Magnetization Configuration and Switching Behavior of $Ni_{80}Fe_{20}$ Ring Elements

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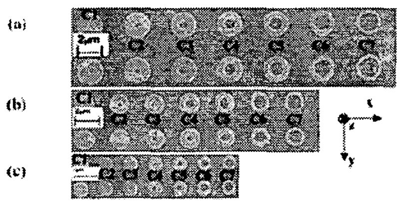

Fig. 1 SEM images of NiFe ring elements. Thickness of ring elements is 40 nm. From the top to bottom, the outer diameter of ring element is (a) 2.0 μm, (b) 1.6 μm, and (c) 1.1 μm respectively.

Arrays of submicron $Ni_{80}Fe_{20}$ ring elements with various ratios of inner to outer diameter ($R_{I/O}$), thicknesses and ring sizes were fabricated by sputter deposition, electron beam lithography, and ion milling method with the objective to investigate magnetization configurations and switching behaviors. Figure 1 shows scanning electron microscope images of patterned ring elements with various $R_{I/O}$ and ring sizes. Magnetization configurations at remanent state were observed by magnetic force microscope (MFM), operating in tapping/lift mode, and oscillating at its resonant frequency. From the MFM images at remanent state after saturating to 5000 Oe along the y direction, two types of domain configuraitons were observed in the ring elements: vortex and onion states. We found that onion states become stable as $R_{I/O}$ increases or film thickness decreases. However, there is no significant effect of ring size on the magnetization configuration. This is attributed to an insignificant increase of the exchange energy with decreasing ring size in this study. Remanent curves of an array with an in-plane applied field were constructed to study the switching behavior of onion-state-stable ring elements. Unrepeatable switching was observed in the ring elements with $R_{I/O}$ near the transition between vortex- and onion-state-stable elements. Therefore, these elements were excluded from the construction of remanent curves. For the 40nm thick ring element, the switching field (here we define the "switching field" as a field required to annihilate a vortex transition state) increases with increasing $R_{I/O}$ and decreasing ring size. Interestingly, the vortex-state-stable field region shifts to a higher field with increasing $R_{I/O}$ and its field range becomes wider. An increasing rate of the switching field does not linearly change with the $R_{I/O}$. The switching field of ring elements in an onion state rapidly increases with increasing $R_{I/O}$ in a narrow ring. This indicates that a small change of $R_{I/O}$ causes a large change in the switching field. Unlike 40 nm thick elements, the $R_{I/O}$ and ring size dependences of switching behaviors of 65 nm thick elements are more complex. We will discuss these behaviors in detail.