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CMRR Report

Center for Magnetic Recording Research

Research Highlight

Enhanced Magnetic Properties of Bit Patterned Magnetic Recording Media by Trench-Filled Nanostructure

Contents:

Number 32 Summer 2009

Steven Swanson - New CMRR Affiliate

Steven Swanson, an assistant professor of Computer Science and Engineering at UCSD's Jacobs School of Engineering, has recently been named a CMRR Affiliated Faculty Member. An experimental computer architect, Steve is co-founder (with Prof. Rajesh Gupta) of the Non-volatile Systems Laboratory (NVSL) at UCSD. The NVSL focuses on the development of prototype systems that further the understanding of hardware, software, security, and reliability implications of non-volatile, solid-state memories.

Steve is a leader in the recently established Solid-State Drive (SSD) project at CMRR. He and his research group bring the capabilities and expertise to conduct studies that extend from basic device-level characterization all the way up to system-level evaluation of the impact of SSD on operating systems, green computing, universal memory, and data-centric computing.

“Steve and his students at the NVSL have played a critical role in the successful launching of this new SSD project,” says CMRR Director Paul Siegel. “Through their existing contacts in academia and industry, as well as their active and extensive

(Continued on page 3)

Albert Sauveur Achievement Award

Sungho Jin, CMRR Professor, Distinguished Professor in the Department of Mechanical and Aerospace Engineering, and Fellow of the American Society of Metals (ASM) International, will receive this year’s Albert Sauveur Achievement Award for “pioneering research for discovery of new materials and phenomena in the fields of electronic, magnetic and superconducting materials.” This ASM award was established in 1934. It recognizes pioneering materials science and engineering achievements that have stimulated organized work along similar lines to such an extent that a marked basic advance has been made in the knowledge of materials.

The award will be presented at the society’s Annual Awards Banquet on Tuesday, October 27, 2009 in Pittsburgh during Materials Science + Technology 2009 (MS+T '09).

2009 Sheldon Schultz Prize for Excellence

On May 10th, 2009, the **Schultz Prize** was awarded to **Zheng Wu**, a student co-advised by CMRR Professors Paul H. Siegel and Jack E. Wolf. The prize is presented in recognition of CMRR graduate students who have distinguished themselves through the creativity of their research and the impact of their publications.

Zheng received her B.S. and M.S. degrees in electrical engineering from Tsinghua University, Beijing, China. She began her doctoral studies at CMRR in the spring of 2004. Her research focused on recording channel modeling, equalization and detection techniques, and error-control coding algorithms and architectures.

During her tenure at CMRR, Zheng participated in two internships. In the summer of 2006, she worked at Seagate Technology in Fremont, California. Her work involved research on the optimization of channel parameters based on measured signal and noise characteristics. In the summer of 2008, she worked at the Samsung R & D Center in San Jose, California. The topic of her project was write precompensation for nonlinear transition shift (NLTS) in perpendicular magnetic recording systems.

In December 2008, Zheng received her Ph.D. from the ECE Department at UCSD. Her dissertation was entitled “Channel Modeling, Signal Processing and Coding for Perpendicular Magnetic Recording.” Zheng is currently a Staff Engineer at Link-A-Media Devices in Santa Clara, California.

To make a donation of any amount to the **Schultz Prize**, please make checks payable to “UC San Diego Foundation” with a notation on the check or a brief cover letter designating the contribution for the “Schultz Prize.”

You can also submit an online donation at http://www.jacobsschool.ucsd.edu/external/external_giving/ Click on “Give Now” and under “fund” select “Schultz Prize.”

Your donation is 100% tax-deductible, and an official acknowledgement of your contribution will be provided to you. All correspondence pertaining to the Schultz Prize can be directed to:

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University of California-San Diego
Center for Magnetic Recording Research, #0401
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From the Director

Magnetic recording technology is at a crossroads. Anticipating the end of the reign of conventional perpendicular recording, industrial and academic research labs have made major investments of time and expense in two potential successors—bit-patterned media recording (BPMR) and heat-assisted magnetic recording (HAMR). More recently, two-dimensional magnetic recording (TDMR) has entered the picture. Here at CMRR, we continue to address fundamental challenges relevant to all of these approaches, drawing upon our expertise in recording physics, nano-magnetic modeling, magnetic materials, nano-fabrication techniques, signal processing and coding, mechanical interfaces, and servo control. [The Research Highlight on page 4 describes recent progress from Professor Sungho Jin's lab on BPMR.]

Now we have added a new dimension to the Center's technical scope – our Solid-State Drive (SSD) initiative. In cooperation with Professor Steve Swanson, who heads the Non-volatile Systems Laboratory (NVSL) at UCSD, we have launched an exciting program of cutting-edge research devoted to advancing SSD technology, which is already revolutionizing the role of storage in computing systems and consumer electronics. Current SSD projects address key challenges in ensuring reliability, security, and data integrity of next generation flash-based storage systems. In last issue of CMRR Report, I introduced this emerging effort, and the Research Highlight presented some early results on error-correction coding for flash memory. The SSD project was more formally unveiled at the Flash Memory Summit this past August, with four outstanding technical presentations by graduate student researchers, as well as posters, a slide show, and hardware demos at our booth in the Summit exhibition area. [See the article on page 10, and visit the SSD project webpage at http://nvsl.ucsd.edu/ to see the presentations and posters.] The response to the debut of the SSD project has been impressive, and several newly funded projects have already been initiated, with plans for several more unfolding.

CMRR and NVSL intend to play a leading role in the establishment of an academic research agenda on SSD technology and systems. Our early work has already received international recognition: CMRR graduate student researcher Eitan Yaakobi recently received the very prestigious 2009 Marconi Young Scholar Award for his work on coding for flash memories. [See details on page 9.] Plans are also underway to host the first UCSD Non-volatile Memory Workshop, to be held next spring, with the goal of bringing together experts from industry and academia to focus attention on vital research problems and to foster technical collaborations.

In summary, CMRR continues to educate and innovate at the leading edge of research in storage technology and systems. If you are not already partnering with us, now is a great time to join. As always, the CMRR faculty and I welcome any inquiries you might have about opportunities for technical collaboration and sponsorship.

Now, enjoy the rest of this issue of CMRR Report!

(Continued from page 1) - Steve Swanson Affiliated Faculty Member

participation in the recent Flash Memory Summit [see related article on page 10], they have helped bring considerable attention to the project in a very short period of time. We are looking forward to very close collaboration with Steve as this exciting new activity goes forward."

Steve received his Ph.D. in 2006 from the University of Washington, where he developed WaveScalar, a novel dataflow processor architecture. As a graduate student, Steve received numerous prestigious awards, including graduate research fellowships from the NSF and Intel, as well as the University of Washington CSE Microsoft Endowed Fellowship. He was also the recipient in 2003 of the Best Student Presentation Award at the 36th Annual International Symposium on Microarchitecture. In 2007, Steve received an NSF Faculty Early Career Development (CAREER) Award, the most prestigious honor bestowed by the NSF in support of junior faculty members.

Research Highlight Enhanced Magnetic Properties of Bit Patterned Magnetic Recording Media by Trench-Filled Nanostructure

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Abstract

The structure and properties of nanoscale magnetic island arrays for bit patterned media (BPM) have been studied. A periodic Si nano-island array was fabricated by nano-imprint-lithography (NIL), with the trench-filling and flattening achieved by resist spin coating followed by reactive ion back-etching. A [Co 0.3nm\Pd 0.8nm]$_8$ multilayer magnetic media with a perpendicular anisotropy was then sputtered and lifted-off so that the processed nanostructure array now has the magnetic material only on the top of the pillars. This process significantly improved the magnetic characteristics of the bit patterned media. A planarization by hydrogen silsesquioxane filling can reduce the tribological interference of the protruding nanoisland heights in the bit patterned media.

I. Introduction

For hard disk magnetic recording media with substantially improved recording capacity of 1 Tbit/in^2 or higher recording density, a reduction in the feature size is one of the key requirements[1]. Bit patterned magnetic recording media (BPM) have attracted much attention due to the projected increase in magnetic recording density. Some of the important intrinsic parameters that affect the recording media performance are the thermal stability factor (K_uV/k_BT), proper anisotropy (K_u) and magnetization values with a narrow K_u distribution.[2, 3]. Important extrinsic parameters include the uniformity of the nano geometry in the processed patterned media.

Two major nano-fabrication methods exist for deposition of magnetic material for the patterned media[4, 5, 6]. The first approach is the substrate patterning, followed by magnetic layer deposition. The substrate is pre-patterned into islands using e-beam or nano-imprint lithography before the magnetic material is deposited. The main advantages of this method are that (i) no chemical or reactive ion etching process is required for metallic magnetic layer once the substrate island array structure is prepared, (ii) and hence the possible damage of the magnetic material associated with ion etching process is minimized, (iii) and a high throughput process is possible. However, the magnetic material is also deposited in the trenches (between the protruding Si or other substrate islands), which introduce undesirable noises during the read/write process and can cause magnetic interactions between the media material deposited in the trench or island sidewall and that on the top of the islands[5]. The second approach of placing the magnetic layer is to first deposit the high coercivity magnetic thin film material on a flat substrate, then followed by direct patterning of the media layer into discrete magnetic island bits by ion beam etching or focused ion beam milling (FIB). The main advantage of this method is that the magnetic material left between the neighboring bits is minimized to reduce interfering magnetic signals. However, this method has a low throughput with slow etching process for magnetic metal patterning by ion milling, with possible complications of magnetic material re-deposition during the ion-etching process. Also, the magnetic material can more easily be damaged by the ion bombardment required for metal etching.[6]

We have demonstrated significantly improved magnetic bit patterned media properties by a simple, convenient, and reliable trench-filled nanostructure to ensure the magnetic material deposition only on the patterned media islands. A two-step planarization process of using the PMMA filler first to block the trenches during magnetic layer deposition, followed by hydrogen silsesquioxane (HSQ) filler to planarize and obtain nano-topographically flat recording media was employed. Both polymers can easily be spin-coated to fill the etched areas [7].

II. Experimental Procedures

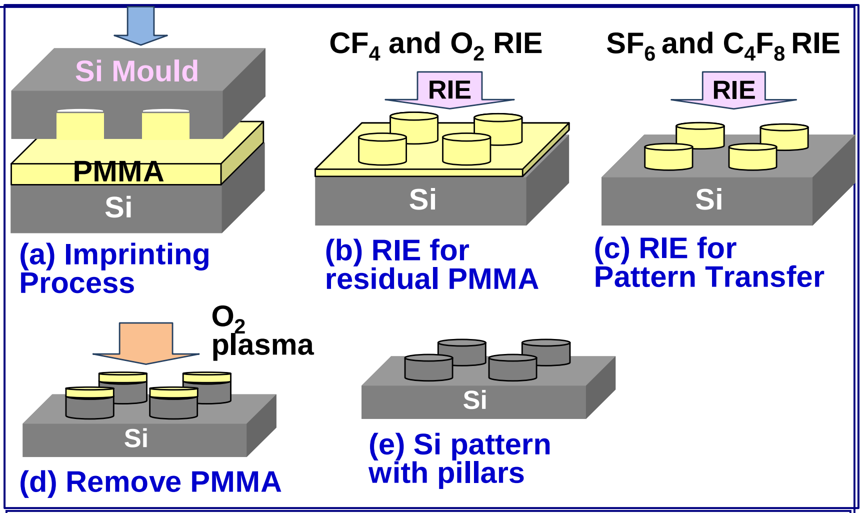

Fig. 1 Schematic illustration of the fabrication processes for bit patterned media (BPM) using trench-filling process.

Figure 1 schematically illustrates the process used for bit patterned media nanostructure fabrication, trench filler additions and planarization. A Si wafer was spin-coated with an approximately 250 nm thick layer of poly-methylmethacrylate (PMMA) (Micro Resist Technology, mr-I 35k PMMA 300). A Si nanoimprint stamp (mould) having a nano-hole array (~100 nm diameter) is then imprinted onto PMMA layer on Si wafer at using an ANT-2 nano imprinter (step (a) in Fig. 1). The nano imprint lithography (NIL) stamp (mould) was created on (100) silicon wafers by deep ultraviolet (DUV) lithography patterning, reactive ion etch (RIE), and surface oxidation [8]. The NIL patterned PMMA was slightly RIE etched (Oxford Plasmalab-80) in a gas mixture of CF_4 and O_2 to form a through hole (Fig. 1 (c)). The hole-patterned PMMA was then used as an etching mask for Si etching to faithfully transfer the patterns into Si wafer using a mixture of SF_6 and C_4F_8 for RIE (Oxford Plasmalab-100) as illustrated in Fig. 1 (d), followed by removal of PMMA by O_2 plasma to produce an array of protruding Si nanoisland columns (~100 nm diameter and ~100 nm tall) Fig. 1(e).

In order to place the magnetic bit layer only on top of pillars, we utilized a nanoscale filling and manipulation of the Fig. 1(e) nanostructured substrate as illustrated by the insets in Fig. 2(c). A thin PMMA layer was first spin coated to fill the valley and subsequently re-etched by a CF4 and O2 mixture RIE to remove the overfilled regions on the substrate for planarization. A magnetically hard Co/Pd multilayer film, having a [Ta 3nm\Pd 3nm\[Co 0.3nm\Pd 0.8nm]8 structure with desirable perpendicular magnetic anisotropy was sputtered on the pre-patterned and planarized substrate.

After magnetic layer deposition, the filling processed BPM was lifted-off by acetone and sonication. A HSQ (hydrogen silsesquioxane) resist film was spun on the BPM to fill the trenches and subsequently back-etched by RIE to remove the “overfilled” extra HSQ material. The surface roughness of the nanostructured BPM before vs after trench filling was monitored by atomic force microscopy (AFM) and scanning electron microscopy (SEM). The magnetic properties of the BPM media material were evaluated by magnetic force microscopy (MFM) and superconducting quantum interference device (SQUID) with vs. without the trench-filled nanostructure.

III. Results and discussion

As a demonstration of principle, we fabricated a ~100 nm diameter periodic array of Si nano pillars using nano imprint lithography (NIL). Each of the samples contained ~100 million Si nanopillars over a relatively large area of 0.6 cm x 0.6 cm. The oblique angle SEM image of the bit patterned media consisting of high-coercivity magnetic multilayer stacks of [Ta 3 nm\Pd 3 nm\[Co 0.3 nm\Pd 0.8 nm]8] deposited on top of Si islands as well as in the valleys (trenches) is shown in Fig. 2(a). Our patterned Si islands have a dimension of ~100 nm diameter, ~ 100 nm height and a periodicity of 400 nm. It is notable that the Si island nanofeature dimension is undesirably altered during the magnetic multilayer deposition, with the magnetic materials deposited in the trench, on the top, as well as on the sidewall of the pillars. Also shown in Fig. 2(b) is the SEM image of the Fig. 2(a) nanopillar structure subjected to an additional process of geometrical planarization using

HSQ (hydrogen silsesquioxane) spin coating, back etch and conversion of the trench HSQ into SiO2 by annealing. The trenches are completely filled by HSQ. The planarization process has reduced the bit height from ~ 100 nm to ~ flat, 15 nm layer. Only the magnetic bit islands are exposed.

In order to restrict the presence of magnetic materials only on the pillar top, not in the unwanted places such as sidewall and valley, the samples were pre-covered by PMMA (poly-methylmethacrylate) using spin coating before magnetic layer deposition so as to exclude the magnetic materials on these unwanted locations. After spin coating, the superfluous PMMA is back-etched by RIE to reveal the top of the Si islands. The required RIE time depends on the thickness of PMMA, the height of the Si pillars, and the etching rate. A SEM image of a BPM with themagnetic recording media material restricted to the Si pillar top area via the trench-filling process is shown in Fig. 2(c). It is apparent that the trench filled nanostructure controls the location of magnetic material in a well-defined manner and prevents the unwanted deposition of magnetic material outside the pillar tip region.

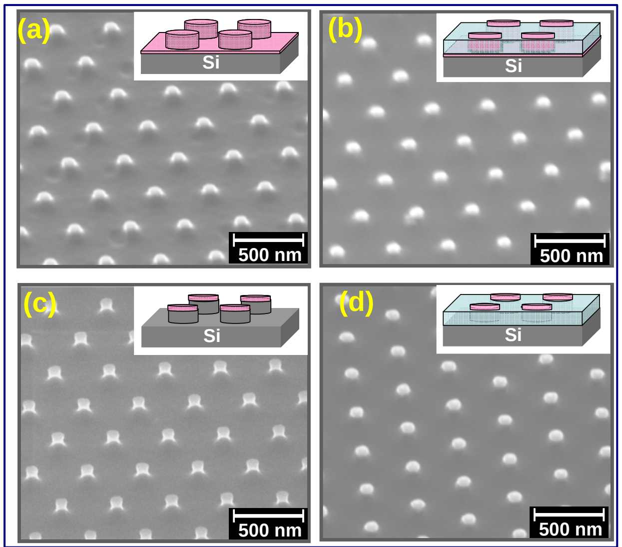

Fig. 2. SEM images showing topographical features of bit patterned media. (a) magnetic media deposited without trench filling, (b) the structure of (a) + additional geometry planarization, (c) magnetic media deposited with trench filling for isolated magnetic islands, and (d) the structure of (c) + additional geometry planarization. The insets show the schematic description of the BPM nanostructures.

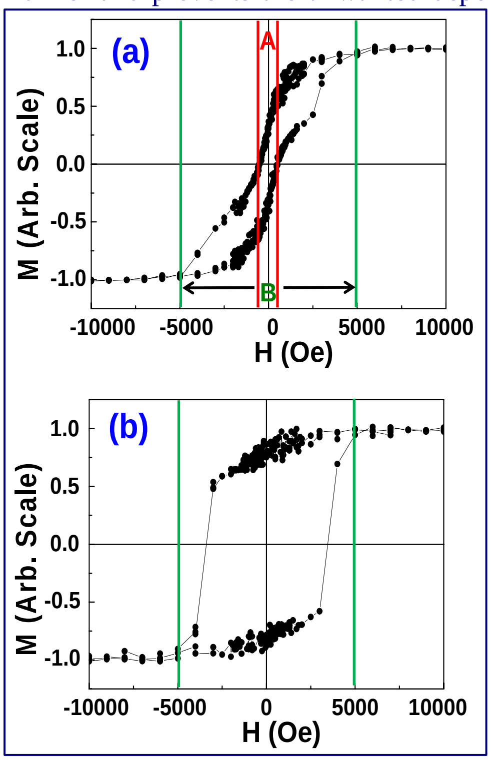

Fig. 3. M-H loop of bit patterned media by SQUID measurements for (a) BPM with unremoved magnetic materials in the trenches, (b) BPM with trench filling process for isolated magnetic islands.

To evaluate how such nanostructural manipulations influence the magnetic behavior of BPM media, the magnetic properties of BPM were measured and analyzed. Figure 3(a) shows the M-H magnetization loop of the patterned media measured by SQUID (superconducting quantum interference device), without the trench filling process. This M-H loop appears to have two distinctly different regions. The Region A (marked in Fig. 3(a)) represents the magnetic signal from the relatively continuous CoPd multilayer film in the valley, which exhibits a low coercivity of only about 600 Oe as anticipated for non-nanosize Co-Pd layer materials. The Region B, on the other hand, shows the magnetic signal from the ~100 nm diameter size-confined CoPd multilayer islands on top of the Si pillars, which exhibits a much higher coercivity of about 5000 Oe. It is known that the smaller CoPd multilayer islands produce much higher coercivity. The M-H loop clearly shows that not only was the magnetic multi layer present on top of pillars, but on sidewall and valley. Shown in Figure 3(b) is the M-H loop measured from BPM with magnetic material confined to the Si pillar top only, accomplished by using the trench-filling process. Contrary to the M-H loop of Fig. 3(a) for the BPM without filling process, the Fig. 3(b) exhibits a much better defined M-H loop indicative of a more uniform material, namely only the pillar top island magnetic material.

Shown in Figure 4(a) are typical magnetic force microscopy (MFM) and atomic force microscopy (AFM) images of the BPM without the filling process. The schematics in the insets illustrate the cross-sectional geometry of the magnetic recording media in relation to the substrate and the HSQ filler material. The AFM data, Fig. 4(a) (rightside image, representing ~5 mm square area) indicates a relatively uniform pillar array. The MFM image (leftside image) shows a somewhat smaller island images, which is possibly related to the larger measurement distance between MFM probe tip and magnetic multilayer surface as compared to the AFM imaging. The light phase vs. dark phase contrast represents opposite magnetization directions in the MFM imaging. It is seen that the valley regions also show some response to the MFM imaging (darker and blurry contrast regions) indicating the presence of magnetic materials in the valley. In the BPM processed with the trench-filling step (thus having the magnetic material only on the island top), the MFM image of Fig. 4(b) leftside is much more uniform than the case of Fig. 4(a) MFM imaging, and exhibits no dark contrast regions from the valley seen in Fig. 4(a).

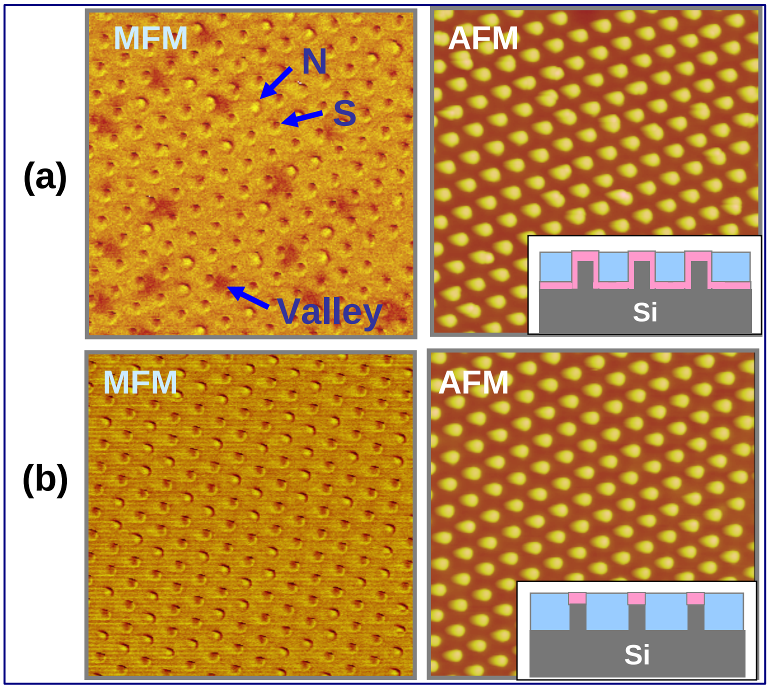

Fig. 4. MFM data (left) and AFM data (right) of BPM (a) without trench filling process vs. (b) with trench filling process.

Higher resolution MFM image of the BPM with the filling process (magnetic material only on the pillar top), Fig. 5, indicates further details of the domain structure. Because of the somewhat larger island diameter of ~ 100 nm, the magnetic island is not a single domain in this particular case, and a two-domain structure is therefore observed. It is anticipated that single domain structure in a periodic arrangement will be obtained if the island diameter is reduced to ~50 nm or smaller, which is one of our current research topics.

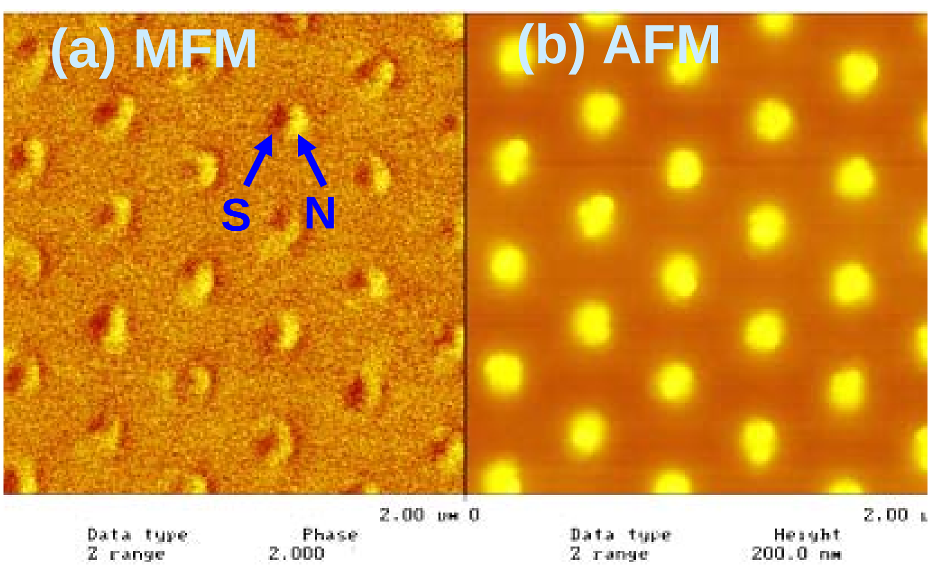

Fig. 5. Higher resolution images of (a) MFM and (b) AFM for the BPM with trench filled nanostructure.

In summary, the structure and properties of nanoscale magnetic island arrays for bit patterned media (BPM) have been studied, in which the deposition of unwanted magnetic materials outside the island region was prevented by trench-filling. A Co-Pd multilayer magnetic media placed on nano-imprint-lithography-processed, periodic Si nano-island array using such trench-filled configurations exhibited significantly improved magnetic characteristics of the bit patterned media.

(Continued from page 7)

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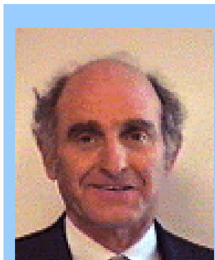
Nobel Prize Predictions



Former CMRR Director, Professor Sheldon Schultz**,** appeared on Thomson Reuters list of predictions for the 2009 Nobel Prize in Physics. Professor Schultz was cited for his development of “a new class of composite materials with 'reversed' physical properties never before seen.”

According to the Thomson Reuters website, two major factors contribute to their accuracy in predicting Nobel Prize winners: “Firstly, is the correlation between high citation frequency of journal papers, and the receipt of prestigious prizes, especially the Nobel Prize. The primary source for Thomson Reuters's forecasts is the *Web of Science*®, which provides quick access to the world's leading citation databases with multidisciplinary coverage from over 20,000 of the most influential, high impact journals and conference proceedings worldwide.

The second reason is by selecting the top 0.1% papers of each scientific field, the scope of analysis can be narrowed to topics and people that are most likely to be nominated by the Nobel selection committee. Citation analysis allows Thomson Reuters to trace the true pioneer of each field or area of research as well as to assess peer recognition of the discovery.”

CMRR Students Selected as Young Marconi Scholars

CMRR graduate student **Eitan Yaakobi** and CMRR visiting graduate student **Marco Papaleo** have been selected as Marconi Scholars for 2009 by the Marconi Society. The honor includes a $4,000 cash prize, which will be presented at the Marconi Society Award Dinner in Bologna, Italy, on October 9, 2009. The prize also includes $1,000 to help defray travel expenses to the event.

Marco Papaleo (left) and Eitan Yaakobi at the Gala Award Dinner on October 9th, 2009, Bologna, Italy

The event includes two days of symposia. October 8th includes a historical focus, and presentations by the Young Scholars. October 9th will include presentations by former Marconi Fellows, as well as this year's winners, and culminates with the Gala Award Dinner.

Marco Papaleo was a visiting graduate student at CMRR from May to October 2009, working with the research groups headed by Professors Paul Siegel and Jack Wolf. He received his B.S. and M.Sc. degrees (summa cum laude) in telecommunication engineering from the University of Bologna, Italy, in 2003 and in 2006, respectively. He received an award for one of the three best theses in telecommunication engineering from University of Bologna for the academic year 2004-2005. In January 2006, he joined the Advanced Research Center on Electronic Systems for Information and Communications Technologies "Ercole De Castro" (ARCES) at the University of Bologna, where he also began his Ph.D. studies in 2007. In the summer of 2008 he was a visiting Ph.D. student at the German Aerospace Center (DLR) Institute of Communications and Navigation in Wessling. He was involved in the design and analysis of LDPC convolutional codes. In 2006, he was a visiting affiliate student at the University College of London (UCL), in England. His current research activities are focused on the next generation of wireless telecommunication systems, for both terrestrial and satellite networks. In particular, he is interested in the design and performance evaluation of error control coding (with emphasis on packet level coding).

CMRR Professor Jack Wolf (left) and Eitan Yaakobi

Eitan Yaakobi received his B.A. and M.Sc. degrees from the Computer Science Department at Technion - Israel Institute of Technology, Haifa, Israel, in 2005 and 2007, respectively. He is currently a Ph.D. candidate in ECE at UCSD, where he is co-advised by Professors Paul Siegel and Jack Wolf. His research interests lie in the area of coding theory, particularly algebraic error-correction codes and their applications in digital data storage systems. He is currently investigating coding techniques for solid-state drives based upon flash memory devices.

CMRR Launches New Solid State Drive Research Initiative at Flash Memory Summit

The 2009 Flash Memory Summit held in Santa Clara, California last August saw strong representation from CMRR and UCSD's Non-Volatile Systems Lab (NVSL). Among the audience of more than a thousand attendees most were from industry. CMRR faculty, students and staff attended the Summit to promote CMRR's new Solid State Drive research initiative and the upcoming Non-volatile Memories Workshop which is scheduled for Spring 2010.

Extremely well received were the four presentations made by students Adrian Caulfield (Secure Erasure of Flash Memory), Joel Coburn (New Abstractions for Fast Non-Volatile Storage), Laura Grupp (Characterizing Flash Memory Devices), and Eitan Yaakobi (Error Correction Coding for Flash Memories). Yaakobi is co-advised by Professors Paul H. Siegel and Jack E. Wolf at CMRR. Caulfield, Coburn, and Grupp of NVSL are advised by CSE Professor Steve Swanson, a newly affiliated faculty member of CMRR [see related story on page 1].

Also popular in the Summit's expo hall was the CMRR-NVSL exhibit showcasing projects from the new Solid State Drive research initiative. Hundreds of visitors to the booth were actively engaged by posters on “Wear Leveling” and “Error Correction Coding for Flash Memories” (presented by Eitan Yaakobi and Ameen Akel (a student of NVSL) and demonstrations of the “Flash Chip Torture Test” and “Real Time Operational Testing” from Prof. Swanson's lab (see photos).

As a follow-up to their successful participation in the Summit, CMRR and NVSL will host the aforementioned two-day Non-Volatile Memories Workshop next Spring. The Workshop will feature technical presentations and commentaries by thought leaders from industry and academia, addressing a range of topics involving Flash, PCM, STT-RAM, and other emerging storage technologies. More details and registration for the Workshop can be found at the CMRR website.

Flash demonstrations by Prof. Steve Swanson (far right)and NVSL students Ameen Akel (center) and Laura Grupp (right) attract the attention of Summit attendees.

“The Flash Memory Summit provided excellent visibility for our new SSD research program, leading to valuable contacts with technical leaders in the industry,” said CMRR Director Paul H. Siegel. “We are very grateful to the FMS organizers - Tom Coughlin and Alan Land - for their enthusiastic encouragement and financial support of our participation in the technical program and exhibition.”

More information on the Flash Memory Summit may be found at: http://www.flashmemorysummit.com.

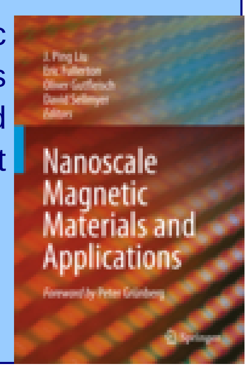
CMRR student Eitan Yaakobi (right) explains his recent work on Error Correction Coding for Flash Memories

Professor Fullerton Edits New Book

CMRR Professor Eric Fullerton is one of four editors of a new book entitled Nanoscale Magnetic Materials and Applications . According to the publisher, "readers will find valuable reviews of the current experimental and theoretical work on novel magnetic structures, nanocomposite magnets, spintronic materials, domain structure and domain-wall motion, in addition to nanoparticles and patterned magnetic recording media."

Cutting-edge applications in the field are described by leading experts from academic and industrial communities. These include new devices based on domain wall motion, magnetic sensors derived from both giant and tunneling magnetoresistance, thin film devices in micro-electromechanical systems, and nanoparticle applications in biomedicine.

In addition to providing an introduction to the advances in magnetic materials and applications at the nanoscale, this volume also presents emerging materials and phenomena, such as magnetocaloric and ferromagnetic shape memory materials, which motivate future development in this exciting field."



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Selected Papers and Talks

A complete listing of CMRR papers & talks can be found at: http://cmrr.ucsd.edu

Professor Emeritus H. Neal Bertram

B. Livshitz, A. Boag, **H.N. Bertram**, and **V. Lomakin**, "Nonuniform grid algorithm for fast calculation of magnetostatic interactions in micromagnetics," *Journal of Applied Physics*, Vol. 105, No. 7, (April 2009), pp. 07D541-1-3.

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Professor Eric E. Fullerton

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The Fall 2009 Research Review and Advisory Council Meeting will be held on October 28-29, 2009. For further information on the CMRR Research Review, please contact Iris Villanueva at 858-534-6196 or ivilla@ucsd.edu .

CMRR Research Review Highlights

The Spring Research Review was held in May 2009. Over 35 people from CMRR Industrial Sponsor companies and other invited guests participated in the meeting, including several who participated via teleconference.

In addition to the sessions devoted to technical presentations of CMRR research results, the Review featured two special presentations. The first special session entitled "Elastic Data Computing: Dynamic Provisioning of Data Intensive Applications" was presented by C.K. Baru from the UCSD Supercomputer Center. The second special session entitled "Non-volatile Memory and Its Role in Future Systems" was presented by Asst. Professor Steven Swanson from the CSE Department at UCSD.

CMRR Sponsor company employees may access the abstracts and viewgraphs of all Research Review presentations on the CMRR website in the Sponsor Resources section at http://cmrr.ucsd.edu/sponsors/
Contact Jan Neumann with any questions regarding Sponsor Resources at jneumann@ucsd.edu .

Graduate Degree Awarded

Ralf Brunner a CMRR student advised by Professor Frank E. Talke, received his Ph.D. in July 2009. His dissertation was entitled "Properties of Carbon Overcoats and Perfluoro-Polyether Lubricants in Present and Future Hard Disk Drives." Ralf is pursuing his career in the hard drive industry and is currently a Principal Engineer at Western Digital, a CMRR sponsor company, in San Jose, California.

New Postdoctoral Scholar

Dr. Lisa Chamberlain has joined Dr. Sungho Jin's group as a postdoctoral fellow. She was awarded her Ph.D. from Colorado State University in 2009 where she studied *in vitro* and *in vivo* inflammatory responses to biomaterials. She is using methods developed previously in Dr. Jin's labs to create a range of nanotextures and study the effects of nanotexture on inflammatory responses *in vitro* and *in vivo*. Additionally, she is investigating the potential of using nanosurfaces for tissue engineering projects.

New Graduate Students

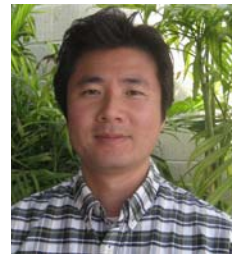
Laura Connelly is a second-year graduate student in Prof. Sungho Jin's group in materials science and engineering and co-advised by Prof. Eduardo Macagno in neuroscience. Her research utilizes the unique superparamagnetic properties of iron oxide nanoparticles to guide and promote the growth of neurons. Such magnetic particles have often been used as contrast agents for magnetic resonance imaging (MRI). She is working to utilize these particles in a new way and create a bridge between magnetic materials technology with biomedical engineering research.

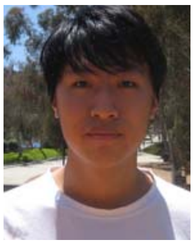
Jirapon (Jeanne) Khanwannah is a first-year graduate student in the Materials Science and Engineering graduate program at UCSD. She has joined Professor Sungho Jin' s research group. She received her B.S. degree in Materials Engineering from King's Mongkut University Technology of Thonburi (Thailand). Her research interests include design, fabrication and applications of nanomaterials for information and energy storage.

Gifts, Grants and Awards

Professor Eric Fullerton has received a four year grant from NSF to support his research project entitled "Magnetic transition metal nanowires."

Caleb (Seong Deok) Kong is a Materials Science & Engineering Ph.D. graduate student who is working under Professor Sungho Jin. He is currently conducting research on fabrication, characterization and applications of magnetite and related magnetic nanoparticles for magnetically induced movement and local heating for biomagnetics applications such as drug delivery and targeting. He received his M.S. degree in chemistry at Yonsei University in South Korea.





Han Wang received the B.Sc. in Electrical Engineering from Tsinghua University, China, in 2008. He is currently a Ph.D. student in Professor Paul Siegel's group. He is working on reverse-concatenation coding architectures for multi-track tape recording systems. His research is supported in part by the INSIC TAPE Program.

Visitor

Benjamin Werner is a visiting graduate student from Germany in Professor Frank Talke's lab. He received his diploma in mechanical engineering from the University of Rostock. At CMRR he will investigate contact between the slider and disk in hard drives using finite element modeling.

Graduate Students & Researchers Near Completion

Student	Level	Advisor	Dept	Area of Research	Completion
Amir (Hadi) Djahanshahi	Ph.D.	Siegel	ECE	Wireless communications, information and coding theory, optimization, estimation, and multi-user detection.	Spring 2010
Seyhan Karakulak	Ph.D.	Siegel	ECE	Channel modeling and detection for patterned media recording.	Spring 2010
Eitan Yaakobi	Ph.D.	Siegel	ECE	Algebraic error-correction codes, coding for flash memory and other applications in data storage and transmission.	Summer 2010
Paul (Yeoungchin) Yoon	Ph.D.	Talke	MAE	Slider dynamics and tribology of the head/disk interface with small form factor disk drives and discrete track (DTR) media.	Spring 2010

Center for Magnetic Recording Research

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Summer Internship

Hao Zheng, a doctoral student of Professor Frank Talke, spent her summer with the Dynamic Flying Height group at Western Digital in Fremont, California. She worked on modeling of a thermal flying height control (TFC) slider. Thermal flying height control has recently been implemented in magnetic recording disk drives to reduce the flying height of the read/write element. Numerical simulation of the TFC slider can efficiently predict temperature increase, thermal deformation and flying height change of the slider. An iterative solution is required to obtain the reduction in flying height caused by the thermal protrusion. The air bearing pressure and the flying height of the slider are obtained by first solving the equations of motion of the slider and the Reynolds equation. Then, the heat transfer coefficient between the slider and the air bearing is calculated. The results are imported into ANSYS and serve as a boundary condition at the air bearing surface for the thermal analysis. The thermal deformation causes a protrusion around the read/write element. This changes the geometry of the air bearing surface. A new air bearing calculation is needed to get the updated pressure distribution and flying height. Iteration continues until the flying height has converged. Hao's project, supervised by Dr. Ladislav Pust, focuses on the development of ANSYS macros to achieve a "one-button" structural/thermal modeling of the TFC slider.

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