

## Magnetization processes controlled by different arrangements of notches in permalloy rings

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Ferromagnetic thin film ring has become a promising candidate for the application of data storage system, and it is also a good system for studying the domain wall dynamics. From previous results it is found that a slight difference in initial magnetization deviation gives rise to clockwise and counterclockwise vortex domain walls nucleated at the two sides of the onion state, and the two vortex domain walls with the same helicity and opposite helicities lead to two kinds of magnetization reversals from onion state to reverse onion state[1]. When the two vortex domain walls in the onion state have the same helicity, two-step switching occurs going through the flux-closure state; when the two vortex domain walls in the onion state have opposite helicities, one-step switching occurs skipping the flux-closure state. Therefore for an ideal ring without specific nucleation sites, the nucleation is random such that the helicities of the two vortex domain walls at the two ends of the onion state are random. So in every magnetization process of an ideal ring one-step or two-step switching also randomly occurs, and the sweep-down and sweep-up processes are not necessarily the same; for example, one may get two-step magnetization curve in the sweep-down process but one-step magnetization curve in the sweep-up process, and obtain an unrepeatable hysteresis loop. To solve this problem, different arrangements of notches as nucleation sites are demonstrated using magnetoresistance measurements (see Figure 1) to effectively control the magnetization processes of permalloy rings. In the ring with notches at the same side with respect to field direction, two same-helicity vortex domain walls in the onion state lead to two-step switching going through flux-closure state; in the ring with diagonal notches two opposite-helicity vortex domain walls lead to one-step switching skipping flux-closure state. In contrast to rings without notches where the switching processes can not be controlled, the switching processes of the rings with notches designed here are repeatable.

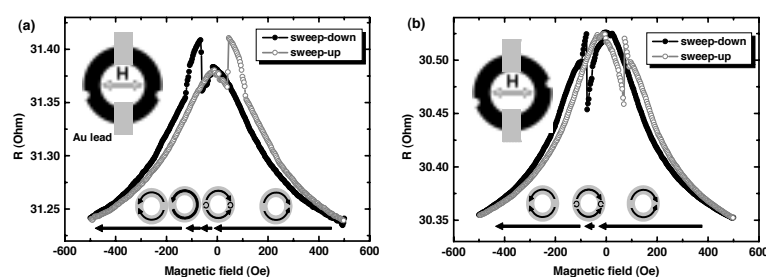


Figure 1: Experimentally obtained magnetoresistance curves of permalloy rings with notches at the same side (a) and diagonal (b) with respect to the field direction. The spatial relationships between the field directions, notches, and Au leads are shown in the insets at upper left-hand corner of each figure. The schematic pictures for the magnetization states are shown in the lower part of each figure.

- [1] M.-F. Lai, C.-N. Liao, Z.-H. San, C.-P. Lee, Y.-P. Hsieh, and T.-F. Ho, *J. Appl. Phys.* **103** (2008), 07C517-1-07C517-3.