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FTIR И ФЛ СПЕКТРОСКОПИЯ ПОРОШКООБРАЗНОГО АЭРОГЕЛЯ КРЕМНЕЗЕМА ar-SiO_x

Проведено исследование оптических и фотолюминесцентных свойств порошкообразного аэрогеля кремнезема с использованием FTIR спектроскопии пропускания и фотолюминесцентной спектроскопии. Порошкообразный аэрогель кремнезема изготавливался на основе водного раствора силиката с использованием технологии золь-гель синтеза. Подтверждено, что исследуемый материал состоит из двух фаз: стехиометрической SiO_2 и нестехиометрической SiO_x. Анализ FTIR спектров пропускания обнаружил присутствие значительного количества гидроксидных групп, которые обуславливают окислителные свойства материала и определяют песпективность его использавания в качестве матрицы для инкорпорирования наночастиц. Зарегистрирована интенсивная ФЛ в сине-зеленой области спектра с максимумами при 1.9, 2.0, 2.2 и 2.6 эВ. Было показано, что эмиссионные свойства порошкообразного аэрогеля кремнезема ar-SiO_x обусловлены наличием значительного количества кислородных дефектных центров, таких как кислородные дырочные центра, пероксидные радикалы и кислородно-дефицитные центры, а также силоксановые и силановые группы. Было также показано, что под воздействием импульсного лазерного УФ облучения наблюдается уменьшение интегральной интенсивности ФЛ. Гашение ФЛ обусловленное трансформацией дефектной структуры материала в процессе фотоокисления.

Ключевые слова: *порошкообразный аэрогель кремнезема, дефектные состояния, FTIR спектроскопия пропусканния, кинетика ФЛ.*

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VISUALIZATION OF MAGNETO-ELECTRIC DISPLAYS IN FG/GGG EPITAXIAL STRUCTURES

Using the method of polarizing microscopy, under the combined effects of static and alternating electric fields and magnetic field, studied the reaction of the domain structure (DS) epitaxial ferrite garnet (FG) films, grown on single crystal substrates of gallium-gadolinium garnet (FG / GGG). In transmitted light visually detected a small effect of the profile changes ("smearing") of the individual local sites of the films domain wall (DW) because of a combination of three-channel external influence.

Keywords: *magneto-electric effect, electric field, magnetic field, domain wall, domain structure, polarizing microscope.*

Introduction. The change of magnetization under the influence of electric field or of electric polarization under the influence of magnetic field are called magnetoelectric (ME) effect. Study of the mechanism of interaction of electric and magnetic subsystems in magneto-electric materials has recently been the subject of many publications. This interest is driven by a need to establish a single fundamental theory of magneto-electric interactions in solids, and wide application possibilities of using magneto-electric materials in electronics.

The first explicit prediction of ME effect in a specific material was made by Dzyaloshinskii who showed that in Cr_20_3 these effects are allowed by the magnetic symmetry [2]. Experimentally, the electrically induced ME effect was first observed by Astrov [1] on a crystal of Cr_20_3 and later Rado and Folen [10]. The first observation of the ME effect in yttrium-iron-garnets (YIG) was reported by O'Dell [9] and later, the ME effect was studied in a number of papers [3÷8, 12]. The external electric field that connected to the crystal of certain magnetic symmetry (eg, YIG), can cause in crystal the manifestations induced optical phenomena, linear or nonlinear in the electric field. One of such phenomenon is the effect of the changes of light polarization plane Faraday rotation in an optically transparent dielectric crystal induced by an electric field, which the authors named as an electromagneto-optical (EMO) effect [8]. Using a highly sensitive method of optical polarimetry, it is possible to measure the changes of light polarization plane rotation in an external electric field, as well as to carry out visual observations of the domain structure of the sample using a polarizing microscope.

Iron garnets are a large class of ferrimagnetic oxides with high Curie temperature (T_c>500K) and have been applied to magneto-optical devices and magnetic bubble memories [11, 13]. The active interest in the structural, magnetic, and magneto-optical properties of garnet films has been related to the fact that all these properties can be widely varied by changing the composition and orientation. Although the parent garnet crystal structure is characterized as the cubic centrosymmetric space group the studies of film structure and magnetic properties have revealed that films tend to have uniaxial or orthorhombic symmetry. The origin of this symmetry lowering is due to growth anisotropy and mismatch between the lattice parameters of the films and substrates. The crystallographic orientation of the substrate is also of primary importance. Garnet crystals are well known to play an important role in technological devices.

Domain structure (DS) of ferrite garnets is periodically interspersed with small regions of antiparallel magnetization direction, which are separated by domain walls. In DW is changing the direction of the orientation of the spins in the same domain to the direction in the nearby. In ferrite garnets it is possible to visualize processes occurring in them due to the magneto-optical Faraday effect.

In this paper, we report the results of studies ME manifestations in epitaxial ferrite garnet films in a two-channel and three-channel external influence. In particular, visual observations were made for the DS of the film with the use of magneto-optical polarization microscopy with high optical permission based on the Faraday effect in two experimental versions: 1) under the joint action of the alternating electric field and constant magnetic field; 2) under the joint action of DC and AC electric field and a constant magnetic field. Investigated epitaxial films grown on (111) substrates of gallium-gadolinium garnets (GGG). The domain structure of the films studied under the polarizing microscope looks like high contrast, which indicates about significant deviation of domain magnetization vectors from the film plane.

Experimental. The test sample was placed between two optically transparent electrodes. The electrodes were deposited by spraying on the inner surfaces of the two thin glass plates. Separately or simultaneously to the sample plugged in the AC and DC voltage. External constant magnetic field was oriented along the plane of the film. The thickness of the film was about 10 μm, the width of domains was about 14 μm at H=0, and the domain-wall width was about 0.5 μm. The test sample we previously several times been the iterative process of quasi-static magnetization in the magnetic field in both directions. The reproducibility of the overall picture domain labyrinth structure in this case was not observed. DW motion occurred intermittently due to the interaction with microdefects and for each area of the DW was of probabilistic nature. The stripe domains are randomly bent and DW located in different places in the film, indicating that complete isotropy of the properties of this film in its plane.

Results and discussion. By visual observation of the domain structure of the following was revealed. For small values of the constant electric field (from 0 to 1.6 kV/ mm) significant changes in the domain structure was not observed. Domain structure remained the same as in the initial state – a disordered maze. Connection to the sample while still a magnetic field, oriented in the plane of the sample, did not lead to any visually observed changes in the domain array of the film. Connection of the third control channel – low-frequency (950 Hz) AC electric field with strength up to 3.5 kV/mm, did not cause changes in the DS of the sample also. But, starting with the value 1.8 kV/mm in the constant electric field and the fixed values of the magnetic and alternating electric fields, DC stability was broken. The general domains picture that observed in the microscope has not changed. However, some small, curved portions of domain heads (domain head is a part of stripe domains, where DW is curved and the radius of curvature of the head is approximately equal to half the width of the domain) of the individual domains became slightly visually "blurry", which can be seen when analyzing the micro-photo. In this case, the geometric shape of the domain did not change and the domain structure remained through the maze, the DW displacement from their equilibrium positions were not observed. For computer processing exposed micro-photo where observe individual domain head, in the same location of the investigated film, but for different values of the constant electric field. The results of analysing of the images where shown in Fig. 1. On the plot (Fig. 1) we can see the estimates of the number of the width changing (h) of the domain wall that we obtained for "blurring" domain head in static electric field E_1 (for fixed values of the alternating electric E_2 and a constant magnetic field H). As can be seen from Fig. 1, changes in the width of the local section of the DW when considering a three-channel external effect on the sample is not significant (the width of the domain wall in the absence of external fields was about 0.5 microns).

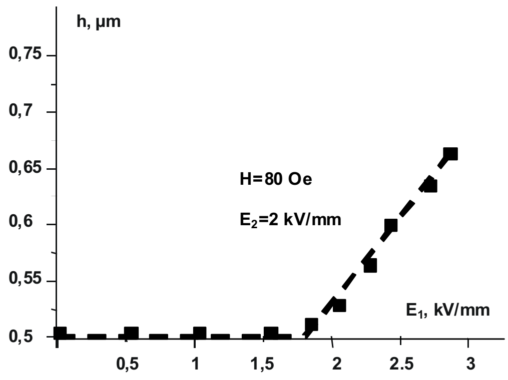

Fig. 1. Estimated dependence for changing of width of local DW site (domain head) from intensity of constant electric field E_1, at the fixed values of variable electric ($E_2 = 2\text{kV/mm}$) and constant magnetic ($H = 80\text{Oe}$) fields

Figure 2 shows the evaluation results after computer processing of visual observations of this domain local area in a two-channel head of external influence – an alternating electric field E_2, with frequency of 950 Hz and a constant magnetic field H.

Spatial fields orientations was the same as in the previous case. As can be seen from Fig. 2, the alternating electric field as at $H = 0$ and when $H \neq 0$ does not cause a visually observable changing of width for investigate domain head or offset.

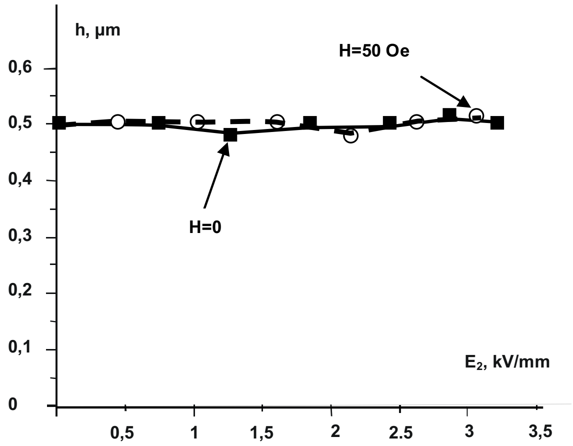

Fig. 2. Results of visual supervision over changes of width for a investigated domain head in the conditions of two-channel external influence - variable electric field E_2 (frequency of 950 Hz) and constant magnetic field H ($H = 0$ and $H = 50\text{Oe}$)

Best of all, the response of domain head for simultaneous connection of the electric fields (alternating and constant) are be seen when connected still a magnetic field, that oriented in the plane of the film (Fig. 3). Even for small values of the magnetic field, as can be seen from Fig. 3, viewed curved portions DW become sensitive to external influence electrical fields.

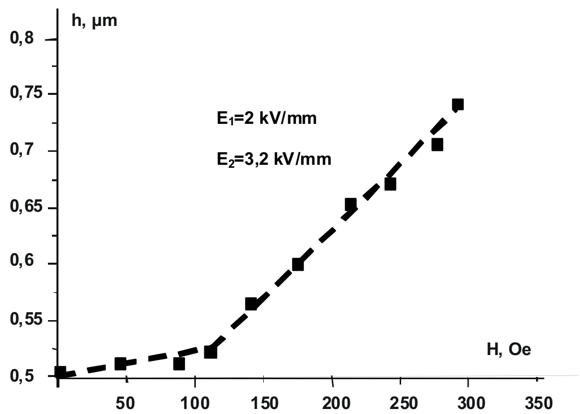

Fig. 3. Estimated dependence of changes of domain head width from intensity of a constant magnetic field, at the fixed values of variable electric ($E_2 = 3.2\text{kV/mm}$) and constant electric ($E_1 = 2\text{kV/mm}$) fields

Feature of the observed local "smearing" of DS is the fact that it was shown only on shorter (curved, irregular shape) regions of the labyrinthine DS - domain heads. Direct (long) segments of DS remained dimensionally stable and their reaction to considering complex external action is not sufficient for direct visual observation. Possible reason for these differences in the response may be some differences in the micro-magnetic structure of the DW in these areas. In the labyrinthine domain in the absence of external fields, in addition to long sections of the DW with the structure of the Bloch type, there are shorter sections with Neel structure. In general, as is known, the DW of magneto-uniaxial films is non-planar interface between adjacent domains. DW is a three-dimensional structured element of finite extent of the domain of the array with a nonuniform distribution of the magnetization vector in them as in thickness, and developed the film plane. The structure of the DW uniaxial films, such a study, is referred to as the twisted type, i.e. is neither Bloch nor Neel. In our experiments, the external magnetic field is applied in the film plane perpendicular to the easy axis (EA) and the DW motion in a magnetic field when it is not. Probably, in the magnetic field changes occur in the structure of the twisted DW and change the ratio in the initial balance between Bloch and Neel components. The magnetization of the wall with increasing magnetic field deviates more and more from the Bloch orientation, i.e. there is a certain structural "imbalance". At the same time, structural changes in the domain heads led to the fact that they were more susceptible to the influence of an external electric field (which changes the parameters of the magnetic anisotropy of the film), oriented parallel to the normal to the sample surface as compared with the more direct, the length of the labyrinth of the DW. The question about the local response of individual sections of the DW to an external electric field, more research is needed.

Conclusions. Thus, our results of imaging studies of magneto-electric interaction manifestations in FG/GGG epitaxial structures with typical maze domain structure showed the following. A very small impact on the value of the joint action of alternating and static electric fields on the domain wall is shown only when the additional connection of a static magnetic field, oriented in the plane of the sample. Visually observed a small effect of the local "smearing" of individual sections of the domain wall can be seen, probably, as a small distortion of the DW profile without DW displacement as a whole.

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ВІЗУАЛІЗАЦІЯ МАГНІТОЕЛЕКТРИЧНИХ ПРОЯВІВ У ЕПІТАКСІЙНИХ СТРУКТУРАХ ФГ/ГГГ

Використовуючи метод поляризаційної мікроскопії, в умовах одночасного впливу постійного і змінного електричних полів і магнітного поля, досліджувалась реакція доменної структури (ДС) епітаксійних плівок феритових гранатів (ФГ), вирощених на підкладинках з галлій-гадолінієвого гранату (ФГ/ГГГ). У прохідному світлі, візуально виявлено малий ефект "розмиття" профілю окремих локальних ділянок доменних меж (ДМ) плівок в умовах комбінованого трьохканального впливу.

Ключові слова: *магніто-електричний ефект, електричне поле, магнітне поле, доменні межі, доменна структура, поляризаційний мікроскоп.*

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ВИЗУАЛИЗАЦИЯ МАГНИТОЭЛЕКТРИЧЕСКИХ ПРОЯВЛЕНИЙ В ЭПИТАКСИАЛЬНЫХ СТРУКТУРАХ ФГ/ГГГ

Используя метод поляризационной микроскопии, в условиях совместного воздействия постоянного и переменного электрических полей и магнитного поля, исследовалась реакция доменной структуры (ДС) эпитаксиальных пленок ферритовых гранатов (ФГ), выращенных на монокристаллических подложках из галлий-гадолиниевого граната (ФГ/ГГГ). В проходящем свете, визуально обнаружен малый эффект "размытия" профиля отдельных локальных участков доменных границ (ДГ) пленок в условиях комбинированного трехканального внешнего воздействия.

Ключевые слова: *магнито-электрический эффект, электрическое поле, магнитное поле, доменные границы, доменная структура, поляризационный микроскоп*

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EVALUATION OF DOSE DISTRIBUTION IN PENUMBRA AREA BY USING LIDHT EMITTING STRUCTURES

A light-emitting diodes possess some essential advantages, compared to all other sources of previous generations, such as low energy consumption, small size, high operating speed, reliability. Dosimetry of radiation field in the penumbra area must be carried out with sensor of minimal size and maximal sensitivity. Gallium phosphide light emitting diode of less than 1mm^2 size. It is appropriate to use LEDs due to their low cost and emitting ability in visible region of spectrum.

Keywords: *gallium phosphide, penumbra, LEDs, light-emitting diodes, dosimetry, spectra.*