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Magneto-optical Visualization of Eddy Current Magnetic Fields

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Abstract

Some important features of magneto-optic eddy current (MOEC) images realized in garnet films during introscopy process and behavior of domain structure in these films were revealed and are discussed. Numerical simulations of eddy current magnetic fields were performed with parameters of the real sample. It is established that the experimental results are in a qualitative agreement with the numerical simulations.

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Keywords: magneto-optical sensor; garnet films; magnetic field visualization; eddy current introscopy

1. Introduction

The generation of the eddy currents and the accompanying magnetic fields (MF) are widely used in the technician, and recently in medicine. So eddy current probes are used for the rapid analysis of cardiac activity, to register venous pulse, hyperthermia etc. [Andrä W. At al, 2007]. In some cases it is necessary to know the distribution of the magnetic fields magnetic nanoparticles [Nikitin P.I., at al, 2007] or various organs of the human [Malmivuo J. at al, 1995]. Promising materials on the basis epitaxial ferrite garnet films (EPFG) can be used for magnetic field sensors. There are various ways of creating magnetic sensors using EPFG. In [Vetoshko P.M. at al, 2013 and 2015] a high-sensitivity magnetic modulation sensor, which can compete with the SQUID by using, for example, in magnetocardiography. On the basis of EPFG can be created magneto-optical sensors. Important advantage such sensors is the possibility of direct observation of the topography of magnetic fields generated by magnetic objects [Vishnevskii V. at al, 2009] or eddy currents excited in the conductive objects [Radtke U. at al, 2001 and Vishnevskii V. at al, 2013 and 2014, Lugovskoy N. at al, 2014]. In this paper the effectiveness of a magneto-

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optical imaging of eddy current introscope is studied and the numerical simulation of the excited eddy current magnetic fields is performed in the model objects.

The principle of operation of the eddy current magneto-optical (MO) introscope is based on the reaction of the dynamic domain structure (DDS) of the magneto-optical sensor to the distribution of magnetic fields generated by eddy currents (EC) in the test sample of conductive material. Eddy currents are excited by an inductor of alternating magnetic field. Visualization of the dynamic domain structure in a magneto-optical sensor is mediated by the Faraday effect. Defects in the test object lead to a change in the trajectory of the eddy currents and a corresponding change in the configuration of the magnetic fields generated by them. As the sensors are the usually transparent films of iron garnets based on the bismuth iron garnet. The optical contrast, size and quality of the MO image depends on several parameters, including frequency and amplitude of the exciting field, and non-linear properties of the dynamic domain structure [Kandaurova G.S., 2002].

2. Experiment

Experiments were carried out on a test specimen of aluminum alloy with two model linear defects: cracks with width of 20 and 40 microns at a distance of 5 mm in the plate thickness 0.3 mm. The frequency of the excitation field varied in the range of 8-60 kHz. Multicomponent iron garnet films thickness 5-10 micron with uniaxial anisotropy $(Bi,Eu,Lu)_3(Fe,Ga,Al)_5O_{12}$ or $(Bi,Tm)_3(Fe,Ga)_5O_{12}$ act as sensors.

Fig.1 shows the dynamics of change MO images slits of 40 µm at f = 60 kHz, zero biasing field, amplitude of the excitation field H_{ex} in the range 0 - 200 Oe. At small amplitudes of the pumping fields, MO images presented white strips. With the increase of the H_{ex} in the center of the white image black streaks appear. Dark stripe corresponds to the reverse magnetization of the sensor in this area.

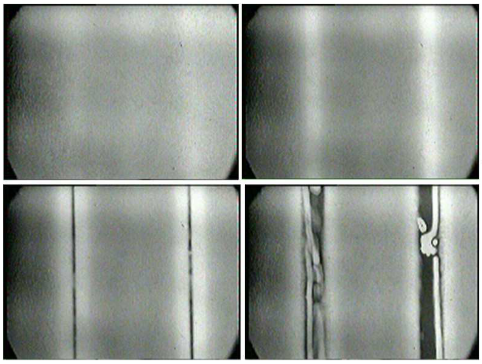

Fig. 1. MOEC images of slits at H_{ex} = 20, 60, 100,180 Oe; f=60 kHz

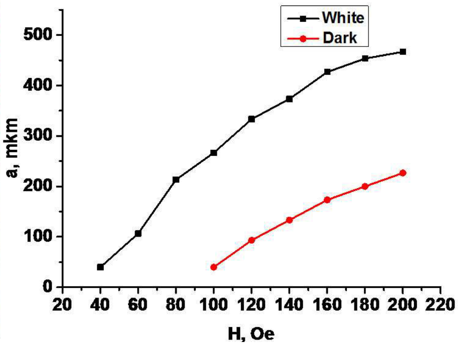

Fig. 2. The width of the white and dark stripes from alternating field Hex for 40 µm slits

With increasing H_{ex}, size of all strips images is increasing. As it is seen from Fig. 2 the size of white and dark MO images significantly exceed the physical size of the gaps by 12 and 6 times, accordingly.

At the large H_{ex} in the center of the dark area of the image appear white areas of reverse magnetization, which complicate the identification of the defect. Such transient DS arises are threshold, above a certain critical field

3. Simulation

The modeling of ECMF based on the method of integral-differential equations relating the density of excited electric charges, eddy currents and magnetic fields generated by them. The corresponding system of equations shown below: