구두발표 II-5

Power-law scaling behavior in Barkhausen avalanches of 2D ferromagnetic MnAs film

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1. Introduction

A ferromagnetic material displays a sequence of discrete and jerky domain jumps when an external magnetic field is applied, known as the Barkhausen avalanche [1]. In recent years, this phenomenon has been considerably studied as a good example of complex dynamical systems showing critical scaling behavior [2,3]. Many experimental results have shown that the Barkhausen avalanche size follows a power-law scaling distribution, suggesting the underlying criticality. Here we present that the scaling behavior of Barkhausen criticality in 2D MnAs films is experimentally controllable with varying temperature.

2. Experiment

The MnAs film with the thickness of 50 nm was epitaxially grown on GaAs(001) substrate at 270 °C by a molecular-beam epitaxy (MBE). The saturation magnetization M_S with temperature has been measured using a superconductor quantum interference device (SQUID) magnetometer, where the value of M_S was found to decrease with increasing temperature. The decrease of M_S with temperature is ascribed mainly to the decrease of the FM a-MnAs volume ratio with temperature, as confirmed from the temperature-dependent x-ray diffraction (XRD) experiment. In this work, Barkhausen avalanche of MnAs film at criticality was directly observed on the sample area with the size of 80×64 mm^2 by means of a magneto-optical microscope magnetometer (MOMM), capable of real-time direct domain observation [4].

3. Results and discussion

Figure 1 shows representative domain-evolution patterns of the 50-nm MnAs film observed three consecutive times by means of MOMM at each designated temperature in the temperature range of 20 ~ 35 °C. The color code from red to blue indicates the elapsed time during 4 sec according to the color palette at the bottom of the figure. In Fig. 1, the domain-evolution patterns at each temperature exhibit a sequence of discrete and jerky domain jumps during the magnetization reversal. Obviously, we can conclude that the domain jumps at each temperature correspond to the Barkhausen avalanches in a critical state. The distribution of the Barkhausen avalanche sizes was obtained through a statistical analysis of the fluctuating size of the Barkhausen jump from more than 1000 times repetitive experiments at each temperature. As shown in Fig.2, we find that the distribution of the Barkhausen avalanche sizes exhibits a power-law scaling behavior at all temperatures from 20 °C to 35 °C. The most striking finding in the power-law distribution of MnAs film is the observation that the critical exponent is continuously varied from 1.32 to 1.04 with increasing the temperature. A theoretical analysis combined with the renormalization group results has been carried out to understand our observed Barkhausen avalanches, from which we could discover a critical scaling law that the critical behavior in a ferromagnetic system is determined from the relative contribution between the dipolar interaction energy and the domain-wall energy.

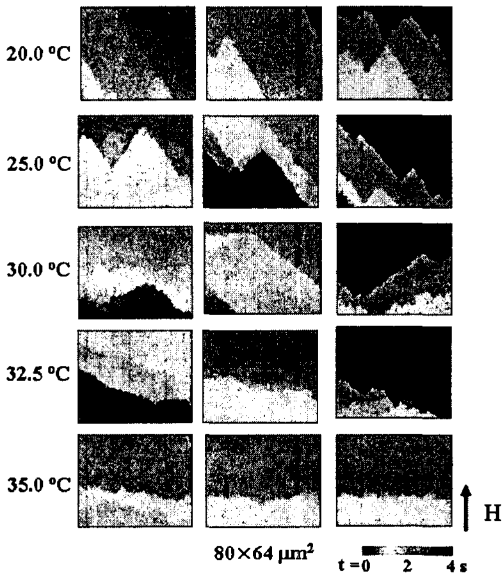

Fig. 1. Representative domain-evolution patterns at several temperatures in the temperature range of 20 ~ 35 °C, directly observed on the *exactly same* 80 × 64 mm^2 area of the MnAs film. Three domain-evolution patterns at each temperature were obtained from the repeated experiments.

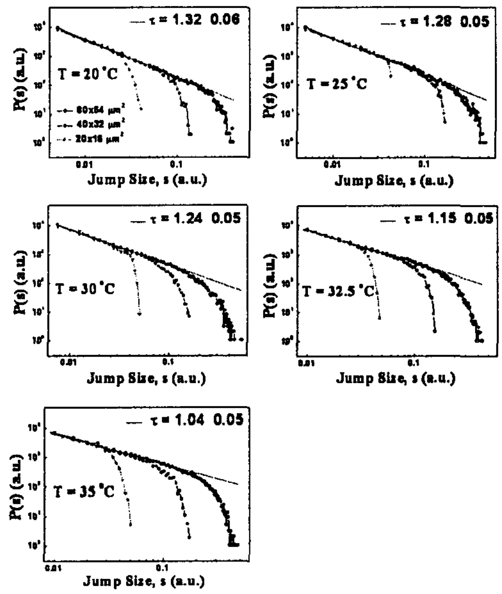

Fig. 2. The distributions of the Barkhausen avalanche sizes in the temperature range of 20 ~ 35°C, obtained from more than 1000 times repetitive experiments observed at each temperature.

4. Reference

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