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Magnetic Vortices: Chirality Control and Interplay with Exchange Bias

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Magnetic vortices in nanomagnets have gained considerable interests in recent years due to their fascinating physics and potential applications in information storage, spin-torque oscillators, and magnetic memory and logic devices. Probing the vortex state, especially in the deep sub-100 nm regime, has been challenging since the vortex core is extremely small, comparable to the exchange length. Taking advantage of the irreversibility associated with the vortex nucleation/annihilation process, we have shown in earlier studies the ability to "fingerprint" magnetic vortices in nanodots and multilayered nanowires using a first-order reversal curve (FORC) method [1-3]. The single domain (SD) to vortex state (VS) crossover can be tailored by controlling the nanomagnet size, aspect ratio, and temperature.

Recently, we have found two distinctly different chirality control mechanisms in e-beam patterned asymmetric dots. Below a critical diameter/ thickness, chirality control is achieved by the nucleation of a single vortex within each dot. The vortex can be manipulated to annihilate at particular sites under different field orientations and cycle sequences [4]. Interestingly, above these critical dimensions a new chirality control mechanism is realized by the nucleation and subsequent coalescence of double vortices, resulting in a single vortex at remanence with the *opposite* chirality as found in smaller dots [5]. Furthermore, the interplay between exchange bias and magnetic vortices has been investigated in Fe/FeF_2 nanodots which contain a mixture of SD and VS reversal modes [6]. The macroscopic exchange bias extracted from conventional major loop measurements is found to be a weighted average of the local exchange bias experienced by the SD and VS nanodots. The fraction of dots experiencing a given reversal mode depends on the cooling procedure, consistent with imprinting the vortex structure into the AF. These results demonstrate new possibilities to achieve reliable control of magnetic vortices.

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[1]. R. K. Dumas, C. P. Li, I. V. Roshchin, I. K. Schuller, Kai Liu, *Phys. Rev. B*, **75**, 134405 (2007).
[2]. R. K. Dumas, Kai Liu, C. P. Li, I. V. Roshchin, I. K. Schuller, *Appl. Phys. Lett.* **91**, 202501 (2007).
[3]. J. Wong, P. Greene, R. K. Dumas, Kai Liu, *Appl. Phys. Lett.* **94**, 032504 (2009).
[4]. R. K. Dumas, T. Gredig, C. P. Li, I. K. Schuller, Kai Liu, *Phys. Rev. B*, **80**, 014416 (2009).
[5]. R. K. Dumas, D. Gilbert, N. Eibagi, and Kai Liu, *Phys. Rev. B*, **83,** 060415 (2011).
[6]. R. K. Dumas, C. P. Li, I. V. Roshchin, I. K. Schuller, Kai Liu, *Phys. Rev. B* **86**, 144410 (2012).