Barkhausen noise in disordered striplike ferromagnets: Experiment versus theory

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Barkhausen noise is a well-known manifestation of crackling noise in magnetic materials and arises from the intermittent motion of domain walls during magnetization reversal. The stochastic voltage pulses recorded in Barkhausen experiments reflect the avalanche dynamics of magnetic domains and provide valuable insight into the microscopic processes governing magnetization dynamics in disordered ferromagnets. Because the Barkhausen noise signal depends on numerous material and experimental factors—including the distribution of disorder due to impurities or defects, the size and structure of crystal grains, the domain configuration, the driving rate of the external magnetic field, sample geometry, and temperature—its interpretation requires an appropriate theoretical framework capable of capturing these complex interactions.

In this work, we present a systematic comparison between experimental measurements of low-frequency Barkhausen noise and numerical simulations of disordered spin systems described by the random-field Ising model (RFIM). The experimental measurements were performed at room temperature on a field-driven metallic glass stripe made of VITROPERM 800 R, a nanocrystalline iron-based material characterized by excellent soft magnetic properties and widely used in technological applications. Barkhausen noise signals were recorded while varying the driving rate of the external magnetic field over a two-decade-wide range, enabling a detailed investigation of the dependence of avalanche dynamics on the driving conditions.

To interpret the experimental results, we employ the athermal nonequilibrium version of the RFIM with a finite driving rate. This model is widely recognized as a suitable theoretical framework for describing avalanche phenomena in disordered magnetic systems. Its applicability is particularly justified in the present case due to the nanocrystalline structure of the investigated material and its relatively high Curie temperature, which allow the dynamics to be effectively described within the athermal approximation.

We performed a systematic analysis of the Barkhausen signal properties and the corresponding magnetization avalanches obtained from both experiments and numerical simulations. In particular, we examined statistical characteristics such as avalanche size and duration distributions and their dependence on the external magnetic field driving rate. The comparison between experimental observations and numerical results demonstrates that, with an appropriate choice of model parameters, the RFIM simulations reproduce key features of the experimentally observed Barkhausen noise.

The obtained agreement indicates that the nonequilibrium RFIM provides an adequate description of avalanche dynamics in nanocrystalline magnetic materials and successfully captures the essential statistical properties of Barkhausen noise. These results contribute to a deeper understanding of the mechanisms governing crackling noise phenomena in magnetic systems and highlight the usefulness of statistical physics models for interpreting complex dynamical behavior in real materials.