Visualization of the Barkhausen Effect by Magnetic Force Microscopy

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The magnetization reversal of a ferromagnet, particularly of thin films, is a technological very important process, which is governed by structural as well as magnetic properties of the material. It is characterized by the hysteresis loop, which consists of a series of discrete magnetization jumps, known as Barkhausen effect. Conventionally, this effect has been observed by slowly changing the external magnetic field and picking up voltage pulses in an induction coil around the ferromagnetic sample. However, this method provides only integral information of the whole sample and is difficult to apply to magnetic thin films because of the much lower signal level compared to bulk samples. We show that magnetic force microscopy (MFM) can visualize individual Barkhausen jumps. It therefore provides a detailed insight into the physical principles governing non-equilibrium magnetization reversal processes, such as nucleation and domain wall propagation, which are related to magnetical and structural properties of the film.

An 80 nm thick $La_{0.7}Sr_{0.3}MnO_3$ film was epitaxially grown on a $LaAlO_3$ (001) substrate by pulsed laser deposition. Because of the small lattice mismatch, a stress induced perpendicular anisotropy is observed. To analyze individual Barkhausen processes, we employed magnetic force microscopy using our home built ultrahigh vacuum low-temperature force microscope [1]. A perpendicular magnetic field was ramped from remanence to saturation and back to remanence while imaging continuously. From this movie-like sequence, the position, size, and nature of reversal processes could be determined as either domain nucleation or growth by wall propagation. Nucleated Barkhausen volumes show a Gaussian size distribution indicating an uncorrelated random process, while grown Barkhausen volumes follow an inverse power law distribution suggesting a critical behavior [2]. The origin of these different characteristics will be discussed and the experimental results compared to existing models.

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[2] A. Schwarz, M. Liebmann, U. Kaiser, R. Wiesendanger, T. W. Noh, and D. W. Kim, Phys. Rev. Lett. **92**, 077206 (2004).