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Magnetization reversal and domain structures in nanoscale ferromagnetic dots

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1. INTRODUCTION

The magnetic properties of mesoscopic structures have recently attracted considerable interest due to the possibility of future high-density data storage applications, spintronic devices, magnetic quantum cellular automata as well as fundamental magnetism studies such as the domain structures and magnetization reversal behavior [1, 2]. Much interest has centered on studies of the magnetization reversal process associated with the magnetic anisotropy and domain configurations in ferromagnetic dots. Patterned magnetic structures are of particular interest since the presence of edges introduces dipolar fields that modify the magnetic anisotropy and magnetization reversal behavior. We present the magnetization reversal and domain structures associated with diameter and thickness of nanoscale ferromagnetic dots.

2. EXPERIMENT

Ferromagnetic (FeCo, FeNi) dots with thickness (*t*) 100 - 600 Å and diameter (*d*) 30 – 500 Å were fabricated by electron beam lithography and a lift-off process. Before pattern transfer, a ferromagnetic film was deposited on the Si(100) at room temperature under ultrahigh vacuum (UHV) conditions with a base pressure of 1×10^{-8} Torr. Each was capped with 20 Å Pt for *ex-situ* measurements in order to prevent oxidation of the ferromagnetic layers. Hysteresis loops were measured at room temperature using AGM (alternating gradient magnetometer). Magnetic domain images were taken using MFM (magnetic force microscopy).

3. RESULTS AND DISCUSSION

Figure 1 shows SEM micrograph of FeCo dots with d = 500 nm and series of hysteresis loops for 100 Å thick dot arrays with decreasing dot diameter. A clear size dependence in the hysteresis loops was found. The continuous film before patterning shows very low coercivity (H_c = 5 Oe), whereas the patterned dots [Fig. 1 (b) - (f)] exhibit much higher coercivity (H_c = 40 - 130 Oe) due to edge-induced anisotropy. Micron-sized FeNi dots are composed of multidomains or a vortex, depending on the strength of the induced uniaxial anisotropy [1]. Recently, it was also found that a transition from vortex to single-domain behavior of supermalloy ($Ni_{80}Fe_{14}Mo_5$) dots in the nanoscale range [2], which is dependent upon the thickness and diameter of the dots. The 100 Å thick supermalloy dots with diameter from 500 nm down to 150 nm were observed to have a vortex state, but the dots with $d \leq 100$ nm show a single domain state. By contrast, we found that only FeCo dots with d = 200 nm exhibit a vortex-like hysteresis behavior, as seen in Fig. 1(e). The detailed reason for this is not clear yet. The domain structures associated with the diameter is under investigation by using MFM.

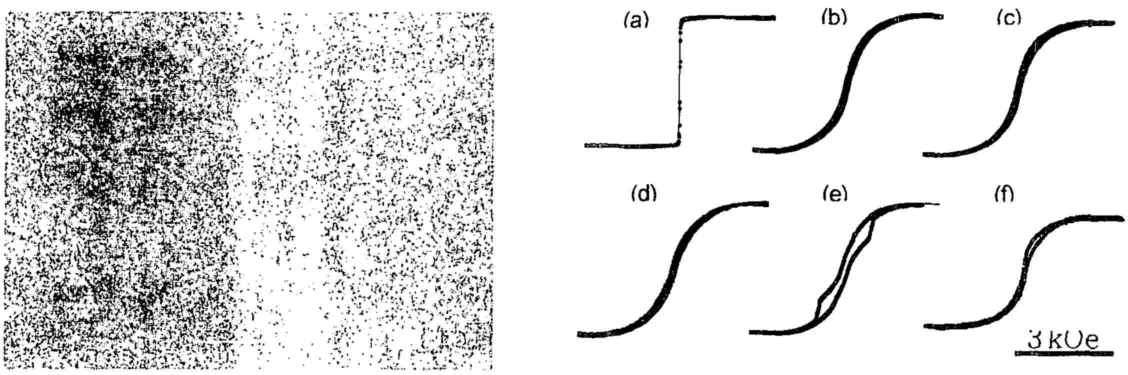

Fig. 1. SEM micrograph of dots with d = 500 nm (left) and series of hysteresis loops (right) measured for 100 Å thick FeCo dot arrays as a function of diameter. (a) Continuous film before patterning (b) d = 500 nm, (c) d = 400nm, (d) d = 300 nm, (e) d = 200 nm, and (f) d = 100 nm.

4. REFERENCES

[1] W. Y. Lee *et al., Appl. Phys. Lett.* **74**, 1609 (1999)

[2] R. P. Cowburn *et al., Phys. Rev. Lett.* **83**, 1042 (1999).