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Thermal Stability of Magnetic States in Circular Thin-Film Nanomagnets with Large Perpendicular Magnetic Anisotropy[1]

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The scaling of the energy barrier to magnetization reversal in thin-film nanomagnets with perpendicular magnetization as a function of their lateral size is of great interest and importance for high-density magnetic random access memory devices. Experimental studies of such elements show either a quadratic or linear dependence of the energy barrier [2] [3] on element diameter. I will discuss a theoretical model we developed to determine the micromagnetic configurations that set the energy barrier for thermally activated reversal of a thin disk with perpendicular magnetic anisotropy as a function of disk diameter [4]. We find a critical length in the problem that is set by the exchange and effective perpendicular magnetic anisotropy energies, with the latter including the size dependence of the demagnetization energy. For diameters smaller than this critical length, the reversal occurs by nearly coherent magnetization rotation and the energy barrier scales with the square of the diameter normalized to the critical length (for fixed film thickness), while for larger diameters, the transition state has a domain wall, and the energy barrier depends linearly on the normalized diameter. Simple analytic expressions are derived for these two limiting cases and verified using full micromagnetic simulations with the string method. Further, the effect of an applied field is considered and shown to lead to a plateau in the energy barrier versus diameter dependence at large diameters. Based on these finding I discuss the prospects and material challenges in the scaling of magnetic memory devices based on thin films with strong perpendicular magnetic anisotropy.

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