The goal of the Laboratory for Energy Storage and Conversion (LESC), at the University of California San Diego, Nanoengineering department, is to design and develop new functional nanomaterials and nanostructures for advanced energy storage and conversion applications. Prof. Shirley Meng, an affiliated faculty member with CMRR, is leading her group to design, optimize and develop new materials for energy storage for electric vehicles and smart grids, as well as permanent magnetic materials for electric driving motors and wind turbines. Meng’s group research focuses on the direct integration of novel experimental techniques with first principles computation modeling methods for rational materials characterization and design.

(Continued on page 4)

News release: Workshop Convenes Best Minds in Data Storage to Break Computing Bottlenecks

San Diego, CA, April 17, 2012 -- To the uninitiated, UC San Diego’s annual “Non-Volatile Memories Workshop” sounds like some kind of group therapy session for those recovering from past emotional traumas. But for those in the technological know, non-volatile memories (NVM) are crucial components of modern computing systems, components that make it possible to store increasingly large amounts of information in smaller spaces, at faster data transfer speeds and (if the industry has its way) at lower cost to the consumer.

All of this is contingent, however, on busting research and development bottlenecks that keep the latest and greatest advances in NVM from entering the marketplace. The third annual Non-Volatile Memories Workshop was a prime opportunity for more than 200 academics and industry representatives from this esoteric but influential field to present their research and stretch this continually evolving technology to the limit.

Read the entire article by Tiffany Fox at: http://www.jacobsschool.ucsd.edu/news/news_releases/release.sfe?id=1199
This newsletter comes after my first year as Director of CMRR. This has been an exciting time and I would like thank the CMRR sponsors, faculty, staff, students and post docs for their support and encouragement. We are continuing our efforts to expand CMRR’s core research in information technologies with various projects in hard disk drives and non-volatile memories. Towards this goal, we are happy to welcome three new sponsors: Huawei which joined as a level II sponsor, LSI which became a full member after a trial membership last year, and Hitachi GST which returned as a level II member. We look forward to working with them and our current sponsors, Western Digital, Toshiba, Marvell to push the frontiers of the information storage, memory and processing and, most importantly, to train students and post docs. As part of this education process we have 11 graduate students performing summer internships this year. I would like to also welcome Vlado Lubarda, Adjunct Professor of Applied Mechanics in the Department of Mechanical and Aerospace Engineering, as our newest affiliated faculty member of CMRR. Professor Lubarda’s research is in the fields of elasticity, plasticity, viscoelasticity, dislocation theory, fracture and damage mechanics, thin films, biomechanics, and materials science. We look forward to his contributions to CMRR in the coming years.

In addition to our core research activities we are also exploiting the CMRR expertise in nano-materials, modeling and devices to attack important problems in permanent magnets, high-permeability materials, nano-photonics and battery technologies. You will hear more of these efforts in the coming research reviews. We are also expanding our educational efforts by organizing various conferences and workshops. Paul H. Siegel and Steve Swanson have organized the Non-Volatile Memories Workshop (NVMW) each of the last three years. The workshop provides a unique showcase for outstanding research on solid state, non-volatile memories. This year CMRR organized the International Workshop on Advanced Micromagnetics (IWAM) as a showcase for new and emerging techniques in the micromagnetic analysis of magnetic materials and devices. It brings together leading experts in computational and theoretical micromagnetics from academia and industry. By having the workshop the same week as the research review we hope this provides an additional benefit to our sponsors who can attend both the workshop and review. We plan on having more of these workshops as part of future research reviews and would like input on potential topics.
Renowned Physicist and Innovator Eric Fullerton Wins 2012 AIP Industrial Application of Physics Prize

The American Institute of Physics (AIP) has awarded the 2012 AIP Prize for Industrial Applications of Physics to Professor Eric Fullerton for his pioneering work in advancing magnetic recording media. Fullerton is a professor in the departments of Electrical and Computer Engineering, and NanoEngineering at the University of California, San Diego, where he earned a doctorate in physics in 1991.

Fullerton joined the UC San Diego Jacobs School of Engineering faculty in 2007 after years working in industry at both IBM and Hitachi Global Storage Technologies.

The AIP Prize for Industrial Applications of Physics recognizes scientists who have developed proven industrial technologies. Fullerton's work on exchange-coupled magnetic recording media helped enable the last 10 years' worth of growth in the storage densities in disk drives. Magnetic storage plays a key role in audio, video, and computer technology. The exponential growth of digital information contributes to ongoing demand for greater hard drive capacity.

Read the complete article by Tiffany Fox at: http://www.jacobsschool.ucsd.edu/news/news_releases/release.sfe?id=1170
Recent Activities in Materials Research for Energy Storage and Conversion Energy

Choosing the best cathode material used in a Li-ion battery is one of the most crucial issues in achieving higher energy densities, since the energy density is directly correlated to the specific capacity associated with that cathode material. The conversion type materials have been studied as potential electrode materials for higher energy lithium ion batteries (at least double the energy density of today’s technology). We have investigated the NiF$_2$ based conversion materials and the conversion reaction includes the nucleation and growth of nanosized Ni particles. In order to understand the conversion mechanism more thoroughly, we utilized a Superconducting Quantum Interference Device (SQUID) magnetometer, which is a powerful technique for detecting nanosized magnetic particles such as Ni nanoparticles that otherwise could be missed by diffraction based analytical techniques.

As shown in Fig. 1, the magnetic hysteresis loops were obtained at 5 K, since the material is in a superparamagnetic regime. Superparamagnetism is a form of magnetism, which appears in small ferromagnetic or ferrimagnetic nanoparticles. In sufficiently small nanoparticles (<10nm), magnetization can randomly flip direction under the influence of temperature. When the time used to measure the magnetization of the nanoparticles is much longer than the Néel relaxation time, their magnetization appears to be in average zero; they are said to be in the superparamagnetic state. On the other hand, the magnetic moments remain at a fixed direction during a single measurement when the temperature is lower than the blocking temperature ($T_B$), where the ferromagnetic moment becomes superparamagnetic. The distinguishable magnetic hysteresis was observed at 5K since NiF$_2$ was mostly converted to nanosized-Ni particles by the conversion reaction. It is also suggested that the conversion reaction in NiF$_2$ is very slow, which contributes to the formation of extremely small particles. These nanoparticles are not precisely detected by diffraction techniques due to the nanosize peak broadening.

Fig. 1. Magnetic hysteresis of NiO-doped NiF$_2$ conversion materials

Based on the SQUID analysis, we could propose the possible conversion mechanisms occurring in NiF$_2$. The magnetic measurements provided more fundamental understanding on the phases including the size information on nanosized-Ni particles during the conversion reactions. This work is published in *Electrochimica Acta* 2012, 59, 213 by Ph.D. candidate Daniel Lee and colleagues.

Meng’s group also recently reported the low coordinated geometries on the surface of the oxides can result in spin states that are distinct from the bulk. Consequently, unique magnetic and electronic properties arise and alter the materials performance in devices. Lithium cobalt oxide...
(LiCoO$_2$) is a compound of great technological importance, as it has been the most widely used positive electrode material for lithium ion batteries for nearly two decades. In recent years, it has been demonstrated that ultra fast charge/discharge rate capabilities can be achieved in this compound when nano-scale ($< 50$nm) particles with morphology optimal for Li intercalation are prepared and tested. We presented in this work that this can similarly be explained by the presence of intermediate spin (IS) or high spin (HS) Co$^{3+}$, a phenomenon which alters the lithium (de)intercalation voltage significantly.

In bulk LiCoO$_2$, Co$^{3+}$ has six 3d electrons, while in octahedral oxygen environment; it would split into t$_{2g}$ and e$_g$ orbitals, which are d$_{xy}$, d$_{yz}$, d$_{xz}$ and d$_{x^2-y^2}$, d$z^2$ respectively. It has been found by previous studies that in bulk, Co$^{3+}$ is in the low spin (LS), where all the electrons are paired in t$_{2g}$ orbitals, as shown in Left Figure (c). On the $\{104\}$ surface, the Co$^{3+}$ ions are coordinated by five oxygen ions, resulting in a square pyramidal configuration. With first principles calculation, we found that the surface energy is lowered significantly when going from the LS configuration (1118mJ/m$^2$) to the IS (312mJ/m$^2$), which has two unpaired electrons. On the $\{110\}$ surface, the Co$^{3+}$ ions on the surface are coordinated by four oxygen ions with a pseudo-tetrahedral configuration. The surface energy is minimized from 2227mJ/m$^2$ (LS) to 1241mJ/m$^2$ (HS), which has four unpaired electrons. Magnetic measurements were performed, using a superconducting quantum interference device (SQUID) at CMRR, at a magnetic field of 1.0 T in the temperature range of 5-300K. The molar magnetic susceptibility of the various sized nano-LiCoO$_2$ particles are plotted as a function of temperature in Right Figure. The magnetic susceptibility of bulk LiCoO$_2$ is very low, which is attributed to the LS Co$^{3+}$ in the layered structure. The magnetic susceptibility increases with the decrease in size, which is contributed from the unpaired electrons on the surface. This work is recently published by Ph.D. candidate Danna Qian and colleagues in *Journal of the American Chemical Society*, 2012, 134(14), 6096.

Rare earth permanent magnets are key components in electric vehicle motors and in wind turbine electricity generators, and there is a growing international concern over the economics of rare-earth raw materials. DOE is addressing the issue from the technology side through its ARPA-E program, REACT—Rare Earth Alternatives in Critical Technologies—whose mission is to develop substitute materials for rare earth permanent magnets. Meng and her postdoc Dr. Kyler Carroll are teaming up with Virginia Commonwealth University to demonstrate a new class of permanent magnets based on a carbide-based composite magnet. For understanding the fundamental mechanism behind the high magnetic energy in these type of carbide composite, Meng’s group have to carry out advanced characterization techniques such as synchrotron X-ray absorption spectroscopy (XAS) in order to understand the local structures of metal – carbon atomic structures. In the picture, the student Ph.D. candidate Michael Verde visited the facility for the first time and is mesmerized by the sophisticated experimental setup at Brookhaven National Laboratory Beam line X18B.

For more information about the Laboratory for Energy Storage and Conversion (LESC) and Prof. Shirley Meng’s research group, please visit [http://ne.ucsd.edu/smeng/](http://ne.ucsd.edu/smeng/)
Selected Papers and Talks

**Professor Eric Fullerton**


**Professor Sungho Jin**


**Associate Professor**

**Raymond A. de Callafon**


A complete listing of CMRRR papers & talks can be found at: [http://cmrr.ucsd.edu](http://cmrr.ucsd.edu)


Young Oh, Chulmin Choi, Daehoon Hong, Seong Deok Kong, Sungho Jin, "Magnetically Guided Nano-Micro Shaping and Slicing of Silicon", Nano Lett. DOI: 10.1021/nl300141k (ASAP article published on line, March 12, 2012).


**Professor Paul H. Siegel**


Selected Papers and Talks (cont’d)

Associate Professor Steven Swanson


Characterization and Error-Correcting Codes for TLC Flash Memories, Eitan Yaakobi, Laura Grupp, Paul H. Siegel, Steven Swanson, and Jack K. Wolf, to Appear in International Conference on Computing, Networking and Communications, Data Storage Technology and Applications Symposium, 2012.


Professor Frank E. Talke

Ovcharenko, A., Yang, M., Chun, K., and Talke, F. E., "Transient Thermomechanical Contact of an Impacting Sphere on a Moving Flat", JOT, 133 (2011) 031404-01


Graduate Students Near Completion

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<th>Student</th>
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<th>Advisor(s)</th>
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<th>Area of Research</th>
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<tr>
<td>Joel Coburn</td>
<td>Ph.D</td>
<td>Professor Steven Swanson</td>
<td>CS</td>
<td>Developing systems for providing strong consistency guarantees for accessing storage systems based on advanced non-volatile memory technologies.</td>
</tr>
<tr>
<td>Alex Eisner</td>
<td>M.S</td>
<td>Professor Steven Swanson</td>
<td>CS</td>
<td>Developing technologies for providing fast access to next-generation non-volatile memory technologies.</td>
</tr>
<tr>
<td>Aravind Iyengar</td>
<td>PhD</td>
<td>Professor Paul H. Siegel</td>
<td>ECE</td>
<td>Synchronization Error Channels &amp; Windowed Decoding in Theory &amp; Practice</td>
</tr>
<tr>
<td>Xiaojie Zhang</td>
<td>PhD</td>
<td>Professor Paul H. Siegel</td>
<td>ECE</td>
<td>Structure and decoding of LDPC codes</td>
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### Internships

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<tr>
<td>Ruinan Chang</td>
<td>Ansys-HFSS</td>
<td>Testing and validation of electromagnetics FEM codes</td>
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<tr>
<td>Marco A. Escobar</td>
<td>Western Digital</td>
<td>Micromagnetic study of magnetic recording system</td>
</tr>
<tr>
<td>Youyi Fu</td>
<td>Western Digital</td>
<td>HAD Simulations</td>
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<tr>
<td>Jimmy Kan</td>
<td>Qualcomm</td>
<td>Advanced MTJ Bit Error Rate Characterization &amp; Magnetic Failure Analysis</td>
</tr>
<tr>
<td>Shaoting Li</td>
<td>Qualcomm</td>
<td>Performance/algorithm tuning on image processing &amp; computer vision</td>
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<tr>
<td>Sohini Manna</td>
<td>MaNEP</td>
<td>Metal oxides spin valves</td>
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<tr>
<td>Liane Matthes</td>
<td>Western Digital</td>
<td>Head disk interface</td>
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<td>Sergio Montoya</td>
<td>General Atomics</td>
<td>Advanced Metamaterial Division</td>
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<tr>
<td>Deng Pan</td>
<td>Western Digital</td>
<td>Lubricant transfer and redistribution using Molecular dynamics modeling</td>
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<td>Zhengqi Tang</td>
<td>Western Digital</td>
<td>Suspension and head/disk simulation</td>
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<tr>
<td>Michael Wei</td>
<td>Microsoft</td>
<td>Applications for CORFU, a design for networked flash</td>
</tr>
</tbody>
</table>

### Visiting Students

- **Majd Kuteifan** received his B.S. in Engineering with two majors: Physics and Management from “Ecole des Mines”, Nancy, France in 2010. As an undergraduate student, he worked on computation of femtosecond lasers damages on materials. Majd joined Fullerton Lab as a visiting student in March 2012 and works on computation of domain wall motion in magnetic nanowires. He is currently pursuing a Master’s Degree in Engineering at “l’Ecole des Mines de Nancy”.

- **Alain Truong** is currently a Master student majoring in Materials Science at École des Mines de Nancy, France. He joined Prof. Fullerton's Group in March 2012 as a visiting student and works on FeRh thin layers for Heat Assisted Magnetic Recording. Alain will pursue research as a PhD candidate at Keio University in Japan, from September 2012.

### New Postdoctoral Researcher

- **Matthias Gottwald** is working as a postdoc in the Fullerton group. He received his Ph.D. in Physics in September 2011 from the University of Nancy, France. His work was focused on magnetic materials with perpendicular magnetic anisotropy for spin transfer torque studies. Until 2008, Matthias was a student in the bi-national German-French Physics program joint between the Universities of Saarbrücken and Nancy. Currently he is working on the development of magnetic tunnel junctions with perpendicular anisotropy.

### New Undergraduate Student

- **Dor Gabay** is a newly employed undergraduate electrical engineering student research assistant who is currently doing research with Professor Vitaliy Lomakin in the theoretical field of Micromagnetics. His work encompasses different applications of magnetic recording, such as BPM and MAMR, as well as some applications to MRAM, such as thermal effects on spin transfer torque with the use of bit patterned nanowires. Dor is seeking to eventually pursue his PhD in the field of Micromagnetics and is eager to work closely with the CMRR as his career in the field progresses.
New Graduate Students

Sergio Montoya received his B.S. in Physics and Mathematics from University of California, Berkeley in 2010. As an undergraduate, he worked on electron-track Compton imaging and studied manifolds with interest in lower dimensional topology. He joined the Fullerton Nanomagnetism group in March 2012, and is interested in exploring novel magnetic materials that operate at high frequency, and have high permeability and low loss.

Youyi Fu is a first year graduate student of Mechanical and Aerospace Engineering Department. He joined Prof. Talke’s group in Nov 2011. His research interests are the Finite Element Analysis of Hard-Disk contact problem and the experimental study on Hard-Disk fretting wear problem. Before coming to UCSD, Youyi got his bachelor’s degree in Mechanical Engineering.

Sidi Fu is a first-year graduate student in the PhD program of Electrical and Computer Engineering Department at UCSD. He received his B.S. degree in Electronic Engineering and double-minor B.A. degree in Economics from Peking University, P.R. China. After that he joined Prof. Lomakin’s group in 2011. Now Ben is working on applications of fast and parallel algorithms on computational magnetics with finite difference (FD), finite element (FEM) and integral equation methods (IE).

Shannon Memorial Lecture Showcases Award-Winning Information Theory Research

Shlomo Shamai, professor of Electrical Engineering (EE) and Statistics at the Technion — Israel Institute of Technology, presented UC San Diego’s 12th annual Claude E. Shannon Memorial Lecture at the California Institute for Telecommunications and Information Technology (Calit2) Auditorium last week before an assembly of students, faculty and members of the community.

Shamai’s lecture addressed the Gaussian interference channel, which statistically models signal interference when multiple users (such as multiple cell phone users) compete for shared resources on the same communication channel. By knowing the degree and the nature of such interference or 'noise,' service providers can ultimately prevent or limit it from disrupting signals.

Also honored at the event was EE Ph.D. candidate Jayadev Acharya, who beat out two other finalists from UC San Diego to win the Shannon Graduate Fellowship.

Read the entire article at: http://www.calit2.net/newsroom/article.php?id=1999
The Schultz Prize was first presented in May 2003 at the 20th anniversary of the founding of the Center for Magnetic Recording Research. The Prize is named in honor of former CMRR Director, Sheldon Schultz, who skillfully guided the Center from November 1990 through August 2000. The Prize is intended to recognize CMRR graduate students who have distinguished themselves through the creativity of their research and the impact of their publications. The selection of the recipient is based upon the recommendation of a committee consisting of CMRR faculty members, with input from selected experts in information storage technology.

Previous Recipients:
- Geoffrey Beach - May 2003
- Kai-Zhong Gao - May 2003
- Brian Kurkoski - June 2004
- Marcus Marrow - June 2004
- Joseph B. Soriaga - May 2005
- Sharon Aviran - May 2006
- Ismail Demirkan - May 2006
- Maik Duwenssee – May 2007
- Bart Raeymaekers - May 2007
- Ralf Brunner - April 2008
- Junsheng Han - April 2008
- Zheng Wu - May 2009
- Edward Choi - May 2010
- Seyhan Karakulak - May 2010
- Eitan Yaakobi - May 2011
- Uwe Boettcher - May 2011

International Workshop on Advanced Micromagnetics (IWAM)

The Center for Magnetic Recording Research launched the first International Workshop on Advanced Micromagnetics on May 21 & 22, 2012. IWAM is a unique showcase for new and emerging techniques in the micromagnetic analysis of magnetic materials and devices. IWAM brings together leading experts in computational and theoretical Micromagnetics from academia and industry. The workshop will include a single oral session and a poster session. This format is geared towards an informal atmosphere facilitating discussions and collaboration between the participants.

Topics of interest include:
- Advanced theoretical models in Micromagnetics
- Multiscale and multiphysics models in Micromagnetics
- Advanced computational models
- High-performance numerical techniques
- Applications of micromagnetic modeling to the study of magnetic materials and devices

Organization Committee:
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  Email: vlomakin@eng.ucsd.edu
- **Prof. Eric Fullerton**
  Director of CMRR
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- **Prof. Thomas Schrefl**
  St. Poelten University, Austria
  Email: Thomas.Schrefl@fhstp.ac.at

**Dr. Manfred E. Schabes**
Hitachi GST, San Jose Research Center
Email: Manfred.Schabes@hitachigst.com

IWAM is co-sponsored by IEEE
Jonathan Sapan Appointed to Student Fee Advisory Committee

Jonathan Sapan, a CMRR graduate student in the Fullerton group, was recently appointed by the Graduate Student Association of UCSD to sit on student fee advisory committee. The UCSD Student Fee Advisory Committee (SFAC) is charged with evaluating Student Fee Funded Units and making recommendations on allocations of the Student Fees. Furthermore, SFAC's duty is to ensure that the proposed Student Fee uses are in the best interests of the University and its students, and in compliance with existing policies and guidelines. While on the committee, Jonathan will represent his fellow graduate students and advocate for their interests. He is an excellent addition to the committee and we look forward to his contributions.

10th Annual Shannon Memorial Lecture

2011 Schultz Prize recipients Uwe Boettcher and Eitan Yaakobi with the prize's namesake and former CMRR Director Prof. Sheldon Schultz

The NVMW 2012 banquet at the Birch Aquarium in La Jolla

The Non-Volatile Memories Workshop 2012