ICAM2009

11th International Conference
on Advanced Materials

Rio de Janeiro Brazil
September 20 - 25

Barkhausen noise in thin magnetic films

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Abstract – We investigate the Barkhausen noise scaling properties in amorphous films with thicknesses between 50 - 1000 nm. We perform, from the Barkhausen noise time series measured through the traditional inductive technique, an extended statistical analysis and determinate the exponents τ, α, $1/(\sigma\eta z)$ and υ. The exponents present a noticeable stability in this wide thickness range and, differently of the values usually observed for films, they are similar to the obtained for bulk amorphous magnetic materials, indicating the films in this thickness range present a typical three-dimensional magnetic behavior.

Barkhausen noise (BN) corresponds to the voltage pulses induced in a sensing coil wound around a ferromagnetic material submitted to a slowly varying magnetic field. The effect has attracted increasing attention as the manifestation of crackling noise in magnetic systems. Its statistical properties can provide information on general properties of the magnetization dynamics, such as the system dimensionality and range of the interactions governing the domain wall (DW) dynamics. For bulk materials there is a well established interpretation for these properties, including jump sizes and durations distributions, average size vs. duration and power spectrum, which are related to the exponents τ, α, $1/(\sigma\eta z)$ and υ, respectively. The exponents indicate bulk samples present a three-dimensional magnetic behavior and can be grouped in two distinct universality classes [1]: $\tau \sim 1.50$, $\alpha \sim 2.0$ and $1/(\sigma\eta z) \sim \upsilon \sim 2$ for polycrystalline, dynamics governed by long-range interactions, and $\tau \sim 1.27$, $\alpha \sim 1.5$ and $1/(\sigma\eta z) \sim \upsilon \sim 1.77$ for amorphous samples, related to short-range interactions. For films, the statistical properties are not well studied due to experimental difficulties, since the works reported make use of magneto-optical techniques which restrict the analysis to the jump sizes distributions. Therefore, a complete comprehension of the DWs dynamics in films is lacking. In this work, we report BN experimental results obtained with the classical inductive method in amorphous ferromagnetic films with nominal composition $Fe_{75}Si_{15}B_{10}$ and thickness in the range 50 - 1000 nm. We investigate the BN properties through an extended statistical analysis, determinating the scaling exponents, τ, α, $1/(\sigma\eta z)$ and υ, in order to understand the effects of the system dimensionality and range of interactions on the DWs dynamics. In the figures below we show selected results of the statistical properties, obtained for the amorphous FeSiB film with thickness of 100 nm. The results show the exponents present a noticeable stability in the wide range of thickness, from 50 to 1000 nm, where $\tau \sim 1.27$, $\alpha \sim 1.55$ and $1/(\sigma\eta z) \sim \upsilon \sim 1.7$, despite of the increasing number of defects with the thickness and the strong modification of the magnetic properties. The most striking feature is that, differently of the values usually observed for films, the exponents are very similar to the values observed for several bulk amorphous and are in a good agreement with theoretical predictions of the CZDS model [2], indicating that these amorphous films present a typical three-dimensional magnetic behavior with predominant short-range interactions. The results are discussed in terms of the DWs structures, dimensionality and range of interactions.

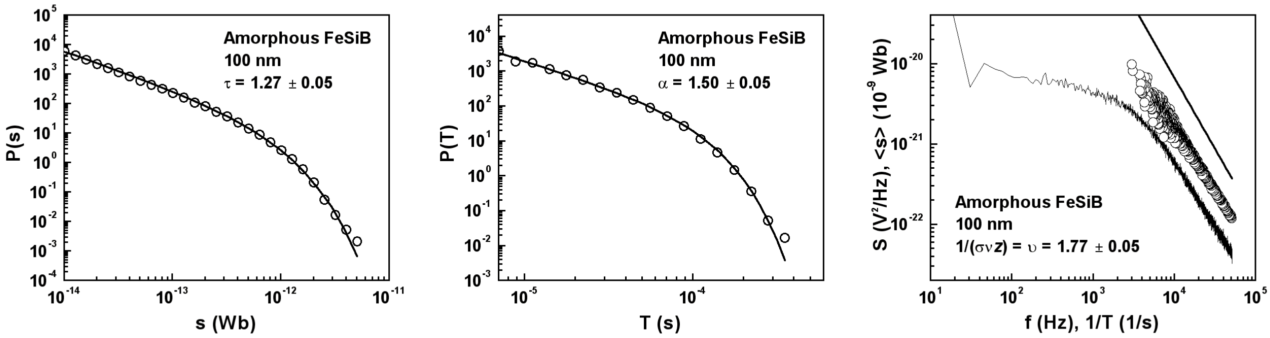

Figure 1: Statistical properties for 100 nm film. Left: Size distribution. Center: Duration time distribution. Right: Average size vs. duration and power spectrum.

References
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