Variable Fractal Dimensions of Magnetic Domain Walls in CoFe/Pt Multilayers with Changing the Number of Repeats

Kang-Soo Lee*, Chang-Won Lee[1], Young Jin Cho[1], Sunae Seo[1],
Dong-Hyun Kim[2] and Sug-Bong Choe
Center for Subwavelength Optics and School of Physics, Seoul National University, Seoul 151-742, Republic of Korea, [1]Samsung Advanced Institute of Technology, Suwon 449-600, Republic of Korea
[2]Department of Physics, Chungbuk National University, Cheongju 361-763, South Korea

1. 개 요

We present the fractal properties of the magnetic domain walls in (CoFe/Pt) multilayer films with the perpendicular magnetic anisotropy. In these films, the magnetization reverses by the domain wall propagation through the films with rare nucleation. With increasing number of repeats, it is observed that the jaggedness of the domain walls increases noticeably, which is possibly due to the accumulation of the irregularities at the layer interfaces. The jaggedness of the domain walls is analyzed in terms of the fractal dimension by use of the ruler method, and it is revealed that the fractal dimension is significantly changed from 1.0±0.002 to 1.3±0.05 with increasing the number of repeats from 1 to 5.

2. 결 론

The fractal properties of magnetic domains have been well described in the thermo-activated relaxation model of the domain wall propagation [1]. In this model, the domain evolution occurs through the Barkhausen jumps of domain walls, where the domain wall overcomes the breakaway energy R by the help of the thermal activation. The probability p for depinning is then given by p~exp(-R/T) for the temperature T. In ref. 1, the thermal activation processes is described by a single characteristic parameter z, which is defined as

$$z = \frac{t}{\xi}\frac{V_A M_S^2}{T} \tag{1}$$

where t and ξ are the film thickness and the lattice cell size, respectively. Here, VA is the activation volume and MS is the saturation magnetization. Consequently, their results show that d is monotonically increased with increasing z. (For details, see Fig. 6 in ref. 1.) For our case, the total thickness t is increased linearly with the number of repeats, whereas ξ is expected to be decreased due to the accumulation of the interfacial irregularities. Therefore, one can expect that z is increased with increasing the number of repeats, which in turn corresponds to the monotonic increment of the fractal dimension.

3. 실험결과

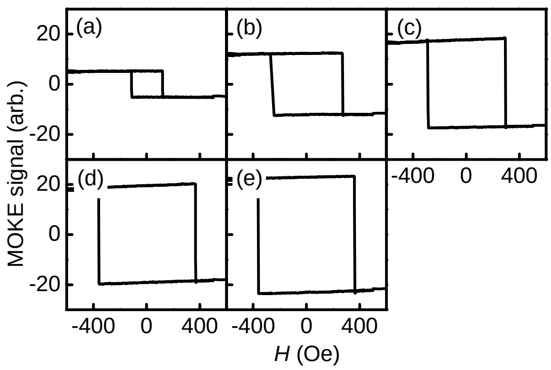

Fig. 1. Out-of-plane magnetic hysteresis loops of the films with different number of repeats, (a) 1, (b) 2, (c) 3, (d) 4, and (e) 5, respectively. The sweeping rate of magnetic field is 66 Oe/sec and the maximum saturating field is 2400 Oe. The coercive field of each film is (a) 113 Oe, (b) 272 Oe, (c) 295 Oe, (d) 360 Oe, and (e) 363 Oe, respectively

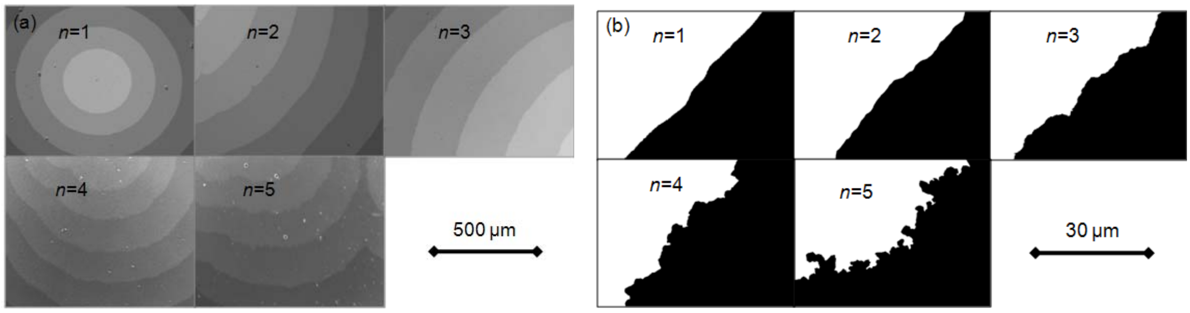

Fig. 2. (a) Typical magnetic domain images with low magnification (×25). The gray contrast corresponds to the domain images taken at different times after applying the magnetic field. (b) Typical magnetic domain images with high magnification (×1,000) after image processes which comprises background substitution and black-and-white conversion.

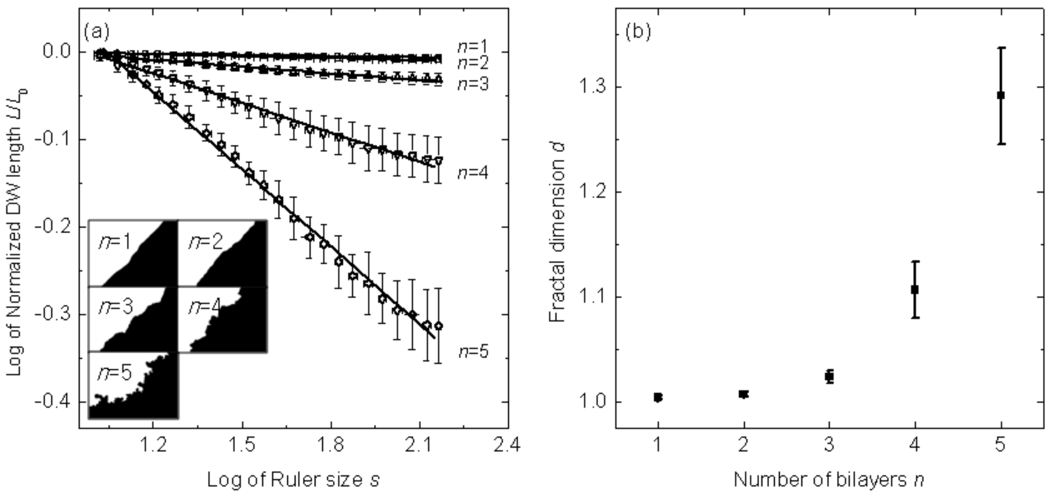

Fig. 3. (a) Log-log plots of the domain wall length with respect to the ruler size for each film. The ordinate is statistical data of normalized length L/L0 of DWs inside the captured images shown in Fig 2(b). We add up statistics on several tens of images for each film. (b) Fractal dimensions with respect to the number of repeats.

3. 참고문헌

[1] G. V. Sayko, A. K. Zvezdin, T. G. Pokhil, B. S. Vvedensky, and E. N. Nikolaev, IEEE Trans. Magn., vol. 28, no. 5, pp. 2931-2933, Sep. 1992.