Critical Scaling Behavior of Barkhausen Avalanches in Ferromagnetic Nanothin Films

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It is recognized that the magnetization reverses with a sequence of discrete and jerky jumps, known as the Barkhausen effect [1]. Recently, interest in the Barkhausen effect has grown as it is a good example of dynamical critical behavior, evidenced by experimental observation of a power law distribution of the Barkhausen jump size. So far, most experimental studies have been carried out on bulk samples using a classical inductive technique, which is difficult to apply to thin film samples mainly due to the low signal intensity. For this reason, very few experiments have been done on two-dimensional ferromagnetic thin films. In this talk, we report a direct domain observation of Barkhausen avalanche at criticality in Co and MnAs thin films investigated by means of a magnetooptical microscope magnetometer (MOMM), capable of time-resolved domain observation with an image grabbing rate of 30 frames/s in real time [2]. In Fig. 1, we demonstrate a series of six representative domain-evolution patterns of 25-nm Co film observed successively by means of the MOMM, where one can directly witness Barkhausen avalanche.

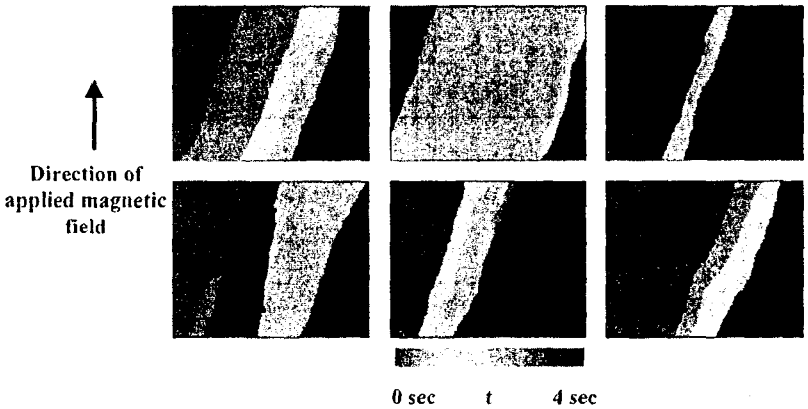

FIG. 1. A series of six domain images showing the avalanches of the domain structure captured successively on the same 400x320 μm^2 area of a 25-nm Co film. The color code represents the elapsed time from 0 to 4 seconds when magnetization reversal occurs.

Through a statistical analysis of the fluctuating size of Barkhausen jump from more than 1000-times repetitive experiments for each sample, the distribution of Barkhausen jump size was obtained. The distribution is found to exhibit power law behavior and fitted as $P(s) \sim s^{-\tau}$ with critical exponent τ = 1.34 ± 0.07, 1.29 ± 0.06, 1.32 ± 0.03, and 1.30 ± 0.05 for 5, 10, 25, and 50-nm Co films, respectively, as plotted in Fig. 2.

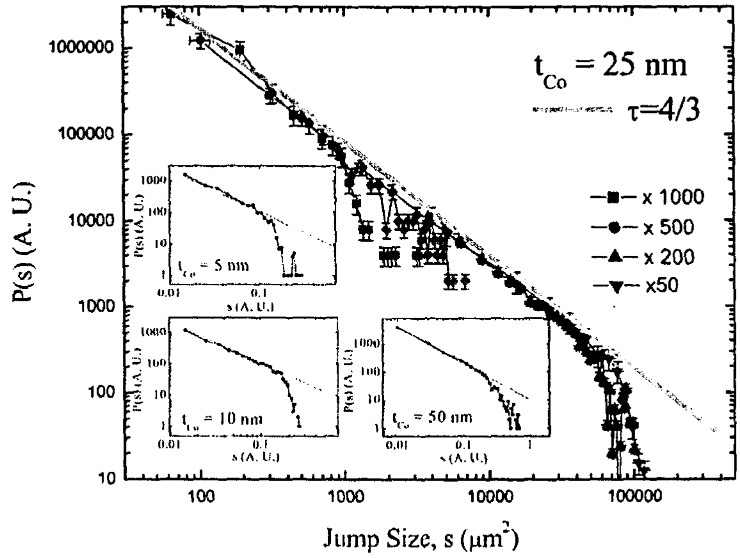

FIG. 2. Distribution of Barkhausen jump size in 25-nm Co samples. Distributions in 5, 10, and 50-nm Co samples are shown in the insets. Fitting curve with τ = 1.33 is denoted at each graph.

The most striking feature of Fig. 2 is the fact that the τ values are in the same universality class ($\sim$ 1.33) for all samples within the measurement error despite of the difference in the film thickness. We may expect that the 50-nm film has about ten-times larger number of defects compared with the 5-nm film, since all samples were prepared with the same preparation conditions except the thickness. This result implies an invariance of the critical exponent τ irrespective of the number of defects in the Co thin films [3]. Our experimental results directly validify the CZDS model [4], where the model describes 180°-type flexible domain wall deformed by localized defects with consideration of long-range dipolar interaction.

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

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