Electrodeposited Co-Pt permanent micromagnet arrays on Cu(111)/Si(110) substrate

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Permanent micromagnets are important components in microelectromechanical systems comprising actuators, biased magnetoresistive sensors, or micromotors. There is no practical process however to produce fully integrated magnets with micrometer scale lateral dimensions, hybrid assembly processes are generally used instead, limiting the achievable miniaturization and increasing the total cost. Electrodeposition into patterned templates is the most suitable technique for the production of integrated micromagnets, as it entails only additive steps and it enables the production of structures with well-defined shapes. Co-Pt alloys have been chosen for this demonstration, as electroplated pattern arrays of this material have been shown to exhibit hard magnetic properties [1].

The substrates consisted of Cu films sputtered on hydrogen terminated silicon (Si-H). Si(110)-H/Cu (100 nm) were prepared by DC magnetron sputtering with no intentional heating. Argon was used as a sputtering gas, at a pressure of 10 mTorr, Cu being sputtered at a power density of 7.96 W/cm^2.

Electrodeposition templates were fabricated onto the substrates by optical lithography, using a Quintel 7000 Mask Aligner. Co-Pt cylinder arrays (55 – 220 nm thickness) were galvanostatically electrodeposited from an amino-citrate based solution [2] containing 10mM Pt and 0.1M Co, at a pH = 8. Deposition was carried out at 65°C from an unstirred solution. A cobalt sheet was used as the counter electrode. Upon electroplating, the resist was dissolved in acetone.

Scanning Electron Microscopy (SEM) as well as Atomic Force Microscopy (AFM) were employed for examining the coverage and the uniformity of the deposit. The magnetic properties were measured using a PMC Alternating Gradient Magnetometer (AGM), with a maximum usable field of 18 kOe.

Figure 1(a1 and a2) shows a SEM micrograph and 1(b) an AFM image of a patterned film with height of 220 nm. They both reveal sharply defined structures and island uniformity over a large area.

Typical hysteresis loops are presented in Fig. 2, specifically for a sample deposited at 30 mA/cm^2 with cylinder height of 220 nm. Despite the shape, the sample exhibits a net perpendicular anisotropy. The arrays show a large coercivity in the perpendicular direction ($H_{C(\_|\_)}$ = 1.1-4.0 kOe), increasing with the dot thickness. Both coercivity and energy product (BH)max increase monotonically with cylinder height, as presented in Fig. 3 for the case of two substrates for comparison purposes (Cu(111)/Si(110) filled symbols and Cu(100)/Si(100) empty symbols). Energy products of up to 4.94 MGOe were obtained, an improvement of sixteen times with respect to previously reported microstructures[4]. The observed linear increase is very encouraging with respect to the possibility to further improve the effective perpendicular anisotropy by increasing the dot thickness.

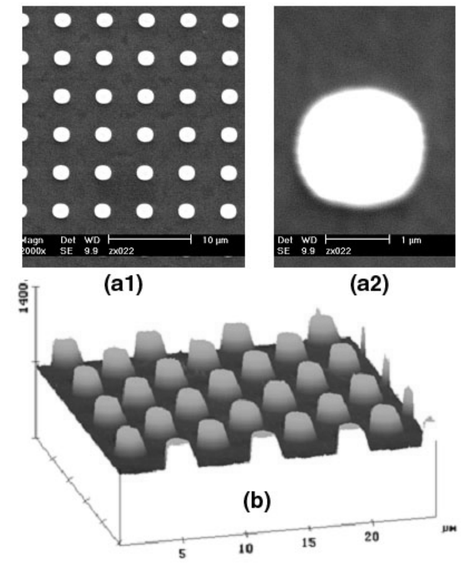

Fig.1 SEM micrograph (a1 and a2) and AFM(b) image of a patterned Co-Pt arrays with the height of 220 nm.

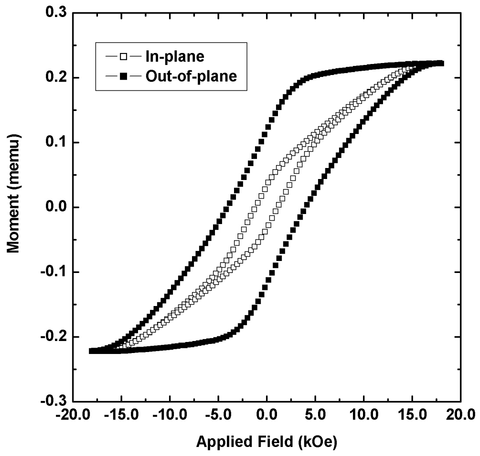

Fig. 2. Typical hysteresis loops (specifically for a sample deposited at 30 mA/cm^2 with cylinder height of 220 nm).

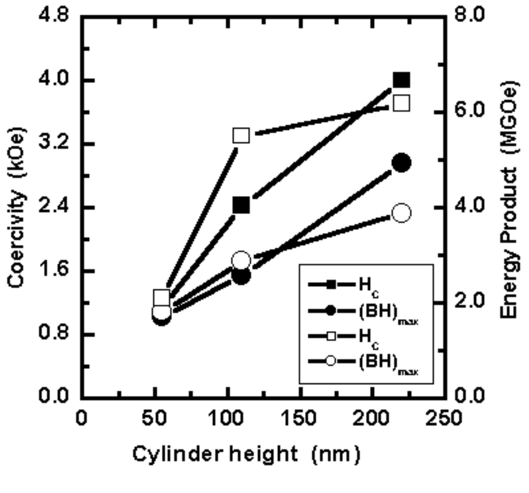

Fig. 3. Perpendicular coercivity and energy product (BH)max versus cylinder height, presented for the case of two substrates for comparison purposes (Cu(111)/Si(110) filled symbols and Cu(100)/Si(100) empty symbols).

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