Conference Paper

Statistical Analysis of Spiral Dynamic Domains Spatial and Temporal Characteristics During Self-Organization Process in Iron Garnets Multidomain Magnetic Films

L.Y. Agafonov, P.I. Gerevenkov, D.S. Mekhonoshin, and L.A. Pamyatnykh

Institute of Natural Sciences, Ural Federal University, 620000 Ekaterinburg, Russia

Abstract

Self-organization processes that appear as formation of spiral dynamic domains were studied in iron garnets epitaxial films. Application of statistics methods to analysis of large experimental dataset on spiral dynamic domains allowed establishing a threshold character of spiral dynamic domains spatial and temporal characteristics temperature dependencies. The threshold temperature, at which characteristics of spiral dynamic domains exhibit a sharp change, coincides with the temperature of most intense formation of the domains.

Keywords: magnetic domain structure; self-organization; iron garnet films

Corresponding Author: L.Y. Agafonov; email: Lev.Agafonov@urfu.ru

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1. Introduction

In epitaxial iron garnets films exposed to alternating magnetic field directed normally to sample surface, self-organization processes are observed. Those appear as formation of dynamic domain structures, such as spiral dynamic domains (SDDs). A review on large amount of experimental research of dynamic domain structures in iron garnets is given in Ref. [1]. It includes experimental results on amplitude and frequency dependencies of SDDs spatial and temporal characteristics obtained by single measurements at room temperature. Amplitude and frequency ranges, where SDDs form in iron garnet film, were found in Ref. [2] over a range of temperatures for the first time (the studied frequency range is 50-5000 Hz). In Ref. [2] at $T' \approx 260$ K for frequency $f = 2500$ Hz a maximum was discovered on a temperature dependence of number of SDDs n that form on 1 mm^2 of sample surface over one second.

The current paper is devoted to the study of temperature dependencies of SDDs characteristics obtained by multiple measurements on large number of SDDs at temperatures near a peak on the $n(T)$ dependence.

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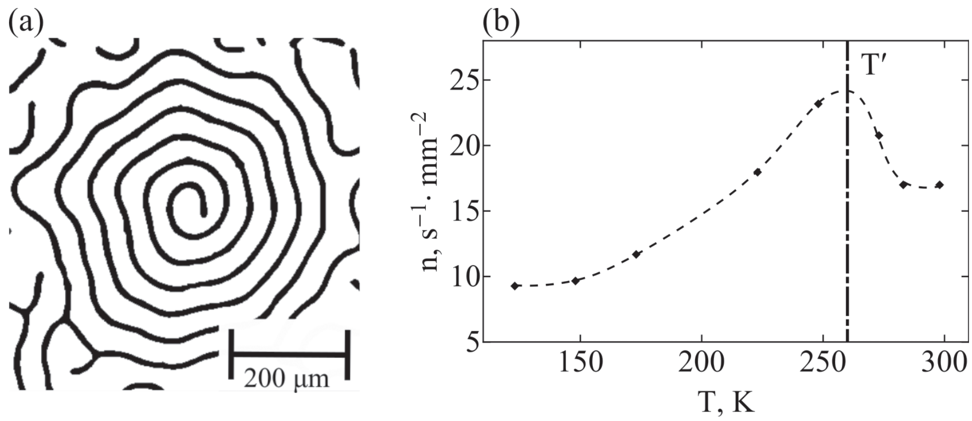

Figure 1: Binarized experimental magnetooptical image of a spiral dynamic domain; (b) spiral dynamic domains formation intensity *n* vs temperature *T*.

2. Methods

The results are given for $(YLuBi)_3(FeGa)_5O_{12}$ iron garnet film with thickness of 8.0 μm and orientation (111) with uniaxial anisotropy constant K_u = 63·10^3 erg/cm^3. Measurements were performed within the temperature range 77÷350 K, frequency range 60÷5000 Hz, and amplitudes up to 100 Oe. Dynamic domain structures were visualized with magneto-optical Faraday effect and captured with high-speed camera at recording rates up to 1000 fps. During experiments, sample temperature, magnetic field amplitude and its frequency were varied. SDDs were recognized with specially developed software and their position and characteristics were tracked starting from their formation and until destruction. With this technique, a set of images for over 150 000 spiral domains was obtained (an example of experimental SDD image is presented in Fig. 1a). For each of those SDDs the following parameters were measured: radius *R*, number of turns *N*, and growth speed $g = dR/dt$.

3. Results

In the current paper, for the first time a large dataset on SDDs was obtained and analyzed with statistical methods in order to study experimental external parameters influence on SDDs characteristics. The data provided in this paper are given for external field frequency f = 5 kHz.

First, the temperature dependence of SDDs formation intensity *n* averaged throughout amplitude range, where SDDs are observed, was obtained (Fig. 1b). A maximum near $T' \approx 260$ K is clearly seen on this dependence, in accordance with Ref. [2]. Second, the distributions of SDDs by their radii versus temperature were measured. Figure 2a shows temperature dependencies of minimum, mean, and maximum SDDs radii R_{min}, R_{mean}, and R_{max} for f = 5 kHz. These radii were measured for each temperature independently of field amplitude and time *t* since individual SDDs formation. It can be seen that within a temperatures range 77 K—T' R_{min}, R_{mean} and R_{max} are practically constant. When temperature surpasses T', mean and maximum values of SDDs radii sharply

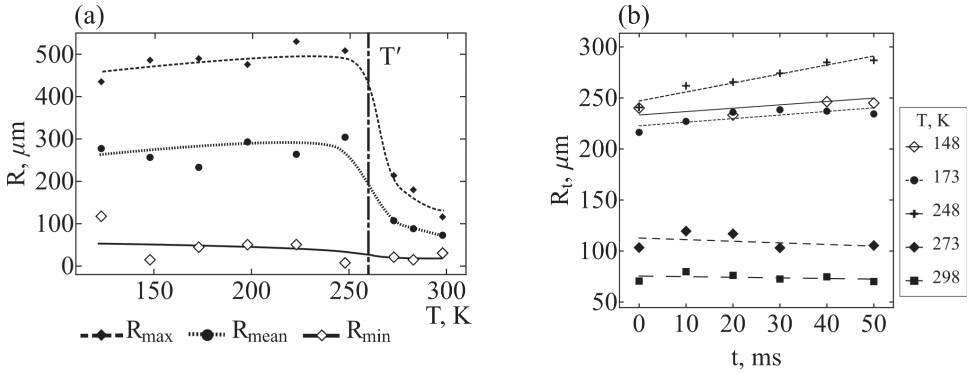

Figure 2: Temperature dependence of averaged over time, minimum and maximum spiral dynamic domains radii *R*; (b) averaged spiral dynamic domains radius R_t vs time *t* counted from their nucleation for several film temperatures.

decrease. It should be noted that the threshold temperature $T' \approx 260$ K coincides with the temperature of maximum on SDDs formation intensity dependence $n(T)$.

In order to study in more detail how SDDs characteristics change near T', variation of SDDs radii with time *t* was considered for temperatures in ranges $T < T'$ and $T > T'$. For this purpose, R_t was measured standing for average SDDs radius measured for each SDD after *t* since its formation at given temperature and frequency. Figure 2b shows $R_t(t)$ dependencies measured at temperatures 148, 173, 248, 273, and 298 K. As can be seen in Fig. 2b, the dependencies are mainly linear and can be characterized by slope, which is positive at temperatures 148, 173, and 248 K and approximately zero at temperatures 273 and 298 K. Since average SDDs radius at fixed sample temperature and pump field frequency is increasing linearly with time, SDDs growth speed $g = dR_t / dt$ can be measured. In range $T < T'$ g is strictly positive and in range $T > T'$ g is indistinguishable from zero.

4. Conclusion

Application of statistics methods to analysis of large experimental dataset on spiral dynamic domains in iron garnets films during self-organization process allowed establishing a threshold character of spiral dynamic domains spatial and temporal characteristics (radius and growth speed) temperature dependencies. The threshold temperature, at which spiral dynamic domains characteristics exhibit a sharp change, coincides with the temperature of their most intense formation.

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References

[1] G. S. Kandaurova, New phenomena in the low-frequency dynamics of magnetic domain ensembles, *Physics-Uspekhi*, **45**, no. 10, 1051–1072, (2002).

[2] O. P. Shetnikov, L. Y. Agafonov, D. S. Mekhonoshin, and L. A. Pamyatnykh, Effect of temperature on the formation of dynamic magnetic domains in ferrite-garnet films, *Bulletin of the Russian Academy of Sciences: Physics*, **78**, no. 9, 950–953, (2014).