Hexagonal Lattice Co/Pd Multilayer Nanodot Arrays Fabricated by Self-assembled Nanosphere Lithography

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Patterned magnetic media consisting of physically isolated magnetic nanodot arrays have attracted significant attention because of their potential applications in ultrahigh-density magnetic recording and their novel physical properties.[1-5] Tremendous efforts have been made during the last few decades to fabricate magnetic nanostructures. Of the various self-assembly methods, colloidal lithography uses colloidal particle arrays as lithographic masks or templates to fabricate nanostructures and has been applied widely because of its unique features: it is inexpensive, inherently parallel, and enables high-throughput nanofabrication.[15,16] In this study, we developed a simple and versatile method for fabricating Co/Pd multilayer nanodot arrays with a wide range of dot sizes using colloidal lithography, and characterized their magnetic characteristics using FMOKE and MFM measurements. We also examined the variation of the coercivity with respect to the nanodot size and the appearance of a maximum in the coercivity variation, which was correlated with magnetic domain structures and the interdot magnetostatic interaction.

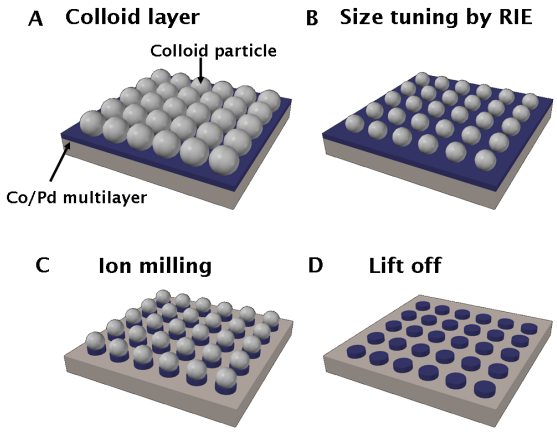

Fig 1. A schematic image describing the size-tunable colloidal lithography process using RIE and ion-milling techniques.

Fig. 1 shows the schematic representation of size tunable colloidal lithography by using the combined RIE and ion milling technique. The crucial aspect of the colloidal lithography for preparing magnetic metal nanodot arrays with a wide range of sizes is the precise adjustment of the size of the colloidal particles with RIE. For the preparation of Co/Pd multilayer nanodot arrays, a multilayer of (2 Å Co/11 Å Pd)$_{10}$ with perpendicular magnetic anisotropy was prepared on silicon substrates using dc magnetron sputtering. A large-area monolayer of polystyrene (PS) or polystyrene/acrylamide (PSAA) spheres close-packed into a hexagonal lattice nanodot array was prepared on a Co/Pd multilayer film by spin casting (Fig. 1A). The radii of the PS and PSAA spheres that were spin-cast into a monolayer on the Co/Pd multilayer can be tuned by varying the reactive ion etching (RIE) conditions (Fig. 1B). The RIE-modified particle array is then used in the colloidal lithography as a mask for the Ar-ion milling (Fig. 1C). By removing the colloidal mask, patterned Co/Pd multilayer magnetic metal dots were obtained (Fig. 1D).

Fig. 2(a-d) shows the variation of the colloidal particle size with the RIE time. The samples were characterized in this study in terms of their initial size r_0 of the colloidal particles, and radius r and inter-dot distance d after RIE

treatment, as shown in Fig. 2. Fig. 2(e-h) demonstrates the hexagonal lattice Co/Pd multilayer nanodot arrays fabricated by using the colloidal mask. For the understanding of magnetic properties of Co/Pd nanodot array, FMOKE and MFM measurements were used to show that both the r_0=183 nm and r_0=100 nm samples have a single-domain structure and exhibit similar evolution patterns with the same maximum location at $\delta \approx 1$ on the normalized interdot distance δ. We conclude from these magnetic force microscopy results that the appearance of maxima in the coercivities is not correlated with a typical multi-domain to single-domain transition but with the interdot magnetostatic interaction in the single-domain region.

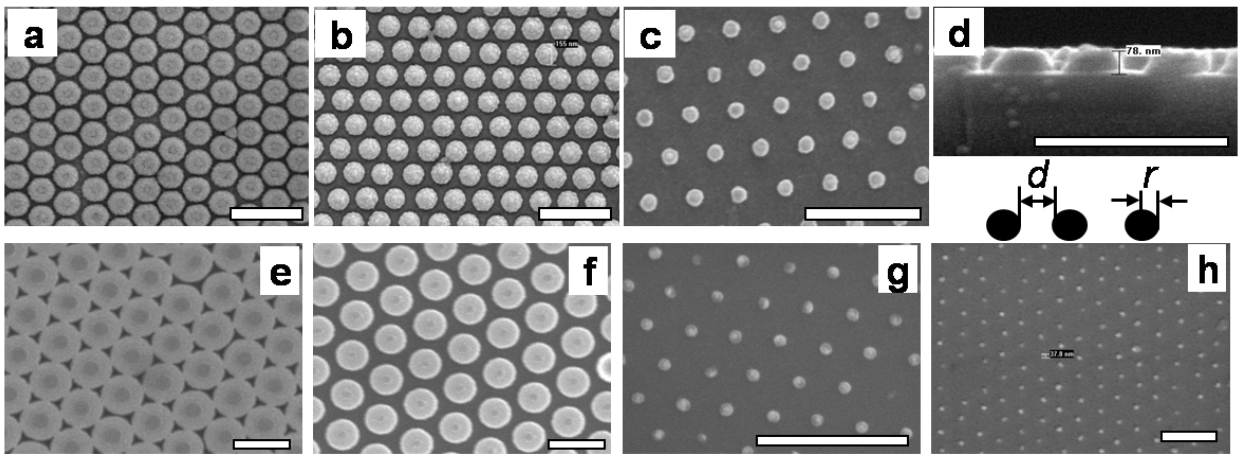

Fig. 2. SEM images for r_0=100 nm colloidal PS particles by varying the RIE time (a) 25 sec, (b) 55 sec, and (c) 70 sec. (d) Cross-sectional SEM image for r=35 nm etched colloidal PS particles on the Co/Pd multilayer film. SEM images of the Co/Pd multilayer nanodot arrays for (e) r=175 nm, (f) 130 nm, (g) 50 nm, and (h) 30 nm. The scale bar is 500 nm.

References

[1] A. Carl, E. F. Wassermann, Magnetic Nanostructures (Ed.: H. S. Nalwa), American Scientific Publishers, Stevenson Ranch, CA, 2002.

[2] C. A. Ross, Annu. Rev. Mater. Sci. 203–235, 31, 2001, and references therein.

[3] G. A. Prinz, Science **282**, 1660– 1663, 1998.

[4] M. Albrecht et al, Nat. Mater. **4**, 203–206, 2005, and references therein.

[5] J.-R. Jeong et al., Small **3**, 1529-1533, 2007.