

INTERFACES



The Newsletter of the Center for Materials Research & Analysis at the University of Nebraska-Lincoln

New Centers Funded by NSF and W.M. Keck Foundation

Materials researchers at the University of Nebraska have won a prestigious \$5.4 million grant from the National Science Foundation. The grant establishes a Materials Research Science and Engineering Center (MRSEC) entitled “Quantum and Spin Phenomena in Nanomagnetic Structures.

The MRSEC is an outgrowth of the Center for Materials Research and Analysis, and involves scientists from the Departments of Physics and Astronomy, Chemistry, Mechanical Engineering, and the School of Biological Sciences whose research focuses on nanomagnetic structures. Their work in magnetic materials at the nanoscale — as small as one-billionth of a meter — has applications in advanced computing and data storage systems, handheld electronic devices, advanced sensors, and possible future medical technologies.



MRSEC Faculty

The MRSEC grant illustrates the success of Nebraska’s investments in research, said Prem Paul, Vice Chancellor for Research and Dean of Graduate Studies.

“Our stature in materials research and nanotechnology is a direct result of Nebraska Research Initiative funding in the past decade. Now we are seeing the return on that investment,” Paul said.

continued on page 4

From the Director

by David J. Sellmyer

It is indeed a pleasure to report on recent achievements of CMRA and its faculty. In the last year



there have been several extremely positive developments, some of which are reported in more detail elsewhere in this Newsletter. We are especially gratified about the establishment of the Materials Research Science and Engineering Center by NSF, and the W.M. Keck Center by the

W.M. Keck Foundation of Los Angeles. These are truly an indication of the assemblage of an outstanding group

continued on page 4

In This Newsletter...

<i>Recent Achievements of Center Researchers</i>	<i>2</i>
<i>Tiny Neutron Detector Developed</i>	<i>3</i>
<i>New Centers Funded, continued</i>	<i>4</i>
<i>From the Director, continued.....</i>	<i>4</i>
<i>Films for High Density Recording</i>	<i>5</i>
<i>CMRA Welcomes Yongfeng Lu</i>	<i>6</i>
<i>Research Spotlight: Craig J. Eckhardt.</i>	<i>7</i>

www.unl.edu/cmra/



Recent Achievements of Center Researchers

Al-Omari Award

Imad Al-Omari, a former PhD student in Physics, UNL, is now a professor in the Department of Physics, College of Science, Sultan Qaboos University. He was the recipient of the prestigious “Abdul Hameed Shoman Award for Young Arab Scientists” in Physics for this year.

APS Service

David Sellmyer completed his term as chair of the American Physical Society’s Topical Group on Magnetism and its Applications.

International Visitors

Prof. Ivan Yakovkin, Ukraine National Academy of Sciences, and Prof. Neil Boag, University of Salford, visited CMRA this past summer for collaborative research with Prof. Peter Dowben’s group.

NSF-MRI Award

A large group of CMRA researchers led by Brian Jones and Minglang Yan were awarded a NSF Major Research Instrumentation grant for a new x-ray diffractometer. The cost of the instrument is \$360,000 and it will be found in the CMRA X-Ray Materials Characterization Central Facility.

Rieke Metals wins Entrepreneur Award

The University of Nebraska Foundation has named Rieke Metals the third winner of the Walter Scott entrepreneurial business award. Professor Reuben Rieke of the Department of Chemistry has been a long-time member of CMRA.

Hao Zeng Research

Recent Ph.D. Hao Zeng, now at IBM-Yorktown, was first author of the Nature paper “Exchange-coupled nanocomposite magnets by nanoparticle self-assembly.”

Student Awards and Honors

CMRA graduate students have recently received the following awards:

Ruihua Cheng (AVS Falicov Award semifinalist, Nottingham award finalist, NU Folsom Doctoral Prize Finalist); **Takashi Komesu** (Nottingham prize finalist); **Bo Xu** (Nottingham prize finalist, Sigma Xi Award); **Cheol-soo Yang** (Best NSTD student paper prize); **Jian Zhou** (Outstanding Student Award, Int. Rare Earth Conference).

The following CMRA-affiliated students have earned their PhDs during the past two years: **Mengjun Bai** (Physics, S. Ducharme), **Ruihua Cheng** (Physics, P. Dowben), **Sangjun Cho** (Elect. Eng., P. Snyder), **Takashi Komesu** (Physics, P. Dowben), **Zhongyuan Liu** (Physics, S. Adenwalla), **Paolo Rossi** (Chemistry, G. Harbison), **Ali O. Sezer** (College of Engineering, J. I. Brand), **Richard Thomas** (Physics, D. Sellmyer), **Bo Xu** (Physics, P. Dowben), **Hao Zeng** (Physics, D. Sellmyer), **Jian Zhou** (Physics, D. Sellmyer).

Corey Bungay (Elect. Eng., John Woollam), **Taras Gorishnyy** (Mech. Eng., S. Rohde), **Timothy Reece** (Physics, S. Ducharme), **Denise Schultze** (Mech. Eng., S. Rohde) and **Xuesong Zhang** (Eng. Mech., J. Yang) have earned M.S. degrees. **Laetitia Bernard** (Physics, P. Dowben) has earned her B.S degree.

Interfaces, the Newsletter of the Center for Materials Research and Analysis, is published periodically. Information, announcements and research updates should be sent to:

Interfaces Newsletter
c/o Zheyang Jane Yang
120 Brace Lab

Tiny Neutron Detector Developed

Reprinted with permission from Scarlet (8/22/02), written by Monica Norby

A highly sensitive, hand-held neutron detection device developed by UNL researchers could be used for locating hidden nuclear materials, monitoring nuclear weapons storage and other national security applications.

The detector, built around a boron-carbide semiconductor diode smaller than a dime, can detect

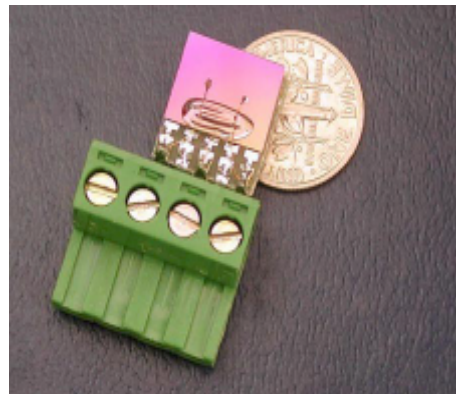
fairly inexpensive and there are manufacturers here in Nebraska with the technology to produce these detectors right now," Dowben said.

Development of the detector was funded largely through the Nebraska Research Initiative, a state-funded competitive grants program.

"This is a story of how the state's investment in research can lead to technology that benefits Nebraskans and the nation," said Prem Paul, UNL Vice



The neutron detector research team members are, from left, Peter Dowben, Shireen Adenwalla, Andrew Harken, Jennifer Brand and Brian Robertson.



The neutron detector, which is about the size of a dime.

neutrons emitted by the materials that fuel nuclear weapons.

"This is a leapfrog technology in neutron detection," said Peter Dowben, UNL physicist who was the first to fabricate a boron carbide semi-conductor. Using Dowben's boron carbide semiconductors, the research team built a detector about the size of a Lego block that is much more efficient, lighter and tougher than existing detectors.

"This device is very small, it can be powered with small batteries or even solar cells, and it can withstand corrosion and extremely high temperatures," said Brian Robertson, who is associate professor in the Department of Mechanical Engineering.

Five patents are held by UNL or are pending on the device itself and on the processes for producing the semi-conductors. The team is continuing to refine the device, focusing on improving its efficiency and reliability, and is exploring commercialization with a Lincoln-based engineering company.

"The materials used to make the device are

Chancellor for Research.

The detector has applications beyond national security, said physicist Shireen Adenwalla. NASA wants a low-mass, thin device like this for their comet landers, which measure the hydrogen content of comets. It also has uses in experimental medical radiation treatments for cancer and for "scattering" experiments performed in basic neutron research.

The research team, all affiliated with UNL's Center for Materials Research and Analysis, includes Robertson, Adenwalla, Dowben, Harken and chemical engineer Jennifer Brand.

Robertson presented a scientific paper on the device at a meeting in July of the International Society for Optical Engineering, generating intense interest and invitations from U.S. national laboratories and European laboratories to present results and participate in research programs.

"This is something people have been trying to do for more than 38 years and haven't been able to accomplish," Robertson said. "We have invented this device and it works very, very well."

Centers Funded by NSF and W.M. Keck Foundation, continued

continued from page 1

In addition, a new center dedicated to the study of mesospin structures was funded by the W.M. Keck Foundation. The W.M. Keck Center for Mesospin and Quantum Information Systems conducts frontier research on mesospin structures. The center involves nine faculty, one postdoctoral research associate and eight graduate students from the departments of Physics and Astronomy, and Chemistry.

The research occurs at the intersection of condensed matter physics, chemistry and materials science. Mesospin structures are extremely small, ranging in size from single atomic spins to high-spin molecules to nanoscale magnetic dots and clusters. These structures have great potential for future technological applications in information processing and storage.

The W.M. Keck Foundation is one of the nation's largest philanthropic organizations, with assets totaling more than \$1.5 billion. Established in 1954 by the late William Myron Keck, founder of the Superior Oil Co., the foundation's grant making is focused primarily on the areas of medical research, science and engineering. The W.M. Keck Foundation seeks to enrich research and teaching through support for equipment, facilities, fellowships and basic research projects at the frontiers of science and engineering.



W.M. Keck Faculty

From the Director, continued

continued from page 1

of faculty here.

We are grateful to the University administration for strong support of our activities in materials and nanoscience. The university established about a dozen academic enhancement programs called "Programs of Excellence (PoE)," including ours on Nanoscale Science and Technology (NST). NST, which is administered by CMRA, will permit the hire of 11 new faculty over 5 years in the departments of Physics (4), Chemistry (2), Mechanical Engineering (2), Electrical Engineering (2), and Chemical Engineering (1). Already hired are Professors Yongfeng Lu (E.E.), Shireen Adenwalla (Physics), Christian Binek (Physics), and Lin Wu (M.E.). The total investment is \$4.2 million including contributions from the Colleges of Arts and Sciences, and Engineering and Technology, as well as the departments, CMRA, and Vice Chancellor for Research. The Nano PoE also supports a "Materials and Nanoscience Seminar Series," setup funding for new hires, and some administrative support costs. The strong administrative support for the Nano PoE surely will help build focused research strength in our field for many years to come.

CMRA faculty are strong in interdisciplinary research collaborations. One example is the ongoing ONR supported program: "Magneto-electronic Structures and Devices." This large collaboration includes about 22 faculty, 5 departments, and two dozen graduate students and postdocs. Another new development is a grant soon to be funded by the DoD on boron carbide semiconducting devices that constitute a new, miniaturized class of neutron detectors.

The above are some highlights focusing on large groups with multiyear funding. Of course, there are a large number of individual investigator grants that form the basis of our research programs. It is a certainty, however, that the Central Facilities and infrastructure provided by CMRA are essential for the whole materials and nanoscience enterprise.

Nanocomposite Films for High Density Recording

By Minglang Yan

In the past few years, the areal density of magnetic recording has been increasing at an annual rate of about 60%, and recently, increasingly driven to 100% per year. In order to continue this growth trend, the development of new media with higher thermal stability is necessary. Nanoscale $L1_0$ CoPt or CoPt-based films are very attractive as extremely high density recording media because their large anisotropy energy (K_u is as high as $6 \times 10^7 \text{ erg/cm}^3$) allows thermally stable magnetic grains with small size.

When the recording density approach 1 Tbit/in^2 , it is also very important to tightly control the media



nanostructure, especially grain size, grain-size dispersion, and chemical isolation to control exchange coupling in order to keep the media noise within an acceptable level. For perpendicular recording media, it is desirable for the easy axis of magnetiza-

tion to be perpendicular to the film plane. Hence, CoPt or FePt-based films should be (001) textured. Normally, such texture can be obtained by epitaxial growth on heated single crystal-substrates. For example, MgO (100) substrates were used for film deposition in order to create epitaxially-grown CoPt or FePt grains and to obtain (001) texture. For practical applications, nonepitaxially grown CoPt or FePt films are much more convenient than those grown epitaxially.

Nonepitaxial growth methods were used to fabricate CoPt or FePt-based nanocomposite films with (001) texture. The method used is multilayer deposition plus subsequent rapid thermal annealing. Films were magnetron sputtered directly on glass or thermally oxidized Si wafer substrates with the multilayer structure of $[\text{Fe}(\text{Co})/\text{Pt}/\text{X}(=\text{C}, \text{SiO}_2, \text{B}_2\text{O}_3, \text{Ag}\dots)]_n$.

The composition of the films was well controlled by adjusting the thickness ratio of each layer. The as-deposited films were then annealed by suitable thermal treatment process. After annealing, the continuous layers were broken up and nanocomposite structured films were formed. Transmission electron microscope observations confirm (Fig.1) that these films consist of high anisotropy $L1_0$ CoPt or FePt nano-

particles with uniform size ($\sim 5 \text{ nm}$) embedded in the nonmagnetic matrix $\text{X}(=\text{C}, \text{SiO}_2, \text{B}_2\text{O}_3, \text{Ag}\dots)$ and appear to be well isolated.

Fig.2 shows the XRD pattern and hysteresis loop of FePt:C

nanocomposite film deposited on a soft underlay FeCoNi. The preferred crystal orientation of $L1_0$ FePt:C nanocomposite film is successfully obtained on this soft

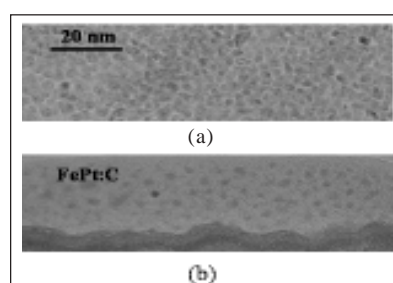


Fig.1. TEM images. (a) FePt:C. Bright-field and (b) Cross=section image.

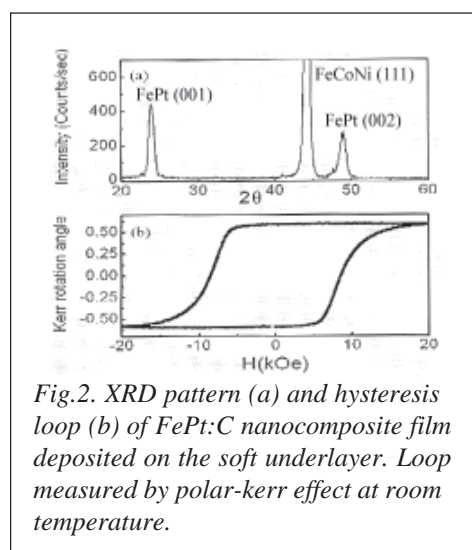
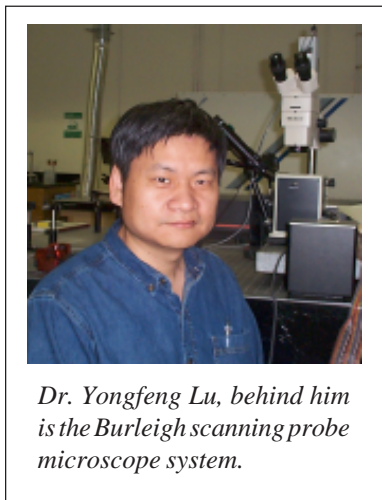


Fig.2. XRD pattern (a) and hysteresis loop (b) of FePt:C nanocomposite film deposited on the soft underlayer. Loop measured by polar-kerr effect at room temperature.

underlayer by nonepitaxial growth. The magnetic measurement shows a loop and with coercivity $H_c = 8.5 \text{ kOe}$, nucleation field $H_n = 5.65 \text{ kOe}$, remanence ratio $S = 1$, and loop slope (at H_c) $\alpha = 3.3$. These properties for FePt:C nanocomposite films approximately satisfy theoretical models of the Information Storage Industry Consortium for 1 Tbit/in^2 recording.

CMRA Welcomes Yongfeng Lu

Dr. Yongfeng Lu is an associate professor in the Department of Electrical Engineering and a member of the Center for Materials Research and Analysis (CMRA). He joined the University of Nebraska-Lincoln in September 2002. Before that, he was associate professor at the National University of Singapore.



Dr. Yongfeng Lu, behind him is the Burleigh scanning probe microscope system.

Dr. Lu obtained his B.Eng. degree in 1984 from Tsinghua University, Beijing, China. He received his M.Eng. and Ph.D. degrees from Osaka University, Japan in 1988 and 1991, respectively. He has an extensive research background in the areas of laser-based micro-scale and

nano-scale material processing and characterization. Dr. Lu has published over 150 peer-reviewed journal papers and over 160 presentations in international conferences including more than 30 plenary and invited talks.

Dr. Lu has served as conference chair, session chair, program committee member and advisory committee member for more than 30 conferences.

Dr. Lu has received a number of national and international awards, including National Technology Award (Singapore, 1998), Asean Engineering Achievement Award (Asean Engineering Association, 1999), and Laser International Award (Germany, 2000). As a research group leader, his research was focused on laser removal of nanoparticles from solid surfaces (commonly known as laser cleaning) and nanoscale patterning by laser-assisted scanning probe microscopy and optical resonance in microparticles. He was one of the pioneers to theoretically propose a model to explain the behaviors of nanoparticles on solid surfaces under laser irradiation, and experimentally obtained the sub-wavelength nanostructures using laser-induced optical resonance in nanospheres.

“Our work encompasses a few important topics including laser writing of sub-wavelength structures, applications of laser removal of nanoparticles, behaviors of nanoparticles under laser irradiation, theoretical modeling, influence of laser wavelength, and particle removal with assistance of thin liquid films,” Dr. Lu said. “We have also been working cooperatively with companies in USA, Japan and Singapore, and developing commercial products for laser etching, laser cleaning, laser deflash, laser cutting and laser surface texturing.”

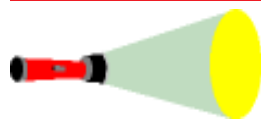
“After joining UNL, my research efforts focus on nanoscale laser material processing and characterization such as laser-assisted nanoimprinting, laser-assisted scanning tunneling microscopy, nanoparticle formation and thin film deposition, and fabrication of nanoscale optical and electrical devices,” Dr. Lu said. One of his current research interests is how to fabricate three-dimensional photonic bandgap crystals by combining laser nanoimprinting and self-assembly of nanoparticles. To date, he has received a few research grants from the National Science Foundation, Department of Defense and industry with a total amount of more than \$400,000.

“My long-term goal is to use lasers as basic tools to bridge nanoscale science, nanotechnology and commercialization,” Dr. Lu said.

Dr. Lu has established a new Laser-Assisted Nano-Engineering Laboratory (LANEL). The lab is equipped with a Lambda Physik Compex 205 KrF excimer laser, a Burleigh scanning probe microscope system consisting of atomic force microscope and scanning tunneling microscope, and a Coherent Innova 306 argon ion laser. A pulsed-laser deposition system and a laser-assisted chemical deposition system are also being built.

From Fall 2003, Dr. Lu offers a new course, Introduction to Nanotechnology, which covers the scientific areas related to nanoscale science and engineering.

“I grew up in a small town near Shanghai, China. Now I am living with my wife (Yan Zhu) and two children (Monica and Leo) in Lincoln,” said Dr. Lu, “We like Lincoln very much.”



Research Spotlight: Craig J. Eckhardt

The main theme of Prof. Eckhardt's research concerns the role of collective excitations on the physical behavior and reactivity of matter. On the microscopic level these excitations are a result of intermolecular interactions, interactions that are beyond the short-range forces involved in formal chemical bonding. Many different techniques are involved in studies of several systems. The latter are invariably solids and from this



Prof. Craig J. Eckhardt

arises a natural connection to investigation of properties of materials.

"The main thrust of research at present is mechanochemistry, the study of chemical reactivity driven by mechanical energy or manipulations," Prof. Eckhardt said. "An example is detonation of

explosives by impact. After a millenium of use, the actual microscopic mechanism that causes detonation is not understood and this is a question that is currently being addressed by my group. A theoretical model for the initial step of detonation has been published with my long-time collaborator, Prof. Tadeusz Luty of the Technical University of Wroclaw. This model has produced a more comprehensive view of the initial fate of mechanical energy in chemical processes and has led to an active collaboration with Prof. Henk Viljoen of the UNL Department of Chemical Engineering who has produced a meso- to macroscopic model of detonation that complements the microscopic model nicely."

These two research groups are pursuing a more comprehensive theory of the initial phase of detonation that is applicable on all scales. The experimental component of these studies involve the measurement of the elastic properties of crystals of explosive materials by Brillouin scattering, determination of the optical vibrational modes of these systems using Raman scattering and infra-red spectroscopy, and determination of their strain Grueneisen parameters through piezomodulated Raman scattering spectroscopy, a technique developed

in the Eckhardt laboratory.

Prof. Eckhardt has twice been an invited speaker at recent meetings of the American Association of Pharmaceutical Scientists, because of the relevance of his research to the processing of drugs, e.g. forming tablets.

A long-standing area of research interest of Prof. Eckhardt's group has been in monolayers of organic films. A quite old but important problem is being able to predict which of the possible 230 crystals a given material will form. The approach of the Eckhardt group is to investigate the problem in two dimensions where only 17 crystal forms are possible. These studies, mainly based on isotherm measurements and imaging by atomic force microscopy, have produced extensive and novel results, one of which, the separation of two-dimensional chiral phases, was published in Nature with Prof. James Takacs of UNL who was responsible for producing the molecule that formed this novel film. Recently, Professors Luty and Eckhardt have published an extensive theoretical model, based on solid-state concepts, that offers a detailed explanation of the phase behavior of simple monolayer films. Collaboration with both Professors Dussault and Takacs in the UNL Department of Chemistry has lead to the development of rather unique monolayer films that promise interesting tribological properties. A new method for reliable measurement of relative friction coefficients of monolayer films has been published.

"A new research area is involved with developing a new class of organic ferroelectric materials, both polymeric and crystalline. Another new area of research activity focuses on inclusion compounds, solids where there are regular arrays of large voids, essentially molecular cages, in which other molecules, guests, can be contained," Prof. Eckhardt said.

"My laboratory is, perhaps, the only one where such measurements can be routinely measured on very low symmetry systems," Prof. Eckhardt added, "A drawback of such systems is lack of robustness, but for nanoscale applications this is less troublesome and the potential for use of such molecules in "fine tuning" materials properties is high."



Center for Materials Research and Analysis
University of NE - Lincoln
P.O. Box 880113
Lincoln, NE 68588-0113