Fabrication and magnetic properties of hundred-nanometer-scaled permalloy cylinders arrays

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Magnetic cylinder structures are a scientifically interesting and technologically important area of research with many present and future applications, such as technological applications in magnetic biotechnology [1]. Many techniques have been developed for the synthesis of magnetic cylinder, such as thermal decomposition of precursors, hydrothermal synthesis, atomic layer growth, and template-based electrochemical deposition [2-4]. However, the techniques used up until now make it difficult to tune the magnetic properties of the structures. Herein, we demonstrate a novel fabrication of magnetic cylinders with a uniform array and well-defined geometry by using a standard electron-beam lithography combined with DC-sputter coating and ion-beam milling processes. Firstly, photo resist pillars array is delineated on commercially available Si substrate, as shown in Fig. 1(a), by using electron beam lithography in conjunction with a negative photo resist (maN-2405). This pillars array is sequentially covered with a 20 nm permalloy film by DC-sputtering, as shown in Fig. 1(b). Finally, an ion-beam milling process is then carried out at nearly vertical direction to the substrate for etching-out the parts of permalloy film on the top of the pillars as well as the surface areas between pillars, leaving permalloy films on the sidewalls only. A completed sample with a finite aspect ratio at 2.5 is shown in Fig. 1(c). The dimensions of individual permalloy cylinder are designed as a diameter of 300 nm, a height of 750 nm, and a wall thickness of 20 nm. Two-dimensional pillars array is arranged in a hexagonal lattice with periods of 500, 600, 750, and 1300 nm, respectively. For understanding the magnetization reversal of the permalloy cylinders array, hysteresis loops are measured by an alternating gradient magnetometer with external fields applied in parallel and perpendicular directions relative to the cylinder axis. Figs. 2(a) and 2(b) show the behaviors of magnetization reversals measured on a continuous pillar-shaped permalloy thin film (before ion milling) and the permalloy cylinders array (after ion milling). The existence of a mixed magnetization configuration, containing an uniform “coherent state” along the cylinder axis in middle part and two non-uniform “vortex states” in both ends with the same or opposite magnetization rotating sense, is elaborated.

Reference

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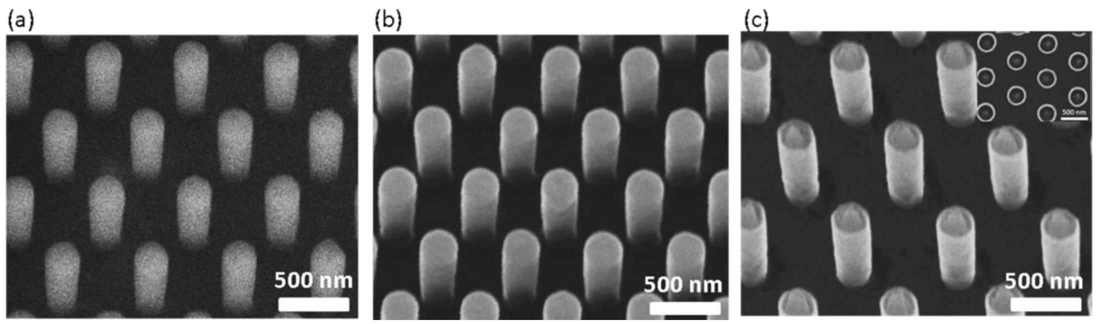

Figure 1. SEM micrographs of (a) photo resist pillars array, (b) photo resist pillars covered with permalloy thin film, and (c) permalloy cylinders array taken from 45^0 angle-view. The inset to (c) shows a SEM micrograph taken from top-view.

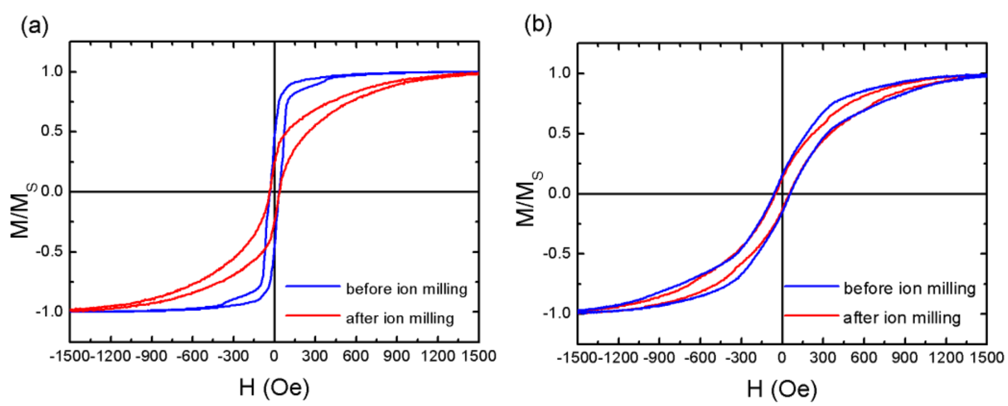

Figure 2. Hysteresis loops of a continuous pillar-shaped permalloy thin film (before ion milling) and a permalloy cylinders array (after ion milling) with external fields applied in (a) perpendicular and (b) parallel direction.