Studies in Synthetic Antiferromagnetically Coupled Ring Array Magnets via Hysteresis Loops

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Magnetic multilayer systems such as spin-valve and magnetic tunnel junction with annular shape have shown its unique magnetic properties for developing ultra-dense storage applications. In the multilayer systems, synthetic antiferromagnets (SAFs) which revealing large pinning field and reduced magnetostatic coupling between free and pinned layers nowadays are generally introduced for designing applicable devices. However, up to date, there are very little reports on the magnetic properties of annular-shaped SAF elements. In this study, we fabricated large arrays of SAF rings with dimensions form micron to submicron scale to systematically analyze the corresponding hysteresis loops.

The stacking structure of our SAF consisting of Ta 5/Ru 10/MnIr 7.5/CoFe 2.5/Ru 0.85/ CoFeB 3/ Ru 1/ Ta 2 (thickness in nm) was fabricated by a dc magnetron sputtering method. Arrays of SAF rings with outer diameter (D_0) ranging from 2μm to 0.3μm and inner diameter (D_i) ranging from 1μm to 0.25 μm were fabricated firstly by electron beam lithography through lift-off process and followed by ion-milling process to transfer the annular patterns into stacking film, as shown in Fig. 1 (a) to (d). The corresponding hysteresis loops were then measured by an alternating gradient magnetometer. Notice that to acquire sufficient signal for the measurements, a total area of 2.5×2.5 mm^2 SAF rings were fabricated for each sized sample.

Figure 2 shows the normalized M-H loops of sheet and patterned films. The sheet film data reveals the coupling strength of 3800 Oe between MnIr/CoFe and 2200 Oe between CoFe/CoFeB. In the case of D_0/D_i of 2/1μm, the coupling strength of MnIr/CoFe and CoFe/CoFeB shows similar result with sheet film. The significant drops of the coupling strength in MnIr/CoFe and CoFe/CoFeB occur in the dimensions smaller than D_0/D_i of 1/0.5μm. The clear size effect is observed in this result. Furthermore, in the dimensions of D_0/D_i of 0.5/0.3μm and 0.3/0.1μm, the switching loops in MnIr/CoFe and CoFe/CoFeB reveal no more hysteresis behaviors. More details of the M-H loops and the corresponding magnetization switching process will be discussed later.

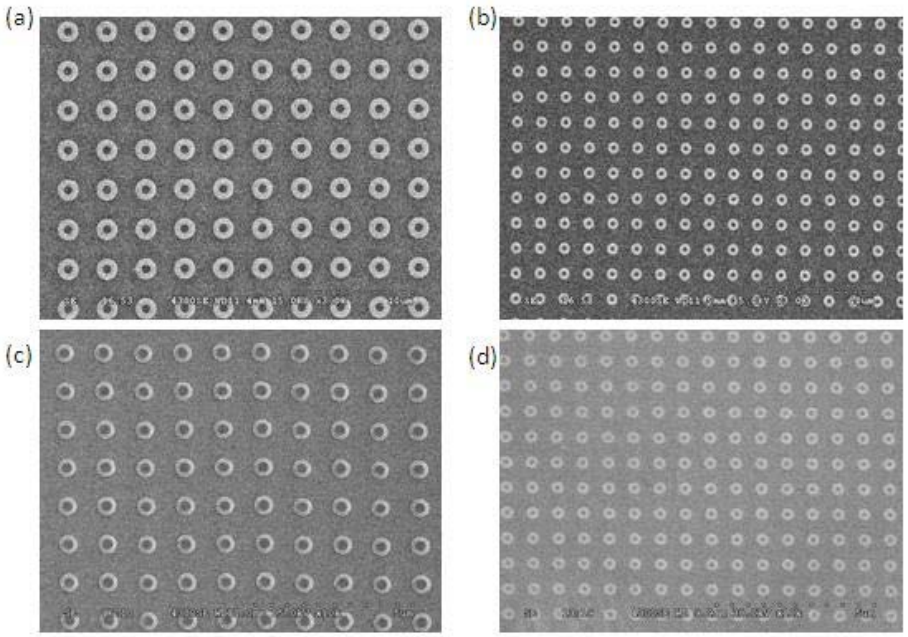

Figure 1: The SEM micrographs of the SAF elements with the dimension in D_0/D_i of (a) 2/1μm, (b) 1/0.5μm, (c) 0.5/0.3μm, and (d) 0.3/0.1μm, respectively.

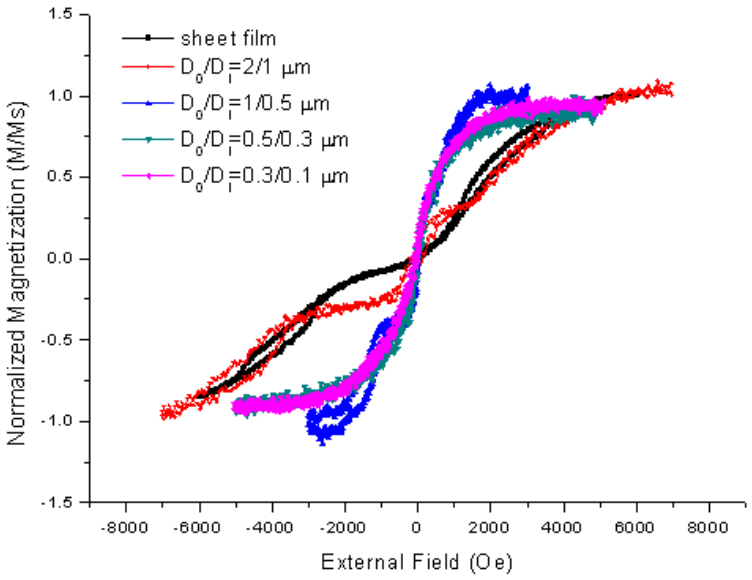

Figure 2: The normalized M-H loops of the sheet and pattern films extracted by an alternating gradient magnetometer represent the corresponding coupling strength in MnIr/CoFe and CoFe/CoFeB, respectively.