Dissertations

Hierarchical Multiple Bit Clusters and Patterned Media Enabled by Novel Nanofabrication Techniques - High Resolution Electron Beam Lithography and Block Polymer Self Assembly

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Abstract
This thesis discusses the full scope of a project exploring the physics of hierarchical clusters of interacting nanomagnets. These clusters may be relevant for novel applications such as multilevel data storage devices. The work can be grouped into three main activities: micromagnetic simulation, fabrication and characterization of proof-ofconcept prototype devices, and efforts to scale down the structures by creating the hierarchical structures with the aid of diblock copolymer self assembly. Theoretical micromagnetic studies and simulations based on Landau-Lifshitz- Gilbert (LLG) equation were conducted on nanoscale single domain magnetic entities. For the simulated nanomagnet clusters with perpendicular uniaxial anisotropy, the simulation showed the switching

field distributions, the stability of the magnetostatic states with distinctive total cluster perpendicular moments, and the stepwise magnetic switching curves. For simulated nanomagnet clusters with in-plane shape anisotropy, the simulation showed the stepwise switching behaviors governed by thermal agitation and cluster configurations. Proof-of-concept cluster devices with three interacting Co nanomagnets were fabricated by e-beam lithography (EBL) and pulse-reverse electrochemical deposition (PRECD). EBL patterning on a suspended 100 nm SiN membrane showed improved lateral lithography resolution to 30 nm. The Co nanomagnets deposited using the PRECD method showed perpendicular anisotropy. The switching experiments with external applied fields were able to switch the Co nanomagnets through the four magnetostatic states with distinctive total perpendicular cluster magnetization, and proved the feasibility of multilevel data storage devices based on the cluster concept. Shrinking the structures size was experimented by the aid of diblock copolymer. Thick poly(styrene)-b-poly(methyl methacrylate) (PS-b-PMMA) diblock copolymer templates aligned with external electrical field were used to fabricate long Ni/Fe magnetic nanowire array, dominant shape anisotropy was observed and compared to the result from previously reported Co nanowire array with strong crystalline anisotropy. Guided diblock copolymer poly(styrene)-b-poly(4-vinyl pyridine) (PS-b-P4VP) self assembly was performed to generate clustered microdomains. Direct e-beam patterning on PS-b-P4VP thin film showed precise and arbitrary patterning on the lateral ordering of the self assembly. Graphoepitaxy of self-assembled PS-b-P4VP copolymers on isolated SiN triangular plateaus successfully resulted in the exact clusters of three microdomains. Theoretical consideration and system modeling based on the micellar configuration of the microdomains were done, and the distribution of the cluster's size and number of elements were explained qualitatively.