Available online at www.sciencedirect.com

SCIENCE DIRECT®

ELSEVIER

Journal of Magnetism and Magnetic Materials 272–276 (2004) 720–721

journal of magnetism and magnetic materials

www.elsevier.com/locate/jmmm

Statistical analysis of fluctuating domain wall during Barkhausen avalanche in Co nanofilms

Dong-Hyun Kim*, Sug-Bong Choe[1], Sung-Chul Shin

Department of Physics and Center for Nanospinics of Spintronic Materials, Korea Advanced Institute of Science and Technology, 373-1, KuSeong-Dong YuSeong-Gu, Taejon 305-701, South Korea

Abstract

We investigate the fluctuating domain walls in Co nanofilms during Barkhausen avalanche from direct time-resolved observation of magnetic domains. By statistical analysis of repeated observations of domain wall configuration, we generate the probability map of finding domain wall at a certain position. Interestingly enough, there clearly exists a more probable region where domain wall prefers to be pinned but still with fluctuation. Our direct and quantitative analysis enables us to determine the degree of reproducibility in avalanche with microscopic details.

PACS: 75.60.Ej; 05.40.−a; 75.60.Ch

Keywords: Barkhausen avalanche; Scaling behavior

Barkhausen avalanche is mediated by successive sudden magnetization jumps in ferromagnetic system when an external magnetic field is applied. Interest in Barkhausen avalanche has exploded, since it is a good example of critical system, where the characteristic length of the system doesn't exist and scaling behavior comes to appear [1]. One of the most important issues in understanding of Barkhausen avalanche is to testify whether an exact reproducibility exists in the critical behavior or the critical system exhibits a completely random dynamics. Numerous studies have been devoted to clarify the reproducibility in Barkhausen avalanche [2–5], where some expect the existence of an exact reproducibility but others deny that possibility. None of them has clearly resolved this controversy on the exact reproducibility and thus, the underlying physics of Barkhausen avalanche is still unclear.

Recently, we have developed a novel experimental technique for direct full-field time-resolved observation of Barkhausen avalanche in thin films, using a magneto-optical microscope magnetometer (MOMM) [6]. Using this novel technique, we have found that Barkhausen avalanche in Co thin film exhibits a scaling behavior, which is understandable within the context of the model originally proposed by Cizeau, Zapperi, Durin, and Stanley [5,7]. In the present work, we provide the quantitative statistical analysis on the fluctuating domain walls during avalanche using MOMM. MOMM basically consists of a polarizing optical microscope set to visualize in-plane magnetic domain via magnetic contrast utilizing longitudinal magneto-optical Kerr effect (MOKE). Details of MOMM are described elsewhere [6]. We repeat our observations at the same area with the same experimental conditions and visualize the microscopic behavior of fluctuating domain walls. By superimposing these fluctuating domain walls of each observation, we can generate the probability map to find domain wall at a certain position, which directly indicates how reproducible the avalanche process at a position will be. We have prepared 25-nm Co films on glass substrates by dc-magnetron sputtering. All samples exhibit in-plane magnetic anisotropy judged from the square in-plane Kerr hysteresis loop.

---

*Corresponding author. Tel.: +82-42-869-8164; fax: +82-42-869-8100.

E-mail address: d.h.kim@kaist.ac.kr (D.-H. Kim).

[1] Present address: Advanced Light Sources, Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA.

0304-8853/$ - see front matter © 2003 Elsevier B.V. All rights reserved.
doi:10.1016/j.jmmm.2003.11.262

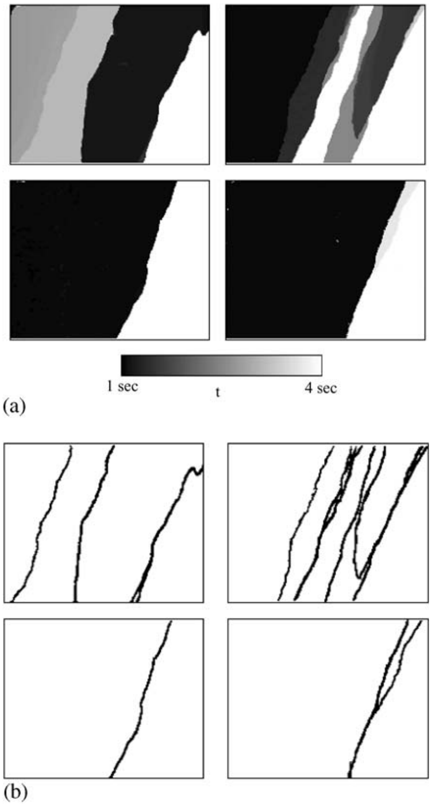

Fig. 1. (a) Time-resolved domain patterns captured successively at the same area with identical experimental conditions. Gray-level represents an elapsed time when magnetization occurs. The sample magnetization was initially saturated downward and then, constant field was applied upward. (b) Domain walls determined via edge-finding image processing technique.

In Fig. 1(a), we demonstrate four representative images of time-resolved domain evolution patterns observed successively at the same area with identical experimental conditions. Note that domain evolution patterns in each picture clearly exhibit discrete and sudden Barkhausen jumps and that domain configuration is not exactly reproducible at each observation.

To quantitatively understand, we statistically analyze the domain wall configurations from our repeated observations. As a first step, we determine the domain wall lines from the domain evolution patterns as illustrated in Fig. 1(b). The images of domain wall lines in Fig. 1(b) are determined from the corresponding images of Fig. 1(a) via edge-finding image processing technique. For 100 repeated observations, we superimpose these images of domain wall lines, where we can generate the probability map by counting how many times the domain wall is found at a certain position. Therefore, the map represents the spatial distribution of probability of finding domain wall at the position as vividly shown in Fig. 2. Interestingly enough, one can clearly notice that there exists a more probable region where the domain wall statistically prefers to exist.

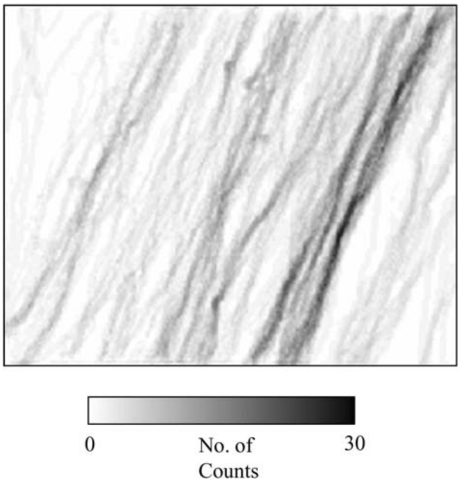

Fig. 2. Probability map indicating spatial distribution of probability to find a domain wall at each position. Gray-level represents probability determined from 100 repeated observation.

We like to stress that our direct observation and quantitative analysis reveal that Barkhausen avalanche is neither completely reproducible nor completely random. Fig. 2 implies that there are some pinning sites possibly originated from the structural defect, which produce the pinning potentials giving the reproducibility to the avalanche process. However, it should be noted that critical randomness still exists and the Barkhausen avalanche proceeds via the critical fluctuation around the statistically reproducible pinning site. Our direct analysis enables us to quantitatively determine the degree of reproducibility with microscopic details, providing significant insight to the Barkhausen criticality.

This work was supported through the Creative Research Initiatives Project of the Korean Ministry of Science and Technology.

References

[1] J.P. Sethna, et al., Nature 410 (2001) 242.
[2] O. Perković, et al., Phys. Rev. Lett. 75 (1995) 4528.
[3] J.S. Urbach, et al., Phys. Rev. Lett. 75 (1995) 4694.
[4] J.R. Petta, et al., Phys. Rev. E 54 (1996) R1029.
[5] S. Zapperi, et al., Phys. Rev. B 58 (1998) 6353.
[6] S.-B. Choe, et al., Rev. Sci. Instrum. 73 (2002) 2910.
[7] D.-H. Kim, et al., Phys. Rev. Lett. 90 (2003) 87203.