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АНАЛИЗ СПИРАЛЬНЫХ ДОМЕННЫХ СТРУКТУР В ПЛЕНКАХ ФЕРРИТОВ - ГРАНАТОВ С РАЗЛИЧНОЙ МИКРОСТРУКТУРОЙ

Аннотация.

В работе исследуются динамические доменные структуры в пленках ферритов – гранатов. Данные исследования посвящены наблюдению и изучению спиральных доменов в тонких эпитаксиальных пленках различного химического состава. Экспериментально наблюдались и регистрировались спиральные динамические доменные структуры, с помощью эффекта Фарадея. Данный эффект основан на вращении плоскости поляризации. Фиксация изображения осуществлялась с помощью высокоскоростной фотографии и видеосъемки. Изучалось влияние состава пленок на внешний вид и поведение спиральных доменов, так же изучалось воздействие на образцы магнитных полей различной амплитуды и частоты и анализировались изменения в спиральных структурах.

Актуальность данной тематики обусловлена применением динамических доменных структур в пленках ферритов – гранатов в магнитооптической обработке сигналов и разработке новых магнитных устройств. Так как спиральные доменные структуры представляют собой сложные, нестабильные конфигурации, их изучение поможет понять динамику магнитных материалов под воздействием внешних полей, что является важным для открытия новых физических явлений.

Ключевые слова: динамические доменные структуры, спиральные домены, магнитные устройства, пленки феррита – граната.

Analysis of spiral domain structures in ferrite-garnet films

with different microstructures

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Abstract.

This paper examines dynamic domain structures in ferrite-garnet films. This study focuses on the observation and study of helical domains in thin epitaxial films of varying chemical compositions. Spiral dynamic domain structures have been experimentally observed and recorded using the Faraday effect. This effect is based on the rotation of the plane of polarization. The image was captured using high-speed photography and video. The influence of the film composition on the appearance and behavior of helical domains was studied, the effect of magnetic fields of different amplitudes and frequencies on the samples was also studied, and changes in helical structures were analyzed.

The relevance of this topic is due to the use of dynamic domain structures in ferrite-garnet films in magneto-optical signal processing and the development of new magnetic devices. Since helical domain structures are complex, unstable configurations, studying them will help understand the dynamics of magnetic materials under the influence of external fields, which is important for the discovery of new physical phenomena.

Key words: dynamic domain structures, spiral domains, magnetic devices, ferrite-garnet films.

Experimental methodology.

Three samples of epitaxially grown ferrite-garnet films were studied [1,2,3].

Different directions of magnetization in the domains cause different rotation angles of the light's polarization plane. After passing through the material and the analyzer (polarizer), these differences translate into differences in brightness, making the domains visible under a microscope. The experiment is based on the fact that linearly polarized light rotates its plane of polarization as it passes through a material in a magnetic field (the Faraday effect), allowing for visualization of the domain structure being studied. A schematic of the experimental setup is shown in Figure 1.

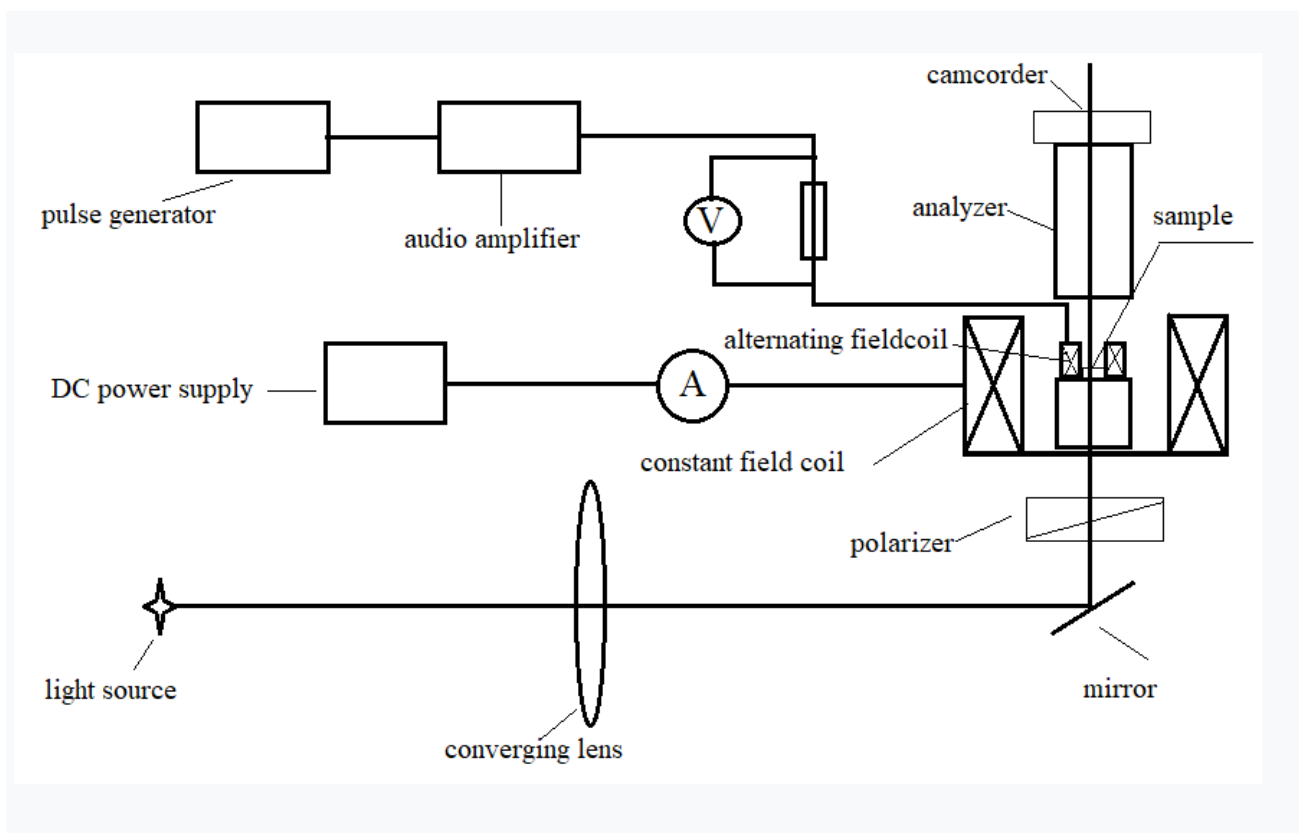


Fig. 1. Experimental setup diagram

Research results and discussion.

The studied samples had different chemical compositions, their characteristics are given in Table 1. The main goal was to observe spiral dynamic domains in films of different compositions [3,4,5], different thicknesses and other magnetic characteristics.

Table 1. Characteristics of the studied samples.

Sample №	Compound	L, MKM	P ₀ , MKM	H _s , Э	l*, MKM	J _s , Гс	H _A , КЭ	Q
1	(Ybi) ₃ (FeGa) ₅ O ₁₂	9,1	31,7	36	2,1	7,5	5,0	53
2	(YLubi) ₃ (FeGa) ₅ O ₁₂	9,5	33,2	50	2,2	11,0	13.2	96
3	(YLubi) ₃ (FeGa) ₅ O ₁₂	15,6	28,5	90	1,5	14,5	11,0	61

L – sample thickness

P₀ – period of the initial domain structure

H_s – static saturation field

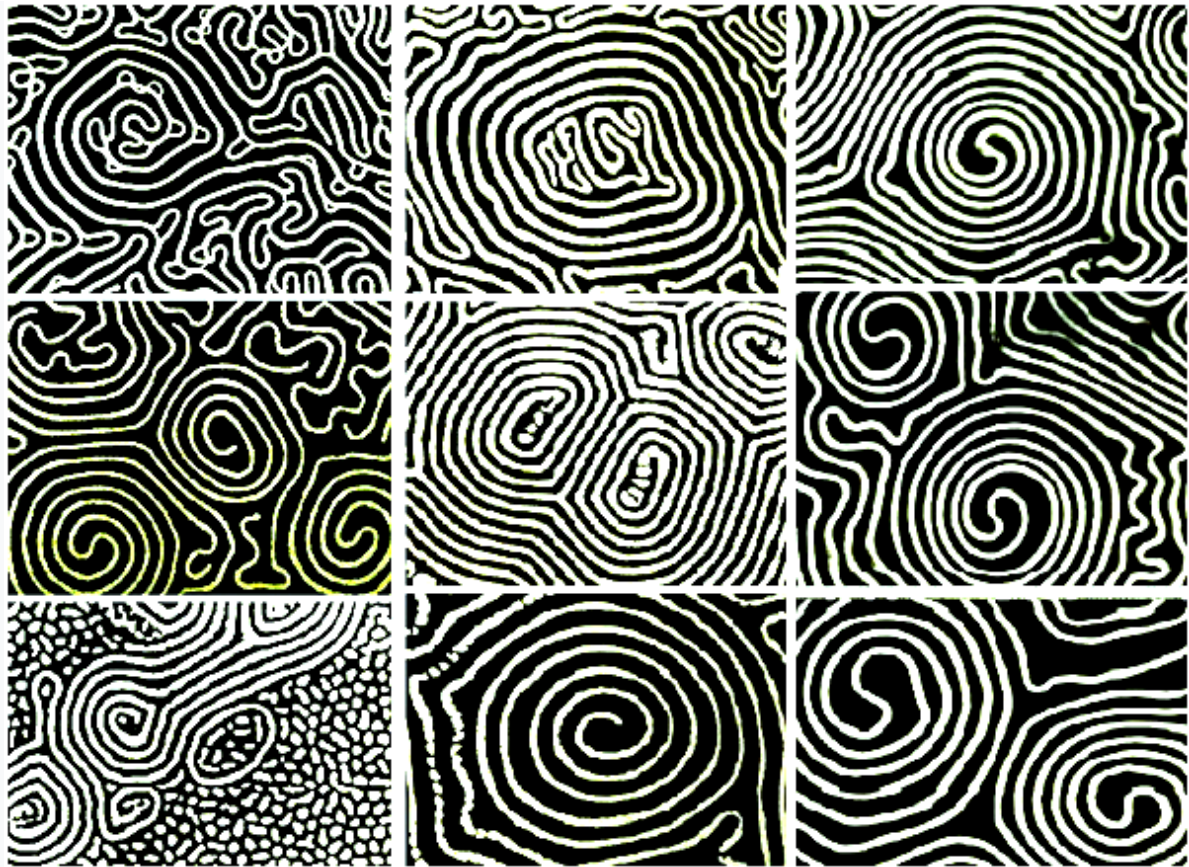
l* – characteristic length of the material, a measure of the domain width

J_s – saturation magnetization

H_A – saturation field

Q – quality factor

The experiment showed that in all samples, at the same amplitude and frequency of the alternating magnetic field, visually different types of spiral domains (SD) are observed [6,7,8]. Fig. 2 (a,b,c) shows the domain structure configurations for all the studied samples. A clear difference in the SD in each sample is clearly visible. Sample №1 (Fig. 2a) exhibits both double-arm and single-arm helices, while sample №2 exhibits only single-arm domain structures, and sample №3 exhibits only double-arm domain structures. All films show dense packing of SD and no single spirals.



a

b

c

Fig. 2 Domain structure in the studied samples in an alternating magnetic field

The appearance, packing, and behavior of domains of this type are strongly influenced by the amplitude and frequency of the alternating magnetic field. As these parameters change, some helices disappear, new ones appear, and the structure either becomes looser or, conversely, denser. Domain structures are transformed from one type to another. This phenomenon requires further study, as it holds promise in areas such as spintronics and magneto-optics, and is also of great importance in fundamental research for the discovery of new physical phenomena.

Conclusion.

Using an experimental setup based on the Faraday effect, domain structure in thin epitaxial films was observed. It was experimentally established that, in an alternating

magnetic field and a specific amplitude-frequency range, helical domain structures are observed in all three samples. There are differences in the structure and behavior of the SD for all three films, which are associated with the chemical composition of the films, size (sample thickness), as well as their magnetic characteristics (period of the initial domain structure, characteristic length, saturation magnetization, quality factor).

Understanding and controlling these structures opens the way to creating faster, more energy-efficient, and more miniaturized magnetic devices. Studying such structures [9, 10, 11] allows for, a better understanding of magnetic switching processes and domain wall motion, which forms the basis for many modern and future magnetic technologies. It can be concluded that this topic is highly relevant, as it addresses both fundamental science and applied research in the field of microelectronics.

Literature

1. Balbashov, A. M. Magnetic materials for microelectronics / A. M. Bal-bashov, A.Ya. Chervonenkis. - Moscow: Energy, 1979.
2. Kandaurova, G.S. Self-organization processes in multi-domain magnetic media and the formation of stable dynamic structures / G.S. Kandaurova, A.E. Svidersky // Journal of Experimental and Theoretical Physics. - 1990. Vol. 97, issue 4. - P. 1218-1229.
3. Kandaurova, G.S. Phase diagrams of dynamic systems of magnetic domains / G.S. Kandaurova, A.A. Rusinov // Reports of the Academy of Sciences - 1995.V.340, N5.- P. 610-613.
4. Kandaurova, G.S. Evolution of spiral dynamic domains in the anchor state of ferrite-garnet films / G.S. Kandaurova, V.Kh. Osadchenko, A.A. Rusinov, E.A. Rusinova // Letters to the Journal of Experimental and Theoretical Physics. - 1996. Vol. 63, issue 6. - P. 453-456.

5. Kandaurova, G.S. Three-dimensional diagrams of the existence of induced anchor states of a multidomain magnetic medium / G.S. Kandaurova, A.A. Rusinov // Solid State Physics. - 1998. Vol. 40, issue 10. - P. 1865-1870. EDN: RYNTUB
6. Rusinov, A.A. Phenomenological approach to the description of dynamic parameters of spiral-type domains / A.A. Rusinov, E.A. Rusinova // Bulletin of the Ural State Transport University. - 2015. No. 1 (25). - P. 18-23.
7. Rusinov, A.A. Modeling of dynamic spiral domain processes in ferrite-garnet films / A.A. Rusinov, E.A. Rusinova, E.I. Avksentyeva // Bulletin of modern studies. - 2018. No. 12.1 (27). P. 401–402.
8. Rusinov A.A. Phase diagrams of dynamic system of magnetic domains / A.A. Rusinov, E.A. Rusinova // International independent scientific journal. – 2020. No. 21, Vol.2.– P. 61–63.
9. Kryuchkova D. S. Influence of magnetic field on the dynamic parameters of domain structures of the "Leading center" type / D.S. Kryuchkova, E.A. Rusinova // Collection of articles based on the results of the International scientific and practical conference. Sterlitamak. - 2021. Pp. 5-12.
10. Rusinov A.A. Amplitude-frequency dependences of the formation of dynamic domain structures in magnetically uniaxial films - crystals of ferrites - garnets / A.A. Rusinov, E.A. Rusinova, I.V. Polents // In the collection: Mathematical modeling and information technology in solving applied problems in a transport university. Federal State Budgetary Educational Institution of Higher Education "Ural State Transport University". Yekaterinburg. 2021. Pp. 91–100.
11. Rusinova E.A. Statistical parameters of domain structures in iron garnet films. / Rusinova E.A., Burylova A.A. // In the collection: Actual problems of engineering sciences. Collection of articles of the regional student scientific and technical conference. Novosibirsk, 2022. Pp. 68–73. "Original research" (ORI).