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Direct Observation of Barkhausen Avalanches during Nucleation-Mediated Magnetization Reversal on a Nanoscale

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Digest Body: Since the first discovery of Barkhausen avalanches magnetization reversal phenomena are considered as prototype examples of complex dynamical systems exhibiting non-trivial fluctuations which can be described by well defined scaling behavior [1]. Barkhausen avalanches occur in the magnetization reversal process as discrete and sudden magnetization changes under an external magnetic field. Of fundamental interest are fluctuating quantities such as Barkhausen jump size and duration showing a power-law scaling behavior. Most studies reported so far have been mainly performed by theoretical predictions and indirect probes through a classical inductive technique. Recently, substantial progress was enabled by direct observations of the phenomenon using magnetic microscopies [2]. However, they have been carried out on the micrometer scale and concentrated mainly on the Barkhausen avalanches process during the flexible magnetic domain wall motion. We investigated the Barkhausen avalanches process under nucleation-mediated magnetization reversal at the nanometer scale utilizing high resolution soft X-ray microscopy at beamline 6.1.2 at the Advanced Light Source in Berkeley CA, which provides a spatial resolution down to 15 nm [3]. Nanogranular CoCrPt alloy thin films which are promising candidates for high-density perpendicular magnetic recording media, were prepared by dc magnetron sputtering at ambient temperature. The magnetic domain configurations were recorded at the Co L3 absorption edge (777eV) with varying applied magnetic fields in full hysteresis cycles. Typical domain configurations taken at applied magnetic fields of +400, +200, 0 Oe in the major hysteresis loop are shown in Fig. 1(a). As demonstrated in the figure the magnetization reversal of the CoCrPt sample is governed by the magnetic domain nucleation process. TEM studies indicate that the nucleation-mediated process of magnetization reversal observed in this system is due to switching of individual grains segregated by higher Cr concentration at grain boundaries. Fig. 1 (b) shows the Barkhausen jump distribution in two-dimensional space, where green and red structures represent the Barkhausen avalanches observed at applied magnetic field of +200 and 0 Oe, respectively. One clearly notes that Barkhausen avalanches vividly illustrate the randomness of size, shape, and location. The random behavior in the locations of the Barkahusen avalanches implies that the numerous pinning sites due to the Cr compositional segregation in this system are randomly distributed and strongly localized.

The statistical nature of Barkhausen avalanches was studied by repetitive measurement for magnetic domain configurations at each applied magnetic field of +400, +200, 0 Oe. Through a statistical analysis of jump size from several hundreds of domains, the distributions of Barkhausen jump size are obtained (Fig. 2). They exhibit a non-trivial fluctuation and can be described by power-law scaling distributions of $P(T_0)-(T_0)^{T}$ with a scaling exponent –1.Scaling exponents taken at applied magnetic field of +200 and 0 Oe are found to be identical within the measurement error. They are consistent with theoretical values derived from a random-field Ising model including the effect of long-range dipolar interaction 4]. Our study experimentally supports a long-standing theoretical prediction, namely that long-range dipolar interactions play a decisive roles in the statistical behavior of Barkahusen avalanches in nucleation-mediated magnetization reversal processes

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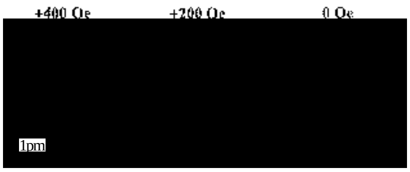
(a)



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