Perpendicular magnetic nanodot arrays patterned by nanosphere lithography

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Motivation
Bit patterned graded media with high perpendicular magnetic anisotropy indicates great promise for overcoming the tradeoff between thermal stability and recording writability. Efforts to make patterned nanodot arrays with sub-100 nm size were conducted by using nanosphere lithography (NSL) with size-tuned polystyrene spheres (PSS) as masks. Perpendicular anisotropy CoPt films were patterned into dots of 40-90 nm. Increased coercivity and squareness resulted with decreasing nanodot size.

Nanosphere lithography
(a) Perpendicular media deposition
(b) Bottom-up self-assembly of PSS
(c) Smart size tuning by RIE to make masks
(d) Top down patterning of magnetic layer

Magnetic dot pitch is determined by the PSS size, and dot size is determined by the RIE time and selectivity of the mask to the film

Full CoPt film deposition
A pre-seed layer of Ta is used to align the Ru seed layer which gives a narrow c-axis dispersion in CoPt hcp (0002), resulting in a high perpendicular magnetic anisotropy.

Control of PSS mask size
Reactive ion etching process variables are optimized to achieve controllable mask size and desired morphology

Magnetic properties of patterned dots
Size dependence: Magnetic moment decreases with nanodot size because of effective area of magnetic materials decreases. Coercivity and squareness increase with decrease of nanodot size, due to the magnetic switching changing from domain wall motion-dominated to coherent rotation-involved switching. Nucleation field changes toward the second quadrant, and squareness increases to about 1, due to the decrease of demagnetization field. However, the coercivity is not as high as expected even for the 40 nm dots, which is partially due to the dot size non-uniformity at area where the PSS is more than a monolayer (SEM images)

Conclusions and future work
• Successfully sputtered perpendicular CoPt films with high uniaxial anisotropy constant by using RuCu/Ta seed layer.
• Patterned perpendicular magnetic nanodots of sub-100 nm, down to 40 nm, with controllable dot diameter and specific pitch, by using nanosphere lithography with reactive ion etching and ion beam etching.
• Significantly increased the coercivity of CoPt after patterning.
• Initiated a patterning approach for us to study anisotropy graded media. For more details, please go to poster: Fabrication and Characterization of Graded Magneto-Crystalline Anisotropy CoPt Thin Films, Robert Morris, Xiao Li, Zeenath Tadisina, J.W. Harrell, Su Gupta and Gregory B. Thompson.
• Future work: Make high aspect ratio pillars and prove the concepts of exchange spring media.

References: