CB05

Critical Velocity of Vortex Core Motion as the Universal Criterion for Core Magnetization Reversals in Soft Magnetic Nanodots

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Quite recently, nontrivial dynamic properties, such as magnetic vortex core (VC) reversal by small-amplitude, linear oscillating magnetic fields or currents [1], have emerged as subjects of growing interest, for their potential application to information recording in future solid-state information storage devices [2]. Moreover, the underlying mechanism, the physical origin of VC switching (reversal), and the elementary rotating eigenmodes of the vortex gyrotropic motions, were elucidated in our earlier work [3]. However, the universal criterion required for VC switching has yet to be clarified, though it is a practically crucial factor in determining the optimal parameters of the external driving force required for the reliable manipulation of VC switching. Thus, it is essential to elucidate the universal criterion for VC switching and its relations to the external driving force parameters, as well as the size and shape of nanodots.

In the present work, we found by micromagnetic simulations and analytical calculations that the critical velocity of VC motion serves as the universal criterion. This criterion does not depend on external driving force parameters, as well as the dot dimension and shape. The simulation results reveal that the critical velocity can be explicitly expressed as $\nu_c=(1.66\pm0.18)\gamma\sqrt{A_{ex}}$ with the exchange stiffness A_{ex} and the gyromagnetic ratio γ, and $\nu_c=330\pm37$ m/s for Permalloy. Consequently, the material parameter governing ν_c is only the value of A_{ex} for a given material. Based on the universal criterion parameter ν_c and Thiele's equation of vortex motion, furthermore, we analytically derived two useful quantities: phase diagrams of VC reversal criterion and its switching time with respect to both the field strength and frequency of a counterclockwise (clockwise) circularly rotating field for a given dot in the core-up (down) vortex state. These phase diagrams provide practically useful information on how to reliably manipulate VC switching in practical information-storage devices using a nanodot array of vortex states, as well as offer further advanced step towards realizing vortex random access memory.

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CB06

Real-time Detection of Current-induced Dynamics of Magnetic Vortex Core by Using TMR Effect

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The magnetic vortex structure [1] is one of the representative spin structures observed in a ferromagnetic circular disk, which is an in-plane curling magnetic structure with the nanometer-sized core at the center. Since the magnetic vortex structure is stable and its remanence field is negligibly small, it is a promising candidate for novel applications such as the non-volatile magnetic memory. To realize the magnetic vortex memory, two techniques, that is, to change and to detect the vortex core polarity, are required. Here, we demonstrate a new detection method of the vortex core polarity by using the TMR effect.

Figure 1(a) shows the schematic illustration of our device and circuit for measurement. The sample was fabricated from the Ru / PtMn / CoFe / Ru / CoFe / CoFeB / MgO / CoFeB / Permalloy / Ta multi-layered film on thermally oxidized Si substrate. In this device, the magnetic vortex structure is realized in the lower ferromagnetic layer (FM1). When the circular motion of the vortex core is resonantly excited by an ac input voltage, the magnetization direction below the pillar (FM2) changes periodically, which induces the change of the resistance of the TMR junction. The time-dependent resistance change is probed as a voltage change (Vout) across the device measured through the bias-tee.

Figure 1(b) shows S12 and S21 signal measured by a network analyzer. S21 corresponds to the ratio Vout/Vin under applying an ac voltage to Vin, whereas S12 corresponds to the ratio Vin/Vout under applying an ac voltage to Vout. A clear peak structure can be seen around 89 MHz in S21 signal, indicating the current-induced resonant motion [2]. We have also succeeded in detecting the current-induced vortex core motion as well as the vortex core switching [3] in the real-time measurement.

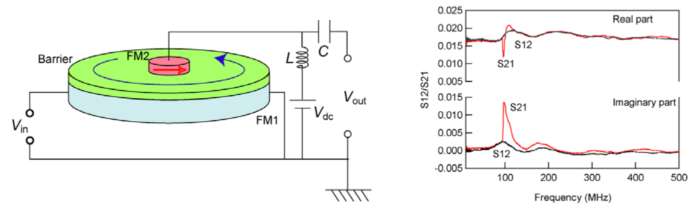

Fig. 1. (a) Schematic illustration of the device and circuit for measurement. (b) S12 and S21 signal measured by a network analyzer. The input power (V_{in}) and the bias voltage (V_{dc}) are set -5 dBm and -0.3 V, respectively.

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