

INTERFACES



The Newsletter of the Nebraska Center for Materials and Nanoscience at the University of Nebraska - Lincoln

Facility Focus: *Nano-Fabrication Facility*

by Ned Ianno

The Nano-Fabrication Facility is housed temporarily in Ferguson Hall, but is being designed to allow faculty and students to work together in a state-of-the-art environment to create novel nanostructures from a variety of materials. The Facility in the new NanoScience Facility will contain 4 separate areas (bays). Each bay will be a laminar flow area equivalent to a class 1000-5000 clean room, with all non-clean room compatible equipment, such as mechanical vacuum pumps contained in access corridors placed between or behind the bays. Each bay will be on the order of 400 square feet, plus the area of the equipment corridors. The bays are roughly defined as lithography, etching, deposition and analysis/characterization.



Focused-Ion Beam Workstation at its current location 16 Ferguson Hall.

The lithography bay will contain both direct write electron beam lithography as well as back side alignment capable optical lithography. The electron beam lithography system is the primary choice of Nano Research Centers for ultra-high-resolution patterning in the nanometer range. A 20-MHz pattern generator using optimized pattern filling modes shortens exposure times. Stability is improved by newly designed shielding with independent temperature control.

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From the Director

It is a pleasure to have this opportunity to describe some of the new research achievements and developments in the Nebraska Center for Materials and Nanoscience. Our faculty and their research groups are amazingly productive and especially active in promoting interdisciplinary work involving people from different departments and colleges.



Efforts begun in 2004 to obtain new buildings for NCMN and the Department of Physics and Astronomy are coming to fruition! Construction of the Physical Sciences Building (PSB) is underway on 16th Street, with completion scheduled for Fall 2009. The NanoScience Facility (NSF) is now in the architectural-design stage with the same firm (Perkins and Will) employed for the PSB. The NSF, scheduled for completion in Fall 2010, will be connected to the PSB and will be just South of the present Reunion Building. The NSF will house NCMN administrative offices and seven Central or Core

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Recent Achievements of Center Researchers

Awards, Honors

Christian Binek received the Sigma Xi Outstanding Young Scientist Award in 2007 for “setting a first-class laboratory to fabricate magnetic thin films and novel magnetic heterostructures with an emphasis on finding new and clever ways of controlling the exchange bias phenomenon in magnetic structures.”

Peter Dowben was named a Fellow of the American Vacuum Society.

Yuris Dzenis received the Sigma Xi Outstanding Scientist Award in 2007 for “his international recognition as a leader on the practice and theory of nanotube/nanofiber synthesis.”

Axel Enders has been awarded a NSF Career Award for his project “Self-Assembled Magnetic Nanostructures.”

Axel Enders, Ruqiang Feng, and Timothy Gay have been awarded the “Certificate of Recognition for Contributions to Students” by The Parents Association and The Teaching Council of UNL.

Yongfeng Lu was named a SPIE Fellow 2008 and was selected a Board Member of the Laser Institute of America.

Evgeny Tsymbal was named a fellow of the UK Institute of Physics and received the 2007 Outstanding Research and Creative Activity Award from the A&S College.

Hendrik Viljoen was named the Willa Cather Professor of Chemical & Biomolecular Engineering. He is the first College of Engineering faculty member to earn a Willa Cather or Charles Bessey professorship.

Xiao Cheng Zeng was named a Fellow of the American Association for the Advancement of Science.

Outstanding Papers

The article “Structural Nanocomposites” by **Yuris Dzenis** (Eng. Mech.) was published in the January 25, 2008 issue of Science.

Student Awards and Honors

Andrew Baruth (Physics, S. Adenwalla), **John D. Burton** and **Karolina Janicka** (Physics, E. Tsymbal), and **Lu Yuan** (Physics, S.-H. Liou) received the 2007 Sigma Xi Outstanding Poster Award.

John D. Burton (Physics, E. Tsymbal) received the A&S College Outstanding Graduate Research Assistant Award and was awarded the Presidential Fellowship for the 2007-2008 Academic Year.

Danqin Feng (Physics, P. Dowben) and **Chris Schwartz** (Chemistry, P. Dussault) were selected for Outstanding Graduate Student Awards. Ms. Feng was cited “for high research productivity to fundamental understanding of polymer device electronics” and Mr. Schwartz was cited “for major research achievements in the area of oxidation chemistry.”

Carolina Ilie (Physics, P. Dowben) received the Sigma Xi Graduate Student paper award (2007).

Xiangxin Rui (Mech. Eng., J. Shield) received the Pearson Outstanding Graduate Research Award.

Weijie Xu and **Shah Huda** (Textiles, Y. Yang) were awarded with the John & Louise Skala Fellowship for 2007-2008.

The following NCMN-affiliated students have earned their PhDs during the last year:

Snjezana (Snow) Balaz (College of Engineering, J. Brand), **Julia Kostogorova-Beller** (Chem. and Mat. Eng., J. Shield), **Yong Chen** (Eng. Mechanics, Y. Dzenis), **Sangeeta Dey** (Chemistry, D. Berkowitz), **Danqin Feng** (Physics, P. Dowben), **Jihee Kim** (Physics, S. Ducharme), **Lihua Liu** (Eng. Mechanics, Y. Dzenis), **Steven Michalski** (Physics, R. Kirby), **Matthew Poulsen** (Physics, S. Ducharme), **Timothy Reece** (Physics, S. Ducharme), **Xi Ren** (Eng. Mechanics, Y. Dzenis), **Xiangxin Rui** (Chem. and Mat. Eng., J. Shield), **Weijun Shen** (Chemistry, D. Berkowitz).

The following NCMN-affiliated students have earned their M.S. degrees during the last year:

Joseph R. Brewer (Chemistry, B. Cheung), **Manoj Dhulipali** (Mech. Eng., J. Shield), **Haojing Lin** (Eng. Mechanics, L. Tan), **Yean Chin Tan** (Textiles, Y. Yang).

The following NCMN-affiliated students have earned their B.S. degrees during the last year:

Bob Buckley (Mech. Eng. and Eng. Physics, R. Kirby).

New jobs:

Snjezana (Snow) Balaz: Postdoc, University of California Riverside.

Steven Michalski: Postdoc/Materials Research Specialist, University of Nebraska.

Sangeeta Dey: Postdoc, University of Pennsylvania.

Weijun Shen: Postdoc, Scripps, La Jolla, CA.

Interfaces, the Newsletter of the Nebraska Center for Materials and Nanoscience, is published periodically.

Information, announcements and research updates should be sent to:

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Magnetic Nanoclusters Put in Order – Insights with Scanning Tunneling Microscopy

By Axel Enders

The impact of nanomagnetism on information technology has been critical in recent years and will remain so in the coming years. Magnetic thin films have been used for data storage in computer hard-disks for decades, and continuous advancements of their properties have led to an amazing increase of the areal storage capacity by many orders of magnitude. The future of magnetic data storage might depend on the development of devices based on patterned layers with ultrahigh densities of discrete magnetic elements and without any moving parts. The ideal magnetic storage device would consist of smallest monodisperse magnetic clusters, densely packed into an ordered monolayer, with stable remanent magnetization at room temperature, accessible switching fields, and negligible interactions. The key to success will be to fabricate hard-magnetic particles of approximately 3 nm diameter, as they still exhibit a stable magnetization direction at room temperature. The magnetization of smaller particles is thermally unstable, whereas big particles lead to a waste of areal density. However, the positioning of nanostructures at surfaces and engineering their properties is a key challenge in nanotechnology.

Our recent advancements in selfassembled growth permit us to fabricate model systems, which are close to the ideal described above. Nanometer clusters are fabricated by buffer layer assisted growth, see Figure 1. The cluster material is deposited on the substrate that is pre-covered with a Xenon layer at 35-40 K. Warming up the substrate causes desorption of the Xe layer. The metal clusters become highly mobile and coalesce, thus growing in size until making contact with the surface. The final cluster size depends on the Xe thickness and on the metal coverage. On flat metal substrates, the clusters are randomly distributed, as can be seen in the scanning tunneling microscopy image in Figure 1.

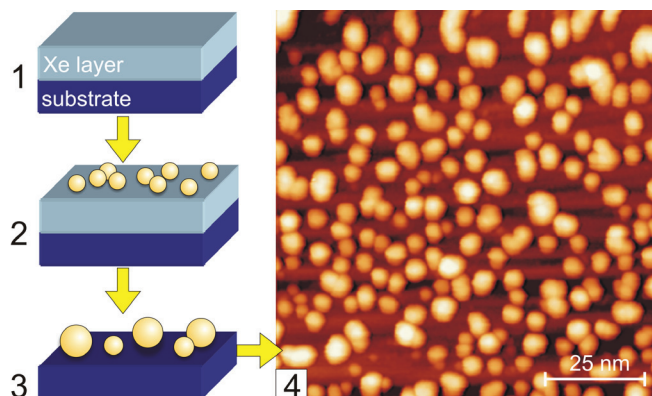


Figure 1. Fabrication of nanometer size clusters with a noble gas buffer layer. (1) Adsorption of Xe on the metal substrate at $T = 30$ K. (2) Deposition of metal onto the Xe. (3) Thermal desorption of Xe; clusters make contact with the surface. (4) STM image of Fe clusters on Pt(111) (Image size 100×100 nm²).

The properties of such clusters, most importantly here their magnetism, are dependent on electronic hybridization between clusters and substrate and can be tailored by controlling such interactions via the substrate material, surface orientation or with interlayers.

Lateral ordering of the nanostructures can be achieved by directed growth on patterned nanotemplate surfaces. Such surfaces provide well-defined energetic sinks with sub-nanometer accuracy, to guide the nucleation processes and diffusion of nanostructures or clusters. Mechanically stable boron nitride nanomesh layers are used here as templates for the fabrication of ordered cluster layers. This approach makes the fabrication inevitably a two-step process. In a first step, the boron nitride template layer is formed, followed by the deposition of clusters during a second step. The boron nitride nanomesh is formed by thermal decomposition of borazine gas,

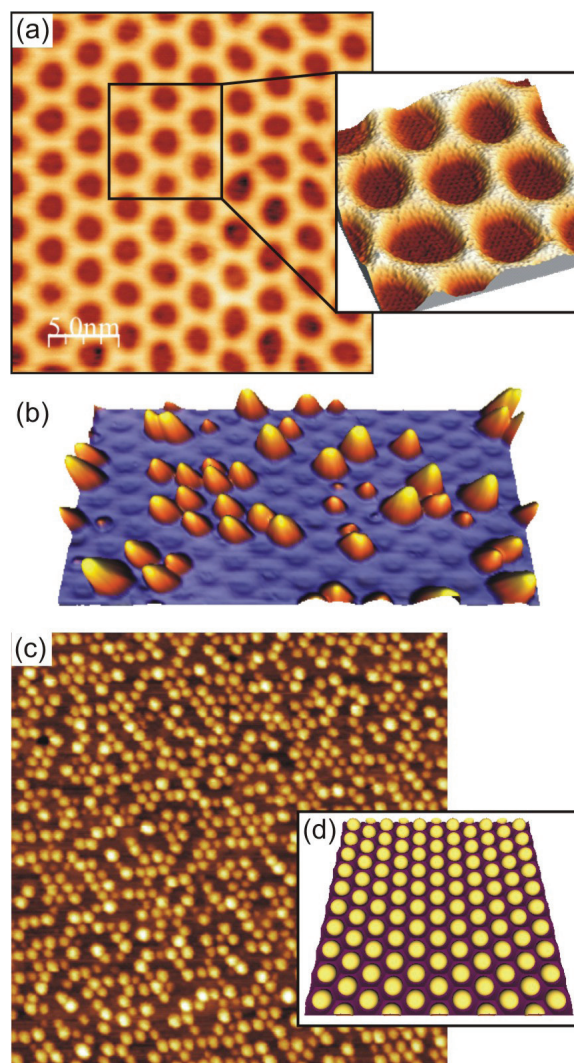


Figure 2. Fabrication of ordered cluster layers with template surfaces, imaged with scanning tunneling microscopy. (a) Boron nitride nanomesh monolayer, imaged with atomic resolution (inset). The distance between the centers of neighboring pockets in the BN layer is 3.2 nanometer. (b) STM image of Cobalt clusters (yellow) on the BN layer (purple) after one deposition cycle. (c) Repeated deposition cycles result in higher cluster coverage; here: 3 deposition cycles. (d) Schematic drawing of an ideal nanocluster layer with potential for application in magnetic data storage.

(HBNH)₃, on Rh(111) surfaces in an ultrahigh vacuum chamber. The resulting h-BN layers are atomically thin, electrically insulating, mechanically extremely stable, and show a strain-driven hexagonally ordered

corrugation with a periodicity of 3.2 nm (Figure 2a). Deposited clusters preferentially occupy the pits of the BN layer, and approximately 30% of the pits are occupied by clusters after one deposition cycle (Figure 2b). Higher nanomesh filling can be achieved by repeated deposition cycles; after three subsequent cycles already 80% of the pits are occupied (Figure 2c). Comparative studies with STM and Monte Carlo simulations show that the filling is somewhat limited by some mobility of the clusters on the BN layer, which results in assimilation of a small fraction (approx. 15%) of newly deposited clusters by larger clusters that have been deposited during an earlier cycle.

Besides being a nanotemplate, the BN layer has two additional traits: it decouples deposited nanostructures electronically from the metal substrate, and it is suitable for robust annealing at high temperatures. Tunneling Spectroscopy studies reveal a Coulomb gap of >160 meV in the electronic structure of the Co clusters on the BN layer, proving their electronic decoupling from the rhodium substrate. BN layers thus turn out to be an ideal playground for the study of the electronic interaction of nanostructures with the substrate. The thermal stability could be exploited to fabricate high-anisotropy $L1_0$ alloy clusters by post-annealing of initially disordered FePt clusters, as the BN layer is expected to suppress cluster growth via Ostwald ripening.

Evidently, the BN nanomesh has big potential to achieve templating on the nanometer scale and electronic decoupling, and could be of considerable practical importance for FePt based recording media. The high periodicity of the cluster layers on the BN makes them suitable for bit-patterned media where one cluster represents one magnetic bit. Some aperiodicity, as visible in the STM images, can actually be accounted for by multiple-pass reading and writing. Future challenges are in the further improvement of the cluster size distribution and ordering, and in the controlled modification of their magnetic properties.

Facility Focus: Nano-Fabrication Facility

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The optical lithography system is widely used for MEMS and optoelectronics applications. It is specially configured for handling non-standard substrates such as hybrids, high-frequency components or fragile III-V materials, such as GaAs or InP. In support of these major facilities, this bay will also contain photoresist application and baking equipment as well as optical inspection microscopes.

The heart of the etching bay will be an inductively coupled (ICP) high density plasma etching system capable of employing chlorine based process gases. The system has been designed to meet all the safety and equipment needs for the most challenging processes including etch applications that require chlorine chemistries. This has been accomplished by employing a fully integrated load-locked delivery system. This system will be complemented by the standard array of fume hoods including hoods that are HF acid compatible, base compatible and organic chemical compatible.

The deposition bay initially will house an electron-beam deposition system for metallization and a forming gas compatible annealing furnace. Also available will be a sputter-deposition system which is a multi-gun, co-sputtering system capable of depositing single layer compound/alloy films. The electron beam system consists of a 4 pocket source, and rotating, heated substrate holder.

The analysis/characterization bay will initially house a scanning probe microscope (SPM). The SPM offers simultaneous high-magnification observation of 3-dimensional shape and properties as well as measurements in various environments. Future equipment in this bay will consist of a general purpose scanning electron microscope (SEM), profilometer and possible optical characterization equipment such as spectroscopic ellipsometry, and reflection/transmission facilities.

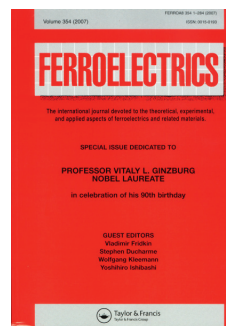
Engineers Part of \$9 Million Project Studying Cell Context of Genes

- Office of University Communications, UNL -

Nebraska's Experimental Program to Stimulate Competitive Research has received a three-year, \$9 million grant from the National Science Foundation to conduct research to better understand gene expression and regulation.

Engineer Joseph A. Turner, chair and professor of Engineering Mechanics and plant scientist Sally Mackenzie, professor in Horticulture and Agronomy, will head teams of 15 other biological and biomedical scientists and engineers who will collaborate to create a research niche for Nebraska in epigenetics research, which is the study of changes in inherited gene functions not associated with changes in DNA sequences.

Published Books



"Special Issue Dedicated to Professor Vitaly L. Ginzburg, Nobel Laureate, in Celebration of his 90th Birthday," V. M. Fridkin, **S. Ducharme**, W. Kleemann, Y. Ishibashi, eds., *Ferroelectrics*, Vol. 354 (Taylor and Francis, Princeton, NJ, 2007), 281 pages.

"Biomedical Applications of Nanotechnology" edited by Vinod Labhasetwar and **Diandra L. Leslie-Pelecky**, Physics (Wiley-Interscience 2007).

"The Physics of NASCAR: How to Make Steel + Gas + Rubber = Speed" by **Diandra Leslie-Pelecky**, Physics (Reed Elsevier Inc. 2008).

"Simple Models of Magnetism" by **Ralph Skomski**, Physics (Oxford University Press 2008).

NCMN Welcomes Eva Franke Schubert

Dr. Eva Franke Schubert has joined the University of Nebraska in Lincoln in 2007 as an Assistant Professor in the Department of Electrical Engineering and as a new member of the Nebraska Center for Materials and Nanoscience. Eva Franke Schubert received her Ph.D. degree in 1998 and her diploma degree in 1994, both



Dr. Eva Franke Schubert

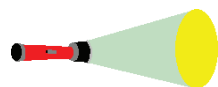
from the University of Leipzig in Germany. She spent her Postdoc time in the Department of Electrical Engineering at the University of Nebraska in Lincoln from 1999 to 2000. After returning to Germany, Eva Franke Schubert worked at the Leibniz-Institute for Surface Modification in Leipzig and served in various positions.

Dr. Franke Schubert's area of expertise is in the fast realm of ion beam processing and material fabrication. Her current research interests are focused on the fabrication and characterization of sculptured thin films with the goal to invent new technologies to exploit materials with unique chiral and non-chiral nanoscale structure properties for future electronic device applications. Sculptured thin films are fabricated by using glancing angle deposition utilizing a particle beam, which reaches a substrate surface under a very oblique angle of incidence during the deposition process. The geometric constellation supports columnar growth with a structure inclination towards the direction of the upcoming particle beam. An instant change of the substrate position relative to the particle beam alters the columnar growth direction yielding to nanoscale building blocks with manifold structure varieties such as post, screws, spirals, zig-zags or combinations thereof. A tremendous opportunity is given by the fact that sculptured thin films can be grown from basically all groups of

materials, which are accessible to physical or chemical vapor deposition.

Dr. Franke Schubert's research is committed to fabricate and investigate new hybrid materials whose physical performance will be designed by a useful combination of intrinsic physical and chemical material properties with the material's shape and dimension. Exemplary, chiral sculptured thin films may be composed of spiral-like nanoscale building blocks. Each of the spirals can be envisioned as a mechanical spring with a spring constant being mainly dependent on the wire material and its diameter. If the spring is made from a piezoelectric material, e.g. zinc oxide, the compression and expansion can be tuned by a small external electrical voltage applied to the nanosprings. Materials like this are foreseen for next generation electromechanically operated nanoactuators for highly precise positioning of small objects. More applications expected from nanoscale sculptured thin films are envisioned for new types of frequency-tunable long wavelength electromagnetic materials, or materials in photonic or magnetic device applications. Dr. Franke Schubert's recent contributions to the field include the description of the growth and modification of sculptured thin films upon thermal annealing and an evaluation of their properties in three-dimensional optical nanogratings or for sub-wavelength anti-reflection coatings in the DUV spectral range. Dr. Eva Franke Schubert is currently developing a new deposition tool, which allows the fabrication of sculptured thin films by means of both, electron beam evaporation or ion beam assisted deposition, respectively.

Dr. Eva Franke-Schubert has published her research results in one book chapter, over 70 scientific publications and 11 invited conference presentations. She is a member of the German Physical Society, Materials Research Society and American Vacuum Society. So far, Dr. Franke Schubert gained a total of \$ 500,000 external research funding from the German Science Foundation and National Science Foundation and received the Young Faculty Award from the University of Leipzig in 2001. Eva Franke Schubert teaches at the undergraduate and graduate level in the Department of Electrical Engineering and has developed new courses on "Fundamentals of Ion-Solid Interactions" and "Electronic Materials for Electrical Engineers," respectively.



Research Spotlight: Barry Cheung

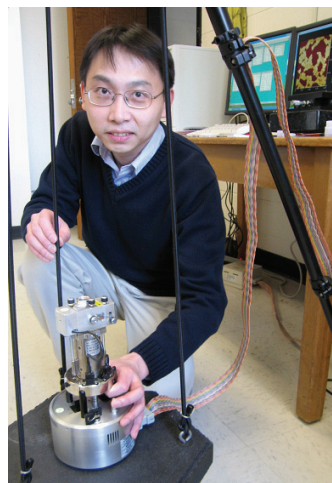
The research team of Barry Cheung focuses on the nanostructure-induced phenomena in metallic boride material systems synthesized by chemical vapor deposition (CVD). The family of metallic boride materials typically has refractory properties including high melting points, high chemical stability and high hardness. Its members exhibit a wide range of other unique physical properties such as low work function, superconducting behavior and high coercivity. Applications of metallic boride materials range from strong permanent magnets (e.g. $\text{Nd}_2\text{Fe}_{14}\text{B}$), superconductors (e.g. MgB_2), electron emission materials (e.g. LaB_6) and to even colorful decoration coatings. Judicious choice of chemical reaction schemes is the most important key for successful growth of nanostructured crystalline materials with designed functionalities by CVD. Precise control of chemical reactant flux, reaction temperatures, and appropriate catalyst systems allow the controlled growth of materials with various shapes down to a few nanometers. Such control also allows the creation of multi-layered artificial nanostructures. These quasi one-dimensional nanostructures are expected to exhibit novel physical properties deviated from those of the bulk materials.

Controlled growth of high-aspect ratio nanomaterials enables the fabrication of efficient field electron emitters. An important part of Cheung's present research involves the investigation of the electron emission characteristics of low work function metallic boride nanomaterials in the field emission and ballistic regimes. Recently, low work function metallic boride materials with shapes ranging from nanoobelisks to nanowires of tip diameters down to a few nanometers have been synthesized by Cheung's team. Presently, they are studying the relationship between geometric shapes and the field emission behavior of these materials.

The major component in Dr. Cheung's research and training involve the creation of novel nanomaterials and tools for studying these nanoscopic systems. Dr. Cheung was born and raised in Hong Kong SAR of China. He earned his Ph.D. degree at Harvard University, where his research focused on the synthesis and the use of carbon nanotubes for scanning probe microscopy. He joined UNL after his post doctoral training on the study of virus assembly model systems at Lawrence Livermore National Laboratory.

Dr. Cheung's team of graduate students Joseph R. Brewer, Gonghua Wang, and Wanwan Huang worked

together with post doctoral researcher Nirmalendu Deo. Their research focus is the development of refractory metallic boride and boron systems of nanomaterials for efficient high current emitters functioning in the ballistic emission regimes. This research may possibly lead to the next generation of high power nanoelectronics ranging from compact tetra Hertz klystron, parallel electron beam writers to field emission displays.



Dr. Barry Cheung

Trans-disciplinary research in Dr. Cheung's group is achieved through collaborations with other NCMN members and national laboratories. Recent collaborative work on the design of medical bioceramic films is carried out with Dr. Namavar, Dr. Zeng, Dr. Mei and Dr. Sabirianov. Potential applications of these materials include implant coating and substrate platform for cell growth study. Besides studying the fundamentals for the growth of metallic boride systems, Cheung's team also investigates the growth kinetics of CVD boron thin films. Through exploiting the conformal boron coating method developed in Cheung's laboratory, Dr. Cheung's team collaborates with Lawrence Livermore National Laboratory in the development of pillar-structure-based thermal neutron detectors.

Dr. Cheung's group applies scanning probe microscopy, electron microscopy, DC and AC electrical characterization under high vacuum, and optical spectroscopic methods to characterize nanostructured metallic boride systems. As a member of the Nebraska Center for Materials and Nanoscience (NCMN), Dr. Cheung's team conduct the structural and chemical characterization facilities at NCMN and the microscopy facilities at the Center for Biotechnology.

From the Director*continued from page 1*

Facilities some of which will be in the basement of the PSB. In addition space is allocated in the NSF for Nanofiber and Biomaterials Facilities. The NCMN Central Facilities include Nanofabrication, Materials Preparation, Electron Microscopy, X-Ray Materials Characterization, Scanning Probe Microscopy, Mechanical Characterization, and Crystallography. The Nanofabrication Facility will be housed in a Clean Room in NSF and will provide new and transformative capabilities for NCMN research. In addition the centralization of these Facilities will provide a huge boost to collaborative research of groups associated with many science and engineering departments.



PHYSICAL SCIENCES LABORATORY BUILDING

PERKINS

A preliminary design of the NanoScience Facility Building, adjacent to the new Physical Sciences Building, is shown in the lower left of the picture.

Last summer I decided to step down as Director of our NSF-supported Materials Research Science and Engineering Center (QSPINS). This was done to promote new leadership for the MRSEC, and because my other research and administrative duties were more than fully occupying my time. The latter included NCMN, the Nanoscale Science and Technology Program of Excellence, and being heavily involved in design of the two new buildings. The new Director of the MRSEC is Professor Evgeny Tsymbal of Physics, whose work as Coordinator of one of the Interdisciplinary Research Groups was highly valued. The MRSEC has passed two of the hurdles in its quest for renewal, and a reverse site

visit to NSF is scheduled for June.

I am pleased to let you know that the level of research funding for NCMN faculty and projects recently has increased significantly. Figures provided by the Office of Sponsored Programs show that for fiscal year 2007-08 the total research funding from all sources was \$ 13.4 million. This record level is the result of extremely hard work by our faculty, research staff, students and administrators. Congratulations!

We were saddened earlier this year at the passing of Professor John Stezowski of Chemistry. John was hired to supervise the operation of our NCMN Crystallography Central Facility. He also was a cheerful collaborator with many groups on problems connected with structural determinations and materials chemistry.

Several of our faculty and staff have taken new jobs recently. These include Professor Diandra Leslie-Pelecky (to University of Texas – Dallas), Professor Xinwei Wang (to Iowa State University), Dr. Brent Wilson (to Amsted, Inc.), Dr. Xiangxin Rui (to Intermolecular, Inc.), and Mr. Brian Jones (to Bruker, Inc.). These faculty and specialists contributed much to NCMN research programs for many years and we wish them well in their developing careers.

I am happy to report that NCMN has added ten new faculty in the last year. These include: Namas Chandra (Coll. of Engineering), Scott Darveau (Chemistry - UNK), Axel Enders (Physics), Christopher Exstrom (Chemistry - UNK), Alexei Gruverman (Physics), Milford Hanna (Biol. Syst. Eng.), Kamlakar Rajurkar (Ind. Management Syst. Eng.), Eva Franke Schubert (Elect. Eng.), Lin Wu (Mech. Eng.), and Yiqi Yang (Textiles, Cloth. & Design). We anticipate many further interactions and collaborations from this group.

We heartily invite your comments and visits, especially by former students and postdocs. Please let us know about your activities.

David J. Sellmyer

UNL Hosts 54th Annual Midwest Solid State Conference

The fifty-fourth annual Midwest Solid State Conference, held in Lincoln on October 6-7, 2007, was organized by Sitaram Jaswal (Chair), Sy-Hwang Liou, Ralph Skomski, and Verona Skomski. Over 110 people from fifteen universities in California, Illinois, Iowa, Kansas, Missouri, Nebraska, Ohio, Oklahoma, South Dakota, and Wisconsin attended the conference.

The conference was sponsored by the Nebraska Center for Materials and Nanoscience (NCMN), the Department of Physics and Astronomy, the College of Arts and Sciences, and the Office of the UNL Vice Chancellor for Research. The first Midwest Solid State Conference was held in 1952 at Purdue University. The most recent conference marks the sixth time that the Physics and Astronomy Department at UNL has hosted the conference.



The distinguished speaker was Prof. Lu Sham from the University of California, San Diego, who presented a lecture on "Quantum Engineering of Individual Electron Spins." Prof. Sham is internationally well-known for his pioneering contributions to the quantum theory of molecules and solids, especially the Kohn-Sham density functional theory.

Additional invited speakers:

- Steve Smith, South Dakota School of Mines and Technology
- Owen Vajk, University of Missouri-Columbia
- Hongxing Jiang, Kansas State University
- Walter Lambrecht, Case Western Reserve Univ.
- Axel Enders, University of Nebraska-Lincoln
- Andre G. Petukhov, South Dakota School of

Mines and Technology

- Viatcheslav V. Dobrovitski, Iowa State Univ.
- Anupam Garg, Northwestern University
- Hui Zhao, University of Kansas
- Michael E. Flatté, University of Iowa
- Wai-Yim Ching, Univ. of Missouri-Kansas City
- Maikel Rheinstädter, Univ. of Missouri-Columbia

The following students (all NCMN!) received the best student poster awards:

- "The Origins of Tunneling Anisotropic Magnetoresistance in Nanoscale Ferromagnetic Metal Break Junctions" by **J. D. Burton** (Physics, E. Tsybmal)
- "Locally Probed Ferroelectricity of Ferroelectric Nanomesas by Piezoresponse Force Microscopy" by **Jihee Kim** (Physics, S. Ducharme)
- "Magnetization Precession and Damping in Ni/Pt Bilayers" by **Steven Michalski** (Physics, R. Kirby)
- "Temperature Dependent Dielectric Function of $Al_{0.52}In_{0.48}P$ and $Ga_{0.52}In_{0.48}P$ " by **Eric Montgomery** (Electr. Eng., M. Schubert)
- "Scaling Behavior of the Exchange Bias Training Effect" by **Srinivas Polisetty** (Physics, Ch. Binek)
- "Thermodynamics of Itinerant Magnets: A Simple Classical Model with Longitudinal Spin Fluctuations" by **Alexsander Wysocki** (Physics, K. Belashchenko).



The participants were entertained after the banquet on Saturday by an excellent performance by the "Kokyo Taiko Drummers." The group specializes in Wadaiko, a Japanese style choreographed drumming.

Kids quotes:

- “Someday we may discover how to make magnets that can point in any direction.”
- “Vacuum: A large, empty space where the pope lives.”
- “Water is composed of two gins, Oxygen and Hydrogin. Oxygen is pure gin. Hydrogin is gin and water.”
- “Water freezes at 32 degrees and boils at 212 degrees. There are 180 degrees between freezing and boiling because there are 180 degrees between north and south.”