ shall be implemented, where H_C is the coercivity force. This parameter determines the minimum region which shall be applied to the domain structure to cause it's movements. For non-execution of one of these conditions the features on the curves cannot be revealed. Apparently in work [8] due to the non-execution of one of these conditions (beam diameter $d = 250\mu m$), these features in the area of domain walls movement were not revealed. In the region of magnetization change, the increase of crystal intensity of magnetization at the expense of domain walls movement take place up to definite magnetic field $H = H_1$, which is determined by the sample shape (demagnetization factor) value for spontaneous intensity of magnetization m_S and direction of magnetic field. This magnetic field is applied across the axle of [100] type yttrium - ferrite garnet and demagnetization factor is equal to 4π ; then value $H = 4\pi m_S \sqrt{3} = 1kOe$. In this case, for fields of $H = 1kOe$, the magnetization regimes change which takes place is accompanied by the disappearance of the part of domain and the intensity of magnetization has a component directed into the H field. χ^{MO} anomalies in the region of field $\approx 1kOe$ are evident, connected with the collapse of uneffective domains, accompanied by a sharp change of the domain boundaries total length.

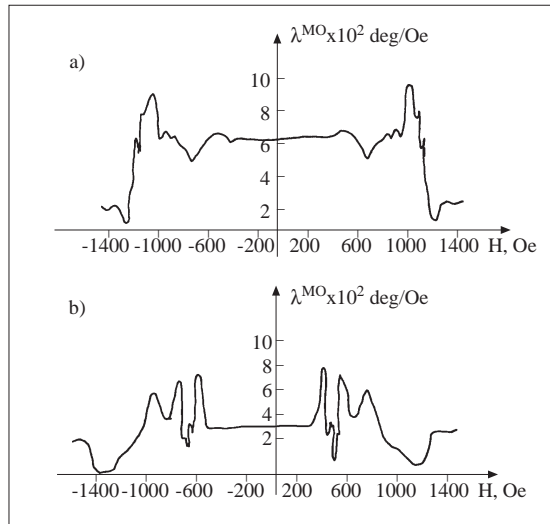


Figure 1. Curves Magneto-optical Susceptibility in YIG on the wave length $\lambda = 1.15\mu m$.

- a) YIG, $d = 50\mu m$, $H_C = 16Oe$
 b) YIG, $d = 55\mu m$, $H_C = 250Oe$.

In the region of magnetization regimes change, as it was shown in work [8], the increase of crystal magnetization at the expense of domain walls movement will take place up to a definite value of the magnetic field $H = H_1$, which is determined by the sample shape (demagnetization factor), spontaneous intensity of magnetization value m_S and magnetic field direction. In investigated samples this process is well observed and conforms with data of the work [8]. On sample 2, this maximum is slightly shifted to the region of smaller fields that is connected with the sample shape (demagnetization factor) i.e. non-uniformities in the sample and leads to the certain spread in values H_1 and H_2 .

In the magnetization region rotation, magnetic effects are considered in detail in [8], and in the saturation region, as it was noted in the work [8] there are no magnetic effects in YIG.

Conclusion

Studies conducted in the works showed that methods described are convenient for the analysis of magnetic characteristics. Application of precision polarimetric method allows to determine new magnetic properties in the field of domain walls movement and were metastable regions were revealed, which lead to crystalline structure distortion as well as thin structure in the region of magnetization regimes change.

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