

Stochastic Dynamics of Domain Walls on a Racetrack: Impact of Inhomogeneity of Magnetic Anisotropy

Anton V. Hlushchenko,^{1,2} Mykhailo I. Bratchenko,² Oksana L. Andrieieva,² Samudrajit Thapa,³ and Aleksei V. Chechkin^{1,2,4}

¹*Max Planck Institute of Microstructure Physics, 06120 Halle, Germany*

²*National Science Center "Kharkiv Institute of Physics and Technology", 61108 Kharkiv, Ukraine*

³*Department of Physics, Indian Institute of Technology Guwahati, Guwahati 781039, Assam, India*

⁴*Faculty of Pure and Applied Mathematics, Wrocław University of Science and Technology, 50-370 Wrocław, Poland*

Racetrack memory is a spintronic technology that stores data in current-driven magnetic domain walls whose motion in ultrathin films enables non-volatile, high-density, and high-speed memory architectures [1,2]. In these memory systems, information is encoded in spin textures, such as skyrmions or domain walls, where data access time is determined by their motion velocity [3]. At the interfaces of ultrathin films, an atomic-scale disorder produces an inhomogeneous energy landscape spanning multiple length scales [4]. Understanding the dynamics of domain wall in such films is challenging, as it requires going beyond standard white-noise models and taking into consideration non-zero correlation lengths. This work proposes modeling random magnetic anisotropy inhomogeneities using two-dimensional Weierstrass–Mandelbrot random functions. A distinctive feature of this approach is the ability to control both the amplitude and the scale of the inhomogeneity. The results demonstrate that magnetic anisotropy inhomogeneities strongly influence pinning formation and the stochastic motion of domain walls on the racetrack. We also calculated the threshold current for the motion of the domain wall as a function of the scale and amplitude of the inhomogeneity, as well as the applied current density. These findings characterize the stochastic behavior of domain walls in non-uniform racetracks and provide a framework for quantitatively estimating error sources in such memory devices.

References:

- [1] S. S. P. Parkin et al. *Science* 320, 190 (2008) 190-194.
- [2] S. Parkin and S.-H. Yang, *Nat. Nanotechnol.* 10, 195 (2015) 195–198.
- [3] Gu, K., et al. *Nat. Nanotechnol.* 17, 1065 (2022) 1065–1071.
- [4] P. G´ehanne et al., *Phys. Rev. Res.* 2, (2020) 043134.

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