ADVANCED STORAGE TECHNOLOGY CONSORTIUM
RESEARCH PROPOSAL TEMPLATE

RADIALLY ORDERED BIT PATTERNED MEDIA USING A COMBINATION OF NANOIMPRINT LITHOGRAPHY AND SELF-ASSEMBLY AND FABRICATION OF PATTERN MEDIA USING ION IMPLANTATION WITH NO NEED OF PLANARIZATION

[01] Front matter

a. Date: April 27, 2011

b. Abstract

With the patterned media moving towards its next goal of >1 Tbit/inch^2, the real estate available to achieve such high densities on a hard disk is shrinking smaller in size down to approximately 12 nm x 12 nm. The material requirements to achieve such high densities are undoubtedly challenging. We propose to achieve such high densities using a combination of nanoimprint lithography and self-assembly. The latter provides assembly on a sub-20 nm scale without a long scale order while the former is capable of achieving long range radial order. A combination of both these technique may result in the achievement of long range radial order of the bit patterned media. Direct imprint lithography of SiO_2 would be used out to achieve radial patterns on the media and inside these patterns self-assembly of PS-PDMS block copolymer would be carried out. SiO_2 from both PDMS and SiO_2 resist would be used as a mask to etch the media underneath. This mask would be further used to selectively kill the magnetization of unmasked region by ion-implantation to fabricate the BPM with magnetic and nonmagnetic regions arranged alternatively. When ion implantation is carried out, the unmasked implanted regions would be magnetically damaged using suitable implanted species at optimized dose and energy, whereas the covered regions still remain magnetic.

c. Proponent(s) and affiliation(s)

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d. Designated contact person.

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[02] Subject of research and relevance to issue(s) to be solved.

a. Complete description of the research matter and its connection with ASTC stated goals

The achievement of >1 Tbit/inch^2 areal densities on patterned media is not possible with only one type of technique. Hence a synergistic approach is needed to harness the advantages of combination of techniques while alleviating their disadvantages. Self-assembly of PS-PDMS block copolymer provides sub-20 nm scale patterning without a long range order. On the other hand, nanoimprint lithography is capable of achieving long range (radial) patterning over tens of cms while its ability to pattern closely spaced features on sub-20 nm is doubtful. However, a combination of advantages of both self-assembly and nanoimprint lithography may open the door for achievement of long range radial order on bit patterned media. By using a suitable combination of materials in both the processes giving rise to SiO_2, and using this oxide as an etch mask, the media underneath (whether continuous or granular) can be etched to form bits.

The bit pattern formed using combination of nanoimprinting and self assembly required planarization for industrial realization. In order to avoid the effect of planarization, we propose the ion implantation method to make the pattern media using self assembly mask of SiO2 as discussed above. When ion implantation is carried out, the unmasked implanted regions are magnetically damaged whereas the covered regions still remain magnetic (Figure a).

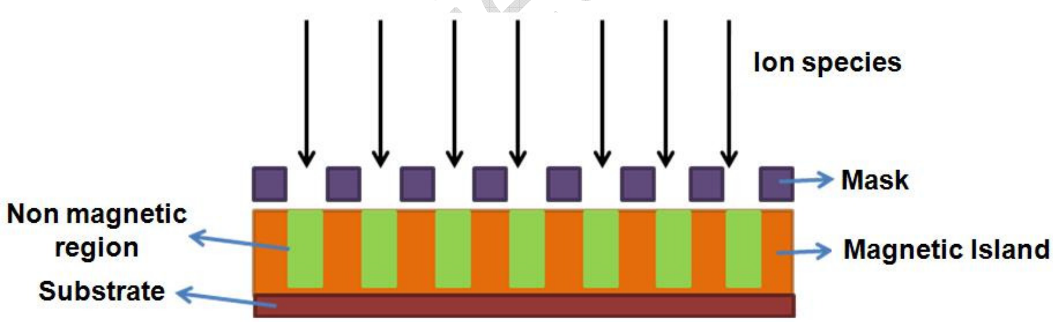

Figure. a. Schematic of patterned media fabrication by ion implantation through PS-PDMS self assembly mask.

b. Proposed research approach(es)

i. Experimental

The experimental work can be sub-divided into four parts, *viz.*, nanoimprint lithography, self-assembly, ion-implantation and finally characterization.

NANOIMPRINT LITHOGRAPHY

With only self-assembly, achieving long range ordering can be difficult. In order to facilitate long range order, topographical patterns like arrays of circular posts and parallel lines on top of the magnetic material can be used to guide the self-assembly of block copolymer. In other words, orientation and the periodicity of the domains can easily be governed over a large area through templated/guided self-assembly using lines and dots. This will be achieved using nanoimprint lithography.

A mixture of silicon methacrylate and acrylate-based cross-linker will be used as a resist for imprinting using a silicon mold. Heat treatment of the imprinted structures (lines or dots) will result in the formation of SiO_2 with much reduced feature sizes. The height of lines or dots can be tailored to sub-50 nm scale – a requirement for the subsequent long range radial ordering of the PS-PDMS dots on the magnetic media during self-assembly.

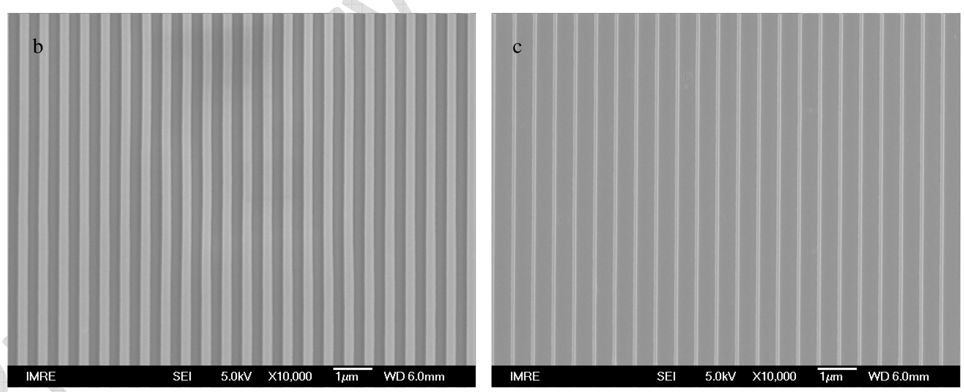

Figure (b) shows the lines imprinted using a silicon mold with 250 nm line/space features. Figure (c) shows the imprinted lines after heat treatment. Shrinkage in feature size can be seen.

SELF-ASSEMBLY

Self–assembly of PS-PDMS block copolymers can result in various morphologies such as nanometre sized spherical domains or pillars. By varying the total molecular weight of the block copolymer and the composition of the blocks in it, the dimensions of the separated domains can be tuned. PS-PDMS of molecular weight 51.5 kg/mol with 16.5% volume fraction of PDMS in it results in a spherical morphology. PDMS dots of 20 nm diameter can be formed in PS matrix. Due to the presence of silicon in the PDMS block, the etch contrast between the two blocks is very high. A few seconds of oxygen plasma can result in the formation of sub 20 nm diameter SiO_2 dots (Fig d)

A solution of the block copolymer in a suitable solvent is made and spin-coated on top of media imprinted with lines and dots of SiO_2 to guide ordered self-assembly. To achieve self-assembly of PS-PDMS, a suitable underlayer is coated on top of the magnetic media to planarize the surface irregularities and provide the block copolymer a smooth surface to assemble. The samples are either solvent annealed or vacuum annealed at an elevated temperature for a known period of time. Solvent can be used to depress the glass transition temperature (T_g) and heat can be used to raise the temperature above T_g (of at least one of the blocks) to make the polymer chains more mobile and eventually phase separate.

Block copolymer concentration, solvent/solvent mixtures used for annealing as well as annealing time are key parameters to enhance the long range order.

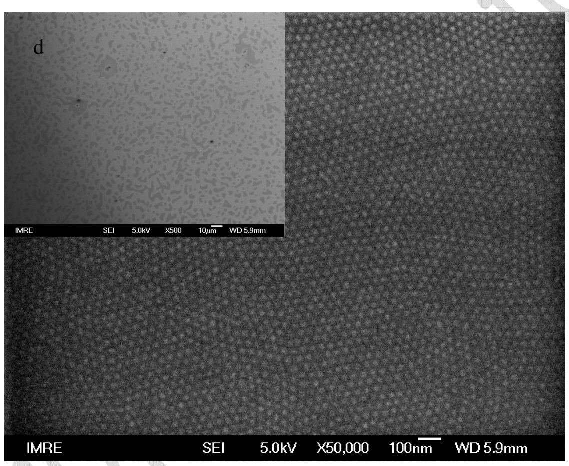

Figure (d) shows the self-assembled oxide dots on CoCrPt granular media. The inset shows a low magnification image of the media. Two regions differing in contrast can be seen. The regions appearing dark have the dots (~20nm) and cover approximately 40% of the total sample area. The sample was 1cm x 1cm.

ION IMPLANTATION

In our preliminary result, the ion implantation of different species in continuous film of CoCrPt-SiO_2 media, coercivity and saturation magnetization reduces as a function of dose (Figure e). Hence, ion implantation through a mask would help in achieving a patterned medium, where non-magnetic regions are formed in a magnetic matrix. In order to materialize this concept first of high anisotropy *hcp* CoPt or $L1_0$ FePt media samples would be fabricated on the suitable underlayer material that can induce perpendicular magnetic anisotropy. The mask would be fabricated using self assembly method as discussed above. Thereafter, using ion implantation technique the magnetic region will be selectively and magnetically destroy to make the pattern media as per the schematic shown in Figure a. The pattern media will be fabricated at IBM research center at J. Watson Research Center, Yorktown Heights (USA) or research tool of Plasma Immersion proposed in our another ASTC proposal.

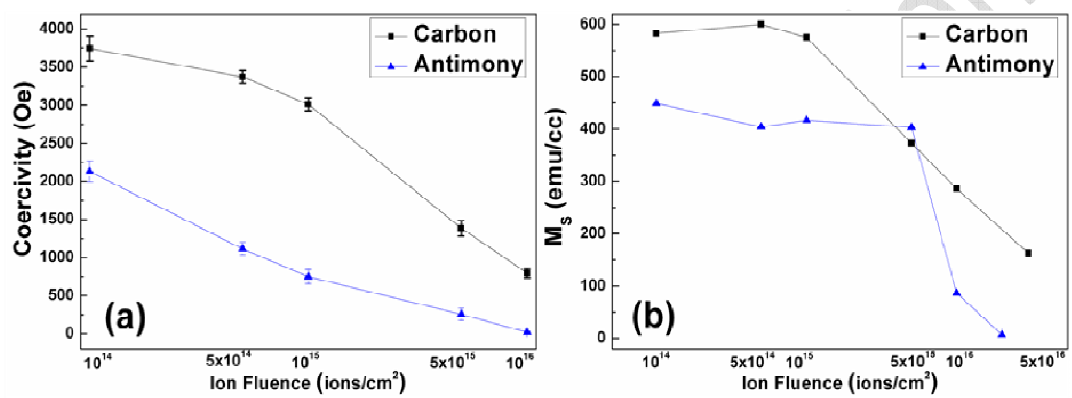

Fig. e. (1) Coercivity (2) Saturation Magnetization (M_S) verses dose for different ions implanted.

CHARACTERIZATION

SiO_2 from imprinting and self-assembled dots will be used as a mask to etch the magnetic media. The dots achieved on media will be characterized by MOKE, MFM and other characterization techniques.

Computational

c. Likely outcome of research

We hope to achieve radially arranged magnetic bit patterned media over a large area. Selective killing of magnetization using the mask may help to realize the patterm media, which may not require planarization.

[03] Resources required to perform project

a. Personnel, students, etc. Post Doc + research engineer +Ph D student (student will be funded from university scholarship). Characterization and process tools will be used in NUS

b. Equipment, lab, etc. Ion millers, ICP etcher, sputtering tool, AFM/MFM etc coaters and spinners, Ion implantation (IBM Research Center Yorktown Heights, USA)

c. Computational (TRIM simulation for Ion Implantation)

[04] Resources other than ASTC funding dedicated to perform project

a. Grants Prof Bhatia has received funding for 10 terabit/in2 with which he has built new research lab (clean room facility) equipped with sputtering, e-beam litho, ion milling, SPM, MFM, TR-MOKE..

b. Not more than one page: Home institutions & resources

c. Resources being utilized at the Institute of Materials Research and Engineering (IMRE), Singapore.

1) Nanoimprinting machines used for topographical patterns – Obducat, Sweden; Imprio 100 (Molecular Imprints, Inc.)

2) Etching machines – Reactive ion etching system, inductive coupled plasma system, UNAXIS shuttle, etc.

d. Contracts N/A

e. Other N/A

[05] Resources requested from ASTC and how they will be utilized

a. Funding

i.	Overhead	30%
ii.	Direct project cost	70K/Yr
iii.	Facility use fees:	10K
iv.	Materials	5K
v.	Postdoc + Research Engineer (~50%)	40 K
vi.	Travel	15K(3 trips/yr to attend ASTC meeting)

NOTE: If ASTC awards project funding to NUS as an “unrestricted gift” then no overhead is required.

b. Expected technical cooperation with sponsor(s): materials to be provided by sponsor(s) (e.g., targets, devices, engineering support, etc.)

c. Sponsors’ facility utilization N/A

d. Expected students’ internships (summer internships possible)

[7] Time line (Gantt chart)

Task	2011-2012				2012-2013			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Fabrication of high anisotropy hcp CoPt and $L1_0$ FePt media	X	X						
Texture and easy axis dispersion control in CoPt and FePt media	X	X						
Fabrication of sub-100 nm line feature using nanoimprinting	X	X	X	X				
Optimization of self assembly fabrication parameters for long range ordering	X	X	X	X				
Self assembly of dot (<20nm) on magnetic media and optimization of etching condition to transfer the pattern to the magnetic media			X	X	X	X		
Optimization of ion implantation parameters such as implanted species, dose, angle of implantation etc.				X	X	X		
Studying of magnetic properties of patterned data					X	X	X	
Summary							X	X

[8] Not more than one-half page per contributor: contact information and biographical sketch of researcher.

1) Dr. M S M Saifullah, Patterning and Fabrication Capability Group, Institute of Materials Research and Engineering, A*STAR (Agency for Science Technology and Research), 3 Research Link, Singapore 117602, Republic of Singapore

2) Prof C. Singh Bhatia worked on magnetic hard disk drives at IBM/HitachiGST for ~30 years and many ideas developed in the lab were commercialized under his management. INSIC presented the 2008 Distinguished Contribution Award to Prof. C. Singh Bhatia in recognition of his dedicated, long term leadership and outstanding level of contribution to the INSIC EHDR Research Program in advanced hard disk storage technology. Dr. Bhatia is the only individual to have twice been awarded the INSIC Leadership Achievement Award (in 1998 and 2003). He was honored for his recent efforts in leading a working group to define approaches to the head□disk interface for 10 terabit per square inch recording, and for his pioneering efforts to

include Singapore in INSIC's research programs. Prof Bhatia joined NUS as Professor in Electrical and Computer Engineering Department, NUS in Aug 2007.

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