University of California, San Diego ISSN: 0888-7381

NUMBER 37 WINTER 2012

CMRR REPORT

Center for Magnetic Recording Research

Recent activities in Materials Research for Energy Storage and Conversion Energy

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.

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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

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From the Director

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.

New CMRR Affiliated Faculty member

Adjunct Professor Vlado A. Lubarda received his mechanical engineering degree from the University of Montenegro in 1975, and his MS and PhD from Stanford University in 1977 and 1979. He has been an Assistant and Associate Professor at the University of Montenegro from 1980-1989, Fulbright Fellow and Visiting Associate Professor at Brown University from 1989-1991, and the Arizona State University from 1992-1997. Since 1998, he is an Adjunct Professor of Applied Mechanics in the Department of Mechanical and Aerospace Engineering of the University of California, San Diego. He has done research work in the fields of elasticity, plasticity, viscoelasticity, dislocation theory, fracture and damage mechanics, thin films, biomechanics, and materials science. Professor Lubarda serves on the editorial board of the Theoretical and Applied Mechanics. He is the recipient of the Barbara and Paul Saltman Distinguished Teaching Award, multiple Teacher of the Year Awards in the MAE Department, and two Tau Beta Pi Outstanding Teacher of the Year Awards. Dr. Lubarda was elected in 2000 for the corresponding and in 2006 for the full member of the Montenegrin Academy of Sciences and Arts.

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.

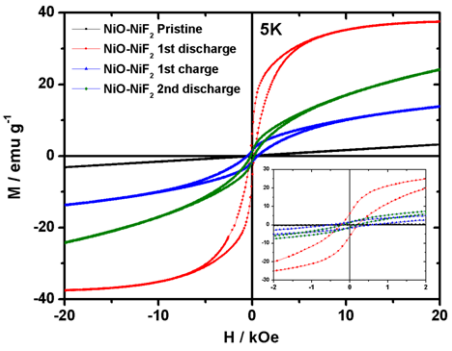


Fig. 1. Magnetic hysteresis of NiO-doped NiF2 conversion materials

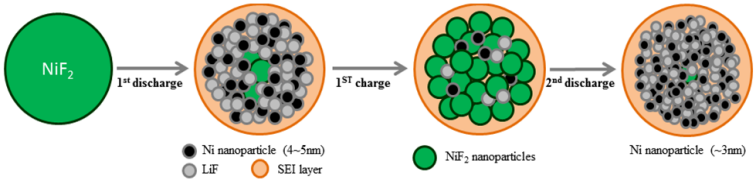


Fig. 2. Schematics illustrating the possible conversion mechanisms occurring in NiF_2

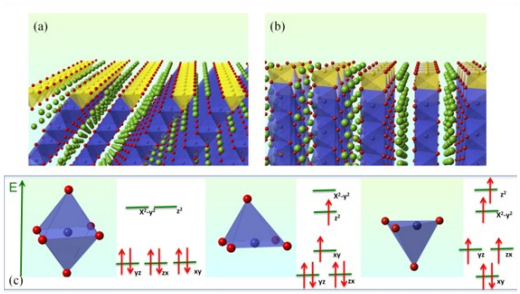
Based on the SQUID analysis, we could propose the possible conversion mechanisms occurring in NiF_2. The magnetic measurements provided more fundamental understanding on the phases including the size information on nanosized-Ni particles during the conversion reactions. This work is published in **Electrochimica 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

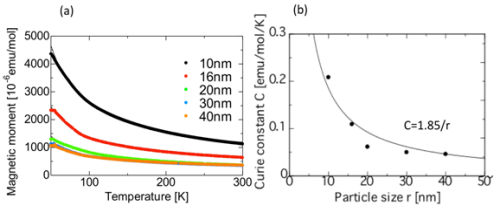
Recent Activities (cont'd)

($LiCoO_2$) 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 (< 50nm) 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.

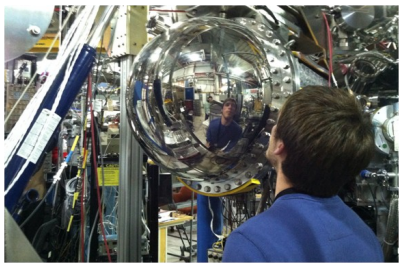
In bulk LiCoO2, Co3+ has six 3d electrons, while in octahedral oxygen environment; it would split into t2g and eg orbitals, which are dxy, dyz, dxz and dx2-y2, dz2 respectively. It has been found by previou0s studies that in bulk, Co3+ is in the low spin (LS), where all the electrons are paired in t2g orbitals, as shown in Left Figure (c). On the {104} surface, the Co3+ 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/m2) to the IS (312mJ/m2), which has two unpaired electrons. On the {110} surface, the Co3+ ions on the surface are coordinated by four oxygen ions with a pseudo-tetrahedral configuration. The surface energy is minimized from 2227mJ/m2 (LS) to 1241mJ/m2 (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-LiCoO2 particles are plotted as a function of temperature in Right Figure. The magnetic susceptibility of bulk LiCoO2 is very low, which is attributed to the LS Co3+ 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/

Selected Papers and Talks

Associate Professor Raymond A. de Callafon

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Professor Sungho Jin

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

Se-Yeon Jung, Sang Youl Lee, June-O Song, **Sungho Jin**, and Tae-Yeon Seong,"Improved light output of GaN-based light emitting diodes by using AgNi reflective contacts", J. Electron. Mater. 40(11), 2173-2178 (2011).

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Chiara Daraio and **Sungho Jin**, "Synthesis and Patterning Methods for Nanostructures Useful for Biological Applications", Chap.2, Parpura Nanotechnology for Biology and Medicine, Gabriel Silva, ed. (in press, 2011).

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Dae Hoe Lee, Kyler J. Carroll, Scott Calvin, **Sungho Jin**, **Ying Shirley Meng**, "Conversion Mechanism of Nickel Fluoride and NiO-Doped Nickel Fluoride in Li Ion Batteries", Electrochimica Acta 59(C), 213-221 (2012).

Jirapon Khamwannah, Sun Young Noh, Christine Frandsen, Yanyan Zhang, Hyunsu Kim, Seong Deok Kong, and **Sungho Jin**, "Nanocomposites of TiO2 and double-walled carbon nanotubes for improved dye-sensitized solar cells", J. Renewable and Sustainable Energy, 2012 (in press).

Young Oh, Chulmin Choi, Daehoon Hong, Seong Deok Kong, **Sungho Jin**, "Magnetically Guided Nano-Micro Shaping and Slicing of Silicon", Nano Lett.

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Professor Paul H. Siegel

Yaakobi, E.; **Siegel, P.H.**; Vardy, A.; **Wolf, J.K.**; , "Multiple Error-Correcting WOM-Codes," Information Theory, IEEE Transactions on , vol.58, no.4, pp.2220-2230, April 2012
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doi: 10.1109/GLOCOM.2011.6134474

Selected Papers and Talks (cont'd)

Associate Professor Steven Swanson

The Bleak Future of NAND Flash Memory, Laura M. Grupp, John D. Davis, and **Steven Swanson,** Proceedings of the 10th USENIX conference on file and storage technologies, 2012.

Providing Safe, User Space Access to Fast, Solid State Disks, Adrian M. Caulfield, Todor I. Mollov, Louis Eisner, Arup De, Joel Coburn, and **Steven Swanson**, Proceeding of the 17th international conference on Architectural support for programming languages and operating systems, New York, NY, USA, March 2012.

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.

Tackling Temporal Variability in Multilevel Flash: New Error-Control Code Design and Architectural Validation, Ryan Gabrys, Laura Grupp, Steven Swanson, and Lara Dolecek, Invited Talk, Forty-Ninth Annual Allerton Conference.

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

U. Boettcher, D. Fetzer, H. Li, R.A. de Callafon, **F.E. Talke**, "Reference Signal Shaping for Closed-loop Systems with Application to Seeking in Hard Disk Drives", IEEE Transactions on Control Systems Technology, 20 (January 2012) 1063-6536.

Song, W., Li, L., Ovcharenko A., Jia D., Etsion I., and **Talke F.E.,** "Plastic yield inception of an indented coated flat and comparison with a flattened coated sphere," Tribology Internaltional, 2012, DOI: 0.1016/ j.triboint.2012.04.022.

Graduate Students Near Completion

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

Internships

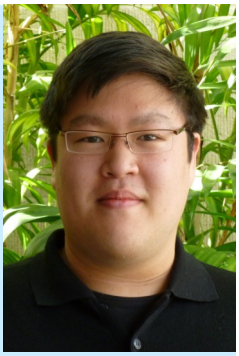
Ruinan Chang	Ansys-HFSS	Testing and validation of electromagnetics FEM codes
Marco A. Escobar	Western Digital	Micromagnetic study of magnetic recording system
Youyi Fu	Western Digital	HAD Simulations
Jimmy Kan	Qualcomm	Advanced MTJ Bit Error Rate Characterization & Magnetic Failure Analysis
Shaojing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

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

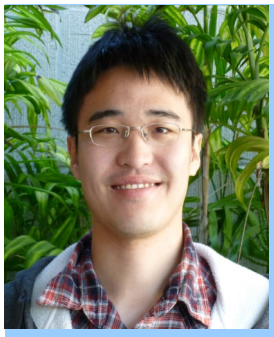
Matthias Gottwald is working as a postdoc in the Fullerton group. He received his Ph.D. in Physics in September 2011 from the University of Nancy, France. His work was focused on magnetic materials with perpendicular magnetic anisotropy for spin transfer torque studies. Until 2008, Matthias was a student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

New Undergraduate Student

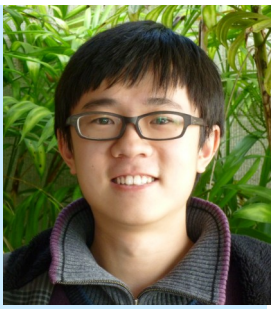
Dor Gabay is a newly employed undergraduate electrical engineering student research assistant who is currently doing research with Professor Vitaliy Lomakin in the theoretical field of Micromagnetics. His work encompasses different applications of magnetic recording, such as BPM and MAMR, as well as 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 Guassian 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

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

IEEE Advancing Technology for Humanity

IWAM is co-sponsored by IEEE

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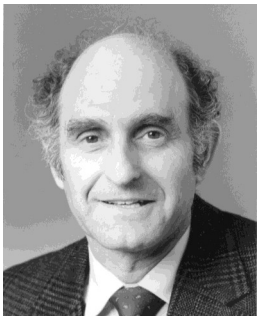
The Sheldon Schultz Prize for Excellence in Graduate Student Research



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 Duwensee – 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

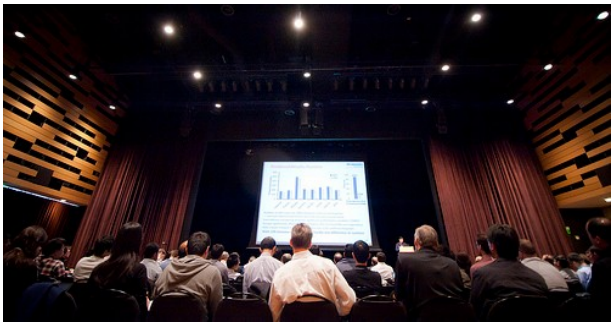
Jonathan Sapan Appointed to Student Fee Advisory Committee

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

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