Magnetic domain wall motion in permalloy wires with nanometer-scaled notches

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Recently, ferromagnetic nanowires have found wide attention due to their potential technical applications in memory and logic devices. Envision of domain wall memory devices on ferromagnetic nanowire enable a single memory storage device with the low cost of hard disk drives in conjecture to high performance and reliability of solid-state memory [1]. Many researchers have suggested to introduce structural constraints such as 'notch' to trap the domain walls, in which a magnetic field or spin polarized current is used for depinning these domain walls (DWs) and control their motion [2]. In this work, permalloy wires having nanometer-scaled notch are fabricated on Si substrate by using electron beam lithography through a lift-off process. The notches of different depth like 127 nm and 171 nm are designed on permalloy nanowires, 12 μm length and 300 nm width as shown in figure 1. The external field is applied along the long axis of notched wires and consequently propagation of domain wall is observed by magnetic force microscopy, as shown in figure 2 and figure 3. Through an in-situ MFM imaging under different external fields, the measurements are in progress to confirm the formation of vortex domain walls as reported previously [3]. In general, the magnetization in individual wire reverse from one end to the other end of the wire and also the domain walls move through every notch with increased magnetic field [4]. Here, three nanowires with notches have been studied, and the MFM images reveal that the interaction forces between neighboring wires can also affect the reversal behavior. Initially, the magnetization in each nanowire could not be switched simultaneously. This behavior can be seen in figure 2(d) which reveals antiparallel configuration (see label A). Therefore, the minimum magnetic energy of the nanowires causes random magnetic configuration, as it is shown in figure 2(e). Thereafter, the magnetic reversal can be seen clearly in the middle nanowire. In the wires with deeper notch, the two consecutive wires are parallel and other one is antiparallel. This behavior is displayed in figure 3 (b) that is labeled as B. Therefore, magnetization reversal in nanowires having depth of 171 nm possess both configurations A-type and B-type as shown in figure 3. Details regarding to the interesting domain wall motion shall be discussed.

References

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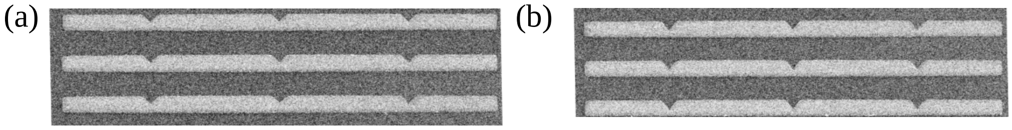

Fig.1 SEM image of notched wires with depth of (a) 127nm and (b) 171nm. Notice that the permalloy thickness is 25 nm.

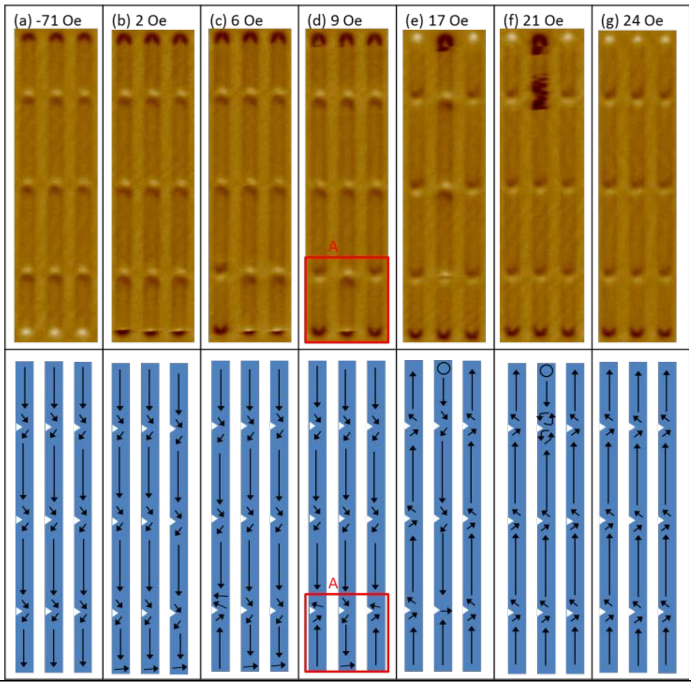

Figure 2: A series of in-situ MFM images observed on the permalloy wires with notch depth of 127 nm. These images were taken in the presence of different magnetic fields as specified (a)~(g) on the top. The corresponding schematics are shown below. Note that an anti-parallel magnetization configuration occurs as designated to be A-type in the text.

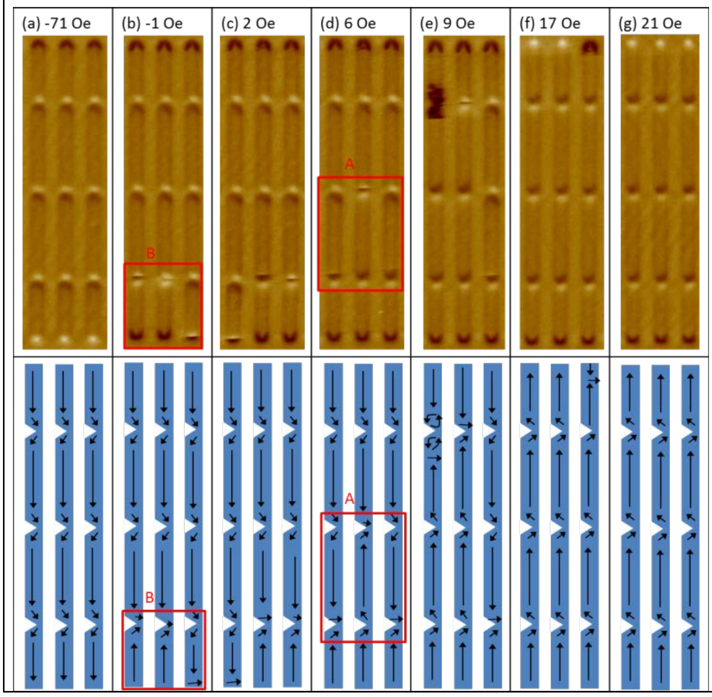

Figure 3: A series of in-situ MFM images observed on the permalloy wires with notch depth of 171 nm. These images were taken in the presence of different magnetic fields as specified (a)~(g) on the top. The corresponding schematics are shown below. Note that another interesting magnetization configuration with two adjacent wires in parallel as designated to be B-type occurs simultaneously in addition to A-type.