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Microcantilever Torque Magnetometery Study of Patterned Magnetic Films.

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The study of the small, defined magnetic structures has attracted much attention due to interest in both technology applications and fundamental research in micromagnetism. Microcantilever torque magnetometry (MTM) is a promising new experimental technique for measuring such small magnetic features [1]. One of the challenges of using this technique is to place the sample on the cantilever. In this work, we develop a new process for preparing patterned magnetic film on cantilever and show a primarily result of magnetic interactions in a paired magnetic bar measured by MTM.

The process of patterning the magnetic film on the cantilever is following: (a) deposit a multilayer Au (200nm)/Cr (10nm) on cantilever, (b) patterning using a focused ion beam (FIB) milling, (c) magnetic film deposition through a mask, and (d) a lift-off process. Fig. 1 shows an example of the patterned cantilever with 300 dots of 500 nm in diameter using this process.

In order to understand the magnetic interaction between a pair of bars, we prepare a sample as shown in Fig. 2. A 7 μm × 7 μm × 30 nm Ni80Fe20 film was put on the top left corner of the MTM cantilever. The Ni80Fe20 film was then patterned by a FIB workstation into two single 7 μm × 3.5 μm × 30 nm bars by cutting a 50 nm gap in the center of the film [Fig. 2(a)]. After the measurement, the top bar was removed with FIB milling and just left a single 7 μm × 3.5 μm × 30 nm bar on the cantilever [Fig. 2(b)].

Magnetic properties of the patterned Ni80Fe20 films were characterized using a MTM at room temperature and in air. All measurements were done with a magnetic field applied in plane and perpendicular to the axis of the cantilever, as marked in the top of Fig. 2(a). Fig. 3 shows the magnetic hysteresis loops for the single and paired 7 μm × 3.5 μm × 30 nm Ni80Fe20 bars. For the single bar, the magnetization reversal occurs around the coercivity field of -1.23 kA/m. It is correlated to the domain wall propagation quickly through the bar. The smaller change in magnetization at - 4 kA/m may be caused by the annihilation of the small domain structure at the edge of the film. For paired bars, the magnetization reversal occurs at -1.3 kA/m and -1.7 kA/m. The first jump at a field of -1.3 kA/m corresponds to the reversal of one of the paired bars. The second jump at a field of -1.7 kA/m corresponds to the reversal of the other one. The fact that the switching field of single bars is larger than the reversing field of only one of the paired bars and less than that of both paired bars indicates magnetostatic interaction exists between the closely paired bars and that consists with micromagnetic simulations.

In summary, we develop a process to pattern the magnetic film on the MTM cantilever. And by using MTM, we can study the magnetic interaction between the closed small sized and shaped-defined magnetic elements with high resolution. [1] M. D. Chabot, J. Moreland, L. Gao, S. H. Liou and C. W. Miller, Journal of Microelectromechanical systems, 14, 1118 (2005).

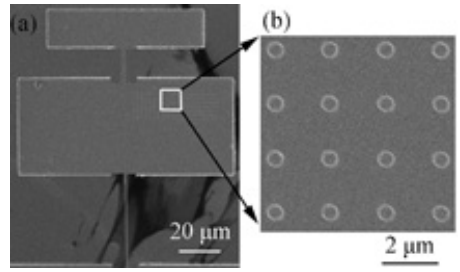

Fig. 1 Nanofabricated the cantilever with 300 dots with diameter of 500 nm. (a) The SEM picture of the cantilever and (b) the enlarged SEM pictures of the patterned circle dots on the cantilever.

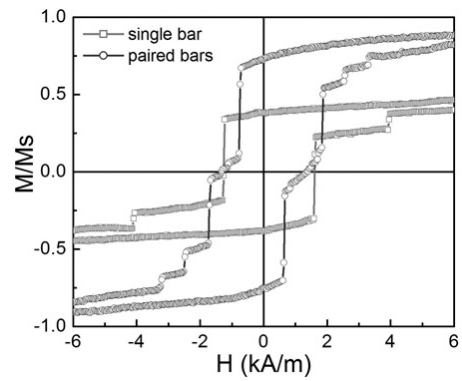

Fig. 3. Magnetic hysteresis loops of the single 7 μm × 3.5 μm × 30 nm Ni80Fe20 bar and same size paired bars with a gap of 50 nm obtained with a microcantilever torque magnetometer.

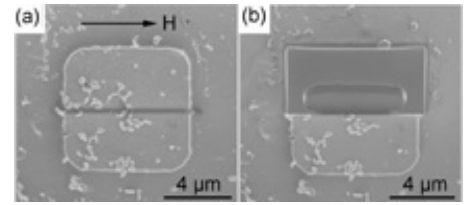

Fig. 2. (a) Double 7 μm × 3.5 μm × 30 nm bars patterned with focused ion beam (FIB) on the 7 μm × 7 μm × 30 nm Ni80Fe20 film with a gap of 50 nm between adjacent bars. (b) Single 7 μm × 3.5 μm × 30 nm bar after removing the top bar with FIB.