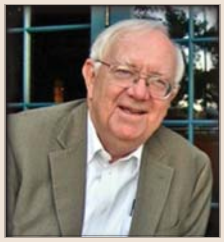
Volume 15, Issue 1 Fall 2015

# INTERFACES

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

## *From the Director*

The beginning of a new academic year is a good time to reflect on and describe recent advances and the status of materials and nanoscience research at Nebraska. We are feeling the winds of change as we have, or soon will have, several new administrators including President, Chancellor, and Senior Vice Chancellor for Academic Affairs. In such times departments and centers tend to reconsider their research and educational goals so as to position themselves for success in the future.



*Dr. David J. Sellmyer*

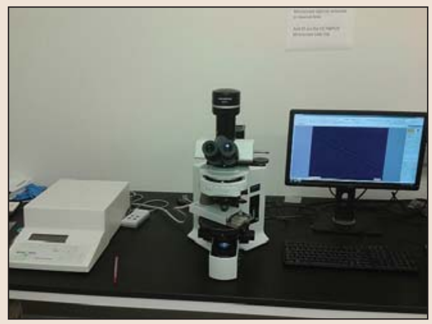
I am pleased to report that NCMN and its faculty have been recognized nationally in several ways. Most recently, NCMN has been awarded a five-year grant (cooperative agreement) from the National Science Foundation for the Nebraska Nanoscale Facility (NNF), a site of the National Nanotechnology Coordinated Infrastructure (NNCI). NNF will provide a center of excellence for instrumentation and service in nanoscale science and technology, especially for the western region of the United States Midwest. Sixteen universities are sites of NNCI as shown in the map below.


NNF will contribute to the United States research and educational infrastructure for transformative advances in the fabrication, understanding and utilization of novel nanostructures, materials and devices. NNF will build upon the established Central Facilities of NCMN, and will be bolstered by our strong research groups in nanoscale magnetism, electronics and materials and structures for energy. Other features of NNF are its outreach to visiting scientists from other universities and com-

*continued on page 9*

## *Facility Focus*

The **Scanning Probe and Materials Characterization (SPMC) facility**, currently housed in the basement of Jorgensen Hall (laboratories 009, 011, and 013), offers faculty and students state-of-the-art instruments for nanometer-scale surface measurement, thermal analysis, and mechanical characterization of a variety of materials.



*Olympus BX51 polarizing microscope*

The facility is roughly defined in three areas (bays) as scanning probe microscopy (room 013), thermal and optical analysis (room 011), and mechanical characterization and sample preparation (room 009).

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## In This Newsletter



*www.unl.edu/ncmn/*

# Research Spotlight: Shireen Adenwalla

***Dynamic Strain as a Driver of Phase Transitions***

Phase transitions refer to changes in a material's properties, often driven by temperature changes. The ubiquitous phase transition of water, which transforms from ice to liquid water to steam as the temperature increases, serves as an excellent example. Pressure significantly alters water's transition temperatures, as anyone who has baked a cake at high altitude well knows. We are investigating the effects of rapidly changing pressure on phase transitions of technologically important magnetic thin film materials by focusing a very fast (ultrasonic) sound wave on the material. By varying the pressure at rates of up to 10 billion times a second, we will probe how the material's properties vary. The fundamental questions being probed are *how* quickly can the material respond, *what* will the response be and *why* does a particular material responds the way it does.

*Dr. Shireen Adenwalla*

With co-PIs Christian Binek and Xia Hong, we target the strain driven paramagnetic-to-antiferromagnetic transition in thin films of the antiferromagnetic (AFM) magnetoelectric $Cr_2O_3$ and the Mott-insulator $NdNiO_3$, because in both materials AFM ordering coincides with another transition, the appearance of surface boundary magnetization in $Cr_2O_3$ and a metal-to- insulator transition (MIT) in $NdNiO_3$. This strain driven approach is applicable to a wide range of strain sensitive thin films materials and we can use these results to expand our investigation to include additional thin films that show strain sensitive ordering effects including high temperature superconductors and ferroelectrics. We will answer two fundamental questions:

I. What are the effects of external strain on the phase transition temperature and the evolution of the order parameter? We will obtain a precise determination of the strain dependent phase diagram in complex thin film materials, without the uncertainties that arise from variations in growth modes that occur on different epitaxial substrates.

II. What is the temporal scale over which these strain driven phase transitions will occur? The measured timescales are a probe of the different intrinsic energies in these systems.

We start by describing the generation of large, high frequency strains. In the two materials chosen, electronic and magnetic phases are intimately connected with their structural properties, as evidenced from thin film growth on a variety of substrates. These fixed, dc strains arising from lattice mismatches are of the order of 1%. Hence to investigate phase transitions at high frequency, we need to produce dynamics strains of this magnitude. To do so we use focused surface acoustic wave transducers. Surface acoustic waves (SAW) transducers are ubiquitous, used in delay lines, fluid sensors and as microfluidic drivers and consist of straight interdigitated (IDT) fingers on a piezoelectric substrate. The application of a voltage across the fingers results in strain within the piezoelectric substrate. RF voltages at the resonant frequency $f=v/\lambda$ will result in a strain wave of maximum amplitude due to constructive interference within the IDT. However, straight IDTs generate small strains, on the order of 0.01%.

In contrast, curved, focusing IDTs (inset of figure 1) focus all the energy into a beam spot approximately on the order of an acoustic wavelength resulting in strains that can be hundreds of times higher than for parallel IDTs. The FIDT in figure 1 (designed, fabricated and measured by graduate student ***Uday Singh***) is designed so that the concentric arcs follow the constant wave velocity contours to obtain the maximum strain intensity and smallest focus. Figure 1 also shows the resonance of the IDT, with a fundamental resonance at 87.95 MHz, designed to match the highest ring frequency of the Advanced Photon Source (APS).

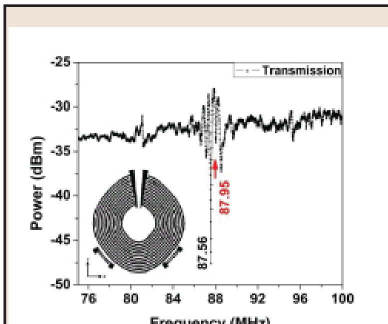



**Figure 1.** Frequency response of the focused IDT (shown in the inset) measured in transmission mode. The highest transmitted signal occurs at 87.85 MHz, very close to the intended design frequency (87.95 MHz).

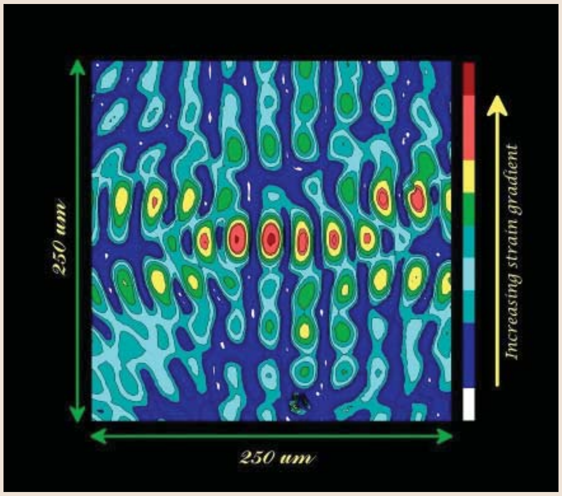



**Figure 2.** A map of the strain gradient of the $LiNbO_3$ surface due to the focusing of high frequency surface acoustic waves at the center of the FIDT. A thin (20 nm) Pt layer is grown in the center to enhance the optical reflectivity. The red regions correspond to areas of high angular deviation and hence high strain.

The choice of this frequency is explained below. Figure 2 shows an optical measurement of the strain gradient profile of this FIDT grown on 128 Y-cut $LiNbO_3$. The highest strain occurs at the center, over a region that is on the order of $\lambda/2$. The data in figure 2 were obtained by measuring the reflected signal of a focused laser beam that was scanned across the surface, with a knife-edge centered in front of the photodiode. With SAW excitation, the reflected beam alternately moves above and below the specular direction by a very small amount, and the knife edge is positioned to select for reflections above the specular angle. These measurements were recently published in IOP Nanotechnology and selected for an Editors Choice In-Depth News article at NanotechWeb. (http://nanotechweb.org/cws/article/indepth/61555).

In order to measure an absolute value of the strain, we use focused, time resolved x-ray diffraction measurements. Beam line 7 at the Advanced Photon Source allows for tight focusing of the x-ray beam, so that we can map both temporal and spatial variations in the x-ray diffraction peak positions and intensities. These, in turn, enable us to extract exact numbers for the strain. Preliminary measurements of a spatial map of the x-ray diffraction peak intensity is shown in the left panel of figure 3 and the focusing effect of the IDT is once again apparent. Even more exciting is the temporal resolution – we can follow the central peak in time with a time resolution of 130 picoseconds, as shown in the right panel of figure 3. Measurements at beam line 7 this summer involved measuring the strain transferred to a thin film on the surface.

With this information, we will now be able to investigate the temporal strain response of thin films of $Cr_2O_3$ and $NdNiO_3$, deposited on $LiNbO_3$, using multiple probes as a function of temperature, strain amplitude and strain frequency. (We already have preliminary evidence suggesting that deposition of these thin films on $LiNbO_3$ in the requisite crystalline orientation is feasible.) These include optical measurements (MOKE for chromia and reflectivity for $NdNiO_3$), time resolved element specific x-ray magnetic circular dichroism photoemission electron microscopy (XMCD-PEEM) and x-ray magnetic linear dichroism (XMLD) for chromia and time resolved x-ray diffraction and XMLD for $NdNiO_3$.

Understanding magnetization dynamics is fundamental to the development of faster non-volatile magnetic memories with ultra-low power consumption. Outside the specific field of magnetization dynamics, the ability to dynamically apply large, focused strain will have an impact on numerous thin film materials that show strain sensitive ordering phenomena. In addition to magnetism these include superconductors, ferroelectrics and multiferroics, to name just a few. The information obtained here can be used to build novel nanoscale electronic and spintronic devices such as magnetic tunnel junctions and spin-valve devices, which operate based on the dynamics of antiferromagnets.

***Dr. Shireen Adenwalla***
***Associate Professor***
***Physics & Astronomy***

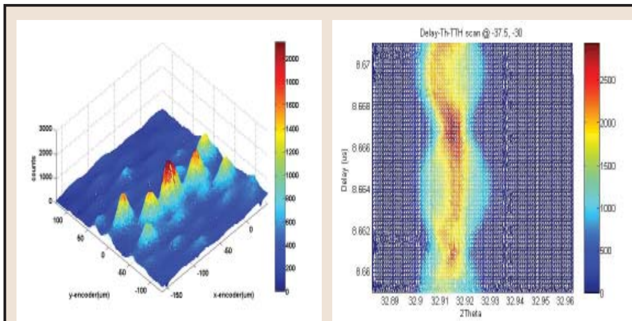


**Figure 3.** (Left) X-ray diffraction measurements, showing regions of high and low strain, generated by the curved IDTs. (Right) Theta-2theta scans at the position of the strain maximum at various time delays between the FIDT excitation and x-ray pulse.

# Faculty Awards and Honors

## Promotions and Tenures

**Christian Binek** was promoted to full professor of physics.

**Stephen DiMagno** was named a Willa Cather/Charles Bessey Professor of Chemistry.

**Jinsong Huang** was named a Susan J. Rosowski Associate Professor of Mechanical and Materials Engineering.

**Yusong Li** was promoted to associate professor of civil engineering and granted tenure.

## Awards and Honors

**Imaddin Al-Omari**, who received his doctoral degree under David Sellmyer and is a visiting professor of physics at UNL in the summers, received the Distinguished Arab Researcher Award from the Association of Arab Universities in the fields of science and engineering for the year 2014.

**Kirill Belashchenko** was selected as an Outstanding Referee for the journals of the American Physical Society (2014).

**David Berkowitz** was elected Co-Chair of the 2018 GRC on Biocatalysis/co-VC of the 2016 GRC on Biocatalysis. He was also appointed Acting Director of the Division of Chemistry of the National Science Foundation.

**Jennifer Brand** was a 2013-14 ELATE Fellow.

**Alexey Kovalev** was selected as one of 44 national recipients of an Early Career Award from the U.S. Department of Energy's Office of Science.

**Andrzej Rajca** received UNL's College of Arts and Sciences Outstanding Research and Creative Activity (ORCA) Award.

**Mathias Schubert** was awarded an honorary doctorate by Linkoping University in Sweden.

**David Sellmyer** was one of six UNL faculty members named fellows of the American Association for the Advancement of Science (AAAS).

**Alexander Sinitskii** earned a CAREER award from NSF to investigate graphene's properties.

**John Woollam** was named a fellow of National Academy of Inventors.

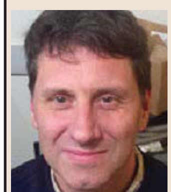
**Xiaoshan Xu** earned an NSF early career award.

## NCMN Ambassador Award

The 2015 NCMN Ambassador Award for outstanding contributions to outreach programming was given to **Axel Enders** and **Xia Hong**. The 2014 awardees were **Eva Schubert**, **Steve Ducharme**, **Rebecca Lai**, and **Christian Binek**. Congratulations!

### NCMN Welcomes New Faculty Members

*Christos Argyropoulos (Elec./Comp. Engineering)*



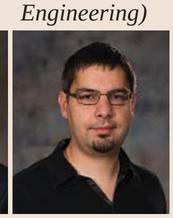
*Herman Batelaan (Physics)*

*Christopher Cornelius (Chemical Engineering)*

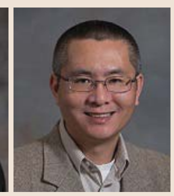
*Bai Cui (Mech./Mtrls. Engineering)*

*Joshua Darr (Chemistry)*

*Yong-Rak Kim (Civil Engineering)*

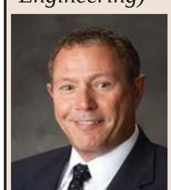


*Alexey Kovalev (Physics)*

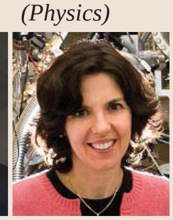


*Hui Li (Chemistry)*

*Stephen Morin (Chemistry)*



*Michael Nastasi (Mech./Mtrls. Engineering)*



*Eli Sutter (Mech./Mtrls. Engineering)*

*Peter Sutter (Elec./Comp. Engineering)*

*Xiaoshan Xu (Physics)*

## Published Books

Reddy, N., and **Y.Q. Yang**. *Innovative Biofibers from Renewable Resources*. Springer, 2015.

**Yang, Y.Q.**, H.L. Xu, and X. Yu, eds. *Lightweight Materials from Biopolymers and Biofibers*. American Chemical Society, 2014.

**Hardy, Robert**, and **Christian Binek**. *Thermodynamics and Statistical Mechanics: An Integrated Approach*. Wiley, 2014.

Huang, Hui, and **Jinsong Huang**, eds. *Organic and Hybrid Solar Cells*. Springer, 2014.

Fridkin, Vladimir, and **Stephen Ducharme**. *Ferroelectricity at the Nanoscale*. Springer, 2014.

**Yang, Jiashi**. *Vibration of Piezoelectric Crystal Plates*. World Scientific, 2013.

# Student Awards and Honors

## Awards and Honors

**Yu Zhao** (Chemistry, X.C. Zeng) received Honorable Mention for the 2014 Outstanding Graduate Research Assistant Award. He is now a postdoc at the University of Michigan.

**Shashi Poddar** (Physics & Astronomy, S. Ducharme) was awarded the inaugural Teaching and Research Fellowship at the CREST Center for Advanced Functional Materials, California State University, San Bernardino. Shashi will work with CSUSB faculty to teach a course on nanoscience and conduct research on Molecular Ferroelectrics for the 2014 fall quarter. Also, his talk entitled "Designing Novel Organic Ferroelectric Crystals" was featured at the 2014 Workshop on Fundamental Physics of Ferroelectrics and Related Materials. For the video please visit: http://ferro2014.carnegiescience.edu/content/video-presentations.

**Xin Zhang** (Physics & Astronomy, P. Dowben) won an American Vacuum Society Travel Award (2014) and was a finalist for the Leo Falicov Prize from the American Vacuum Society (2014).

**Shi Cao** (Physics & Astronomy, P. Dowben) won an American Physical Society GMAG Student Travel Award (2013); a third place poster award, Center for Nanoferroic Devices annual review (2014); and an American Vacuum Society Travel Award (2014).

**Jennifer Hamblin** (Physics & Astronomy, X. Hong) received the 2014 Physics Department Undergraduate Award for Research for her work on PFM imaging of ferroelectric domain walls in PVDF, based on which she also co-authored a paper in JAP (2014).

**Zhiyong Xiao** (Physics & Astronomy, X. Hong) received a poster aw ard at the 57th Midwest Solid State Conference, Lawrence, KS (2013).

## Ph.D. Graduates of NCMN Faculty May 2013 – August 2015

**Chemical & Biomolecular Engineering**

Seungwoo Lee (Saraf), Tobias Louw (Viljoen), Chieu Nguyen (Saraf), Kee Ong (Saraf), Jorge Ragusa (Larsen), Keith Rodenhausen, Jr. (Schubert)

**Chemistry**

Brandon Burnett (Cheung), Socrates Canete (Lai), Haemi Chung (Zhang), Xiang Fei (Berkowitz), Jennifer Gerasimov (Lai), Zane Gernhart (Cheung), Paul Goodman (Redepenning), Shiva Kyasa (Dussault), Arnon Olankitwanit (Rajca), Kaushik Panigrahi (Berkowitz), Wantanee Sittiwong (Dussault), Nathan Thacker (Takacs), Shri Uppaluri (DiMagno), Timothy Vo (Sinitskii), Yali Wang (Harbison), Rachel Willand-Charnley (Dussault), Benjamin Wymore (Redepenning), Anita Zaitouna (Lai), Yu Zhao (Zeng), Yunyun Zhou (Cheung)

**Electrical Engineering**

Lisha Fan (Lu), Yang Gao (Lu), Fen Hanrahan (Ianno), Philipp Kuhne (Schubert), Dan Liang (Eva Schubert), Masoud Mahjouri Samani (Lu), Stefan Schoeche (Schubert), Wei Xiong (Lu)

**Mechanical & Materials Engineering**

Hualong Du (Turner), Yunlong Geng (Shield), Celine Hayot (Turner), Huijing He (Yang), Ping Hu (Turner), Mikhail Kartashov (Dzenis), Lucas Koester (Turner), Christopher Kube (Turner), Aravind Sundaramurthy (Feng), Severine Vennin (Turner), Lili Zhang (Negahban), Shijia Zhao (Gu)

**Physics and Astronomy**

Roger Bach (Batelaan), Xumin Chen (Enders), Joan Dreiling (Gay), Tom George (Sellmyer), James Glasbrenner (Belashchenko), Cheng-Wei Huang (Batelaan), Kristin Kraemer (Ducharme), Donna Kunkel (Enders), Eric Litaker (Gay), Xiaohui Liu (Tsymbal), Haidong Lu (Grouverman), Scot McGregor (Batelaan), Sai Mu (Belashchenko), Munir Pirbhai (Gay), Shashi Poddar (Ducharme), Pankaj Sharma (Grouverman), Rui Zhang (Sellmyer/Skomski)

## Masters Graduates of NCMN Faculty May 2013 – August 2015

**Chemistry**

Rui Lai (Li), Gilbert Mbah (Sinitskii), Katelyenn McCauley (Dussault), Hongbo Zhu (Li)

**Electrical Engineering**

John Clark Bruce III (Alexander), Christopher Ferris (Ianno), Wenjia Hou (Lu), Qinglei Ma (Ianno), Nicholas Rowse (Alexander), Mengxiao Wang (Lu), Christopher Wilson (Alexander)

**Mechanical & Materials Engineering**

Praveen Akula (Gu), Frederic Aubin (Fernandez-Ballester), Emilie Bobo (Negahban), Hugo Boitout (Fernandez-Ballester), Jordann Bornhoft (Shield), Lena Butterfield (Negahban), Corey Kruse (Ndao), Kevin Lefebvre (Tan), Jacob Lewis (Shield), Seyed Mousavi Rizi (Neghaban), Cheng Ren (Dzenis), Benjamin Schamme (Fernandez-Ballester), Evan Schwahn (Negahban), Quentin Viel (Turner), Jason Vogeler (Feng)

**Physics and Astronomy**

Shi Cao (Dowben), Xiaoqian Dang (Tsymbal), Elena Echeverria Mora (Dowben), Qianqian Jiao (Liou), Shijie Li (Belashchenko), Thomas Scott (Dowben), Uday Singh (Adenwalla)

# New Faculty Spotlight: Alexey Kovalev

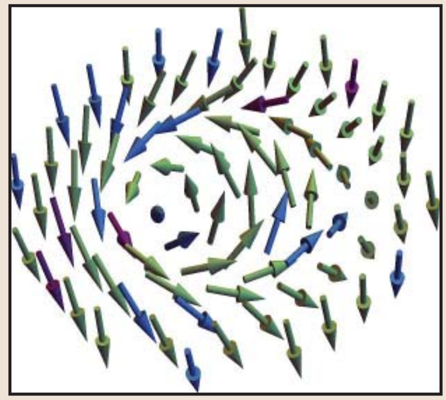
Dr. Alexey Kovalev joined the University of Nebraska–Lincoln in 2013 as an Assistant Professor in the Department of Physics and Astronomy and as a new member of the Nebraska Center for Materials and Nanoscience. Dr. Kovalev received his Ph.D. degree in 2006 from Delft University of Technology and his diploma degree in 1999 from Moscow Institute of Physics and Technology. He worked as a Postdoc for Texas A&M University, UCLA, and University of California, Riverside.

*Dr. Alexey Kovalev*

Dr. Kovalev's interests lie broadly in theory, i.e., magnetism, quantum transport phenomena, and quantum information theory. During his Ph.D. time he generalized the well-known Valet-Fert theory to non-collinear systems and described the spin transfer torque effect in metallic multilayered systems. This effect has found applications in the spin-torque memories. His other important contributions include works that established the basis for future studies of the coupling between the elastic modes and the magnetic order parameter, and works that offered theoretical description of the spin transfer-torque driven ferromagnetic resonance – an important effect used for characterizing ferromagnets and microwave generation.

Dr. Kovalev addresses theoretically both fundamental questions in physics as well as device applications. In particular, he developed a theory of the anomalous Hall effect in multiband systems – a fundamental effect in condensed matter physics that sparked a debate for over fifty years. In collaboration with researchers from University of California, Riverside, he solved fundamental problem of efficient and fault tolerant quantum information storage with the help of quantum low-density parity check (LDPC) codes. In the latest development, Dr. Kovalev addressed novel magnonic effects that could potentially find applications in realizations of novel logic and memory devices.

Dr. Kovalev's current research is related to the understanding of effects related to spin-orbit interactions in the context of equilibrium and nonequilibrium thermodynamics and transport phenomena in mesoscale and nanoscale magnetic systems. Of particular interest are effects related to collective behavior in many-body systems. To address this program, Dr. Kovalev developed a theory of interplay between magnon flows due to temperature gradients and skyrmion dynamics in systems with Dzyaloshinskii-Moriya interactions. Studies of such systems not only offer a glance at fascinating fundamental physics related to phase transitions and dynamic effects but might also offer novel applications in magnetic memories relying on skyrmions as memory bits. Dr. Kovalev is also pursuing studies of quantum low-density parity check codes where similar methods can answer important questions for stability of storage of quantum information. In particular, a combination of numerical methods based on Monte Carlo simulations and analytical methods based on percolation theory can be employed to answer the above questions.



A stable magnetization configuration corresponding to skyrmion can arise in magnets with Dzyaloshinskii-Moriya interactions.

Dr. Kovalev maintains active collaboration with world-class scientists in the US, Europe, and Japan. Dr. Kovalev has published his research results in over 40 scientific publications and presented at 10 conferences and symposiums as an invited speaker. He is a member of the American Physical Society (APS). So far, Dr. Kovalev has gained a total of $1,054,075 in external research funding from the National Science Foundation (NSF) and the United States Department of Energy (DOE), which includes the DOE Early Career Award in 2015. He is also contributing to the NSF-funded Material Research Science and Engineering Center (MRSEC) through a seed project on spin transport. Dr. Kovalev teaches "General Physics" at the undergraduate level and "Quantum Field Theory" at the graduate level in the Department of Physics and Astronomy.

# *New Faculty Spotlight: Stephen Morin*

Dr. Stephen A. Morin joined the University of Nebraska–Lincoln in 2013 as an Assistant Professor in the Department of Chemistry, and as a new member of the Nebraska Center for Materials and Nanoscience. Dr. Morin completed his B.S. in Chemistry at The University of Texas at Austin in 2004. He then joined the Department of Chemistry at the University of Wisconsin–Madison as a graduate student in 2005 and, under the direction of his advisor Professor Song Jin, received his Ph.D. in Chemistry in 2011. From 2011 until 2013, Dr. Morin was a Postdoctoral Fellow in the lab of Professor George M. Whitesides in the Department of Chemistry and Chemical Biology at Harvard University.

*Dr. Stephen Morin*

Dr. Morin's areas of expertise include: nanomaterials synthesis and characterization, bottom-up fabrication, soft lithography, crystal growth, and hybrid materials design. He developed this diversity of skills through research experience gained in a number of materials chemistry (broadly defined) labs. As an undergraduate, Dr. Morin conducted research, under the direction of Professor Keith J. Stevenson, on nitrogen-doped carbon nanofiber electrodes. As a Ph.D. student, his research and thesis, titled "Dislocation-Driven Synthesis and Bioinspired Assembly of Functional Nanomaterials," focused on the rational synthesis and assembly of nanomaterials based on fundamental concepts of crystal nucleation and growth. As a postdoc at Harvard, Dr. Morin conducted research in the areas of soft robotics, digital fabrication, and adaptive materials.

Dr. Morin's research at UNL blends his unique background into a program which aims to utilize soft materials to control (synthesize, assembly, manipulate, fabricate, etc.) hard materials. Current research efforts focus on materials with heterogeneous chemical, structural, and physical properties that can be reversibly reconfigured using simple, macro-scale processes such as mechanical deformation. These materials can be entirely "soft"—fabricated exclusively from elastomeric polymers such as silicone—or they can be "hybrid" systems comprised of both soft materials and hard materials. The micro-scale features (e.g., surface chemistry or structure) of these materials are readily organized and manipulated on length scales commensurate with their size, even when large numbers of objects are involved. The dynamic properties (chemical, physical, and structural) of these systems are useful to applications such as soft sensing and electronics, and they will enable new methods of nano/micromaterial synthesis and new strategies for the fabrication of hierarchical hybrid structures. Active research projects include: (i) mechano-chemical surfaces, and (ii) soft, stretchable reactors. The first research product from Dr. Morin's group was published this year in *Lab on a Chip* (*Lab Chip* **2015**, *15*, 2009), and described a set of soft, microfluidic devices that can be reversibly sealed to a range of materials of arbitrary chemistries, surface topographies, and 3D geometries (Figure 1). The article was featured on the back cover and recognized as a "Hot Article," for its potential impact to the community.

Dr. Morin has over 25 scientific publications, is a co-inventor on 5 patents, and co-author of one book chapter. He has published two papers, as lead author, in the prestigious journal *Science*. He has received numerous awards, most recently the 3M Non-tenure Faculty award in 2015. He teaches at the undergraduate and graduate level in the Department of Chemistry, and is launching a new graduate course tentatively titled: "Synthesis and fabrication of nano- and micro-scale structures in hard and soft materials." He also hosts workshops in the area of soft robotics and lithographic replication through the UNL Makers Club and Innovation Studio on Nebraska's Innovation Campus.

**Figure 1.** Soft reactor sealed to a flask. Cover art *Lab Chip* **2015,** *15.*

# Facility Focus: SPMC

***...continued from page 1***

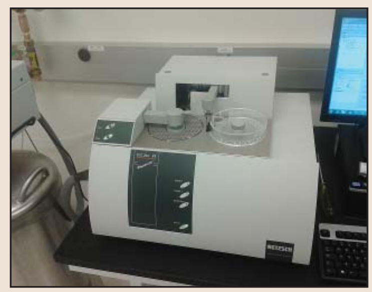
The scanning probe microscopy (SPM) bay contains three SPM microscopies, including BRUKER ICON SPM, EnviroScope Atomic Force Microscope, and Dimension 3100 SPM system. The SPM offers simultaneous high-magnification observation of 3-dimentional images and related physical properties, as well as measurements in various environments. SPM is equipped with:

- Atomic Force Microscopy (AFM) – surface topography imaging
- Magnetic Force Microscopy (MFM) – magnetic force gradient detection
- Electrostatic Force Microscopy (EFM) – measures variation in the electric field gradient above a sample
- Kelvin Probe Force Microscopy (KPFM) – measures material work function as well as surface charge
- Scanning Tunneling Microscopy (STM) – primary highest resolution AFM mode
- Tunneling Current AFM (TUNA) – measures material's electrical conductivity with wide range of currents from fA-µA
- Piezoresponse Force Microscopy (PFM) – studies piezo materials on nanoscale
- Quantitative Nanomechanical Property Mapping (PF-QNM) – elastic modulus (MPa-GPa), adhesion, deformation, and dissipation

These SPM instruments have the ability to operate in ambient air, liquids, vacuum, purged gas, and/or different temperature environments (-30° C to 250° C). The available magnetic devices can supply magnetic fields perpendicular (± 0.25 T) and/or parallel (± 0.35 T) to the sample surface for in-situ MFM imaging. BRUKER ICON SPM features a user-friendly ScanAsyst® automatic image optimization mode based on PeakForce Tapping technology, which enables users to obtain consistent high-quality results easier and faster.

*Dr. Lanping Yue*

The thermal and optical analysis bay provides two thermal analysis systems: a differential scanning calorimeter (DSC 204 F1 Phoenix - pictured below) and a thermogravimetry analysis system (TGA 209 F1 Libra). Both systems operate through a large temperature range from -175°C to 700°C for the DSC, and 25°C to 1100°C for the TGA. These systems allow users to study and measure various thermal properties of materials such as glass-transition temperatures, melting temperatures, melting enthalpy, crystallization temperatures, crystallization enthalpy, transition enthalpies, phase transformations, phase diagrams, and other thermal properties. Also available is an Olympus BX51 polarizing optical microscope (pictured on page 1) which includes differential interference contrast capabilities for sample viewing and image analysis. In addition the thermal behavior of a sample can be observed under the microscope using a Mettler Toledo FP900 thermal system equipped with a FP 82 hot stage with a temperature range from room temperature to 375° C.



*Differential scanning calorimeter (DSC 204 F1 Phoenix)*

Mechanical characterization and sample preparation bay houses (1) Tukon 2500 Knoop/Vickers Hardness tester (Test force: 0.01 kg to 1 kg), (2) BUEHLER ISOMet 1000 Precision Saw, (3) BUEHLER MiniMet 1000 Grinder-polisher, and (4) Sartorius Cubis MSU2.7S-000-DM Microbalance (weighing capacity 2.1 g with readability of 0.0001 mg).

***Dr. Lanping Yue***
***Senior Materials & Nanoscience Specialist***
***Scanning Probe & Materials Characterization***

# Outreach/Education Highlights

**Summer Camps**

NCMN worked with a variety of partners this summer to engage audiences in nanoscale science, technology, and engineering. We provided STEM learning in the ever-growing area of nanoelectronics to underrepresented high school students in the Upward Bound program and challenged Lincoln Public School junior high students' perceptions about car crashes and smart engineering at summer camps.

**Teacher Conferences and Workshops**

STEM/Nano concepts were shared at a variety of teacher workshops and conferences. Each year we participate in the Nebraska Association for the Gifted (NAG) and Nebraska Association of Teachers of Science (NATS) conferences, where we showcase our nanokits to teachers, with practical ideas and hands-on activities about STEM/nanoscience. Also, Dr. Axel Enders, NCMN Education and Outreach Chair, was an invited speaker for business entrepreneurs at the AIM/Infotec Conference on the scientific trends and product applications of nanotechnology in a variety of areas.

**High School Summer Internships**

Thanks to generous funding from a UNL alum, our third High School STEM/Nano Internship program was held the summer of 2015. Select Lincoln-area high school students 16 years of age and older received guidance and training in experimental and theoretical techniques in Chemistry, Physics, and Engineering labs at UNL.

**Museum Partnerships**

NCMN recently received an NSF-funded nano traveling exhibit and will be partnering with Nebraska EPSCoR in bringing STEM/nanoscience programming to six Nebraska museums in the state over the next two years. *Nano* is an interactive exhibition that engages family audiences in nanoscale science, engineering, and technology. Another grant expanded our STEM nano learning experiences to new rural areas where audiences are underserved in terms of science opportunities. Partnering with Hastings Museum, we showcased nano art pictures created from actual research at the University, along with nano activity kits, to thousands of visitors over the summer of 2014.

**Supporting Science Careers through Outreach**

NCMN provides a variety of opportunities for high school and undergrad students to find their career paths in the sciences.

**Peter Kosch** started as an NCMN high school summer intern in one of the Physics labs. This led to an undergrad research job in the same lab after he starting at UNL plus becoming a regular presenter with NCMN's Ed/Outreach program. Peter is now on track to become a high school science teacher with knowledge gained through his experiences with NCMN.

It didn't take long to realize that undergrad **Seth Kurfman** was a natural teacher and researcher. After working with NCMN's Ed/Outreach program Seth was offered an undergrad Teaching Assistant position in the Physics department and received the Outstanding Undergraduate TA award this year. He is a valued contributor in his lab and is preparing for graduate school.

These real-life stories continue to inspire NCMN faculty and staff!

***More information at www.unl.edu/ncmn/outreach-education and www.unl.edu/ncmn/outreach-newsletter!***

# From the Director

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panies in our region, and a strong education-outreach program.

An additional cause for satisfaction is the renewal award last fall of the Materials Research Science and Engineering Center from NSF. The MRSEC, initially established in 2002, has now been renewed twice and focuses on polarization and spin phenomena in nanoferroic structures. It involves about 20 faculty with a similar number of graduate students and postdocs, and also has a strong education-outreach program.

The total research expenditures of NCMN faculty in budget year 2014-15 were about $21 million. The associated grants generate roughly $6.3 million in F & A (overhead) funds for the university, and this income rather easily justifies the much smaller amount given to NCMN to partially support its operation. Moreover, these research expenditures generate about $147 M per year in economic activity in the state, again strongly justifying NCMN's support by the university.

Our faculty are extremely aware of the competition we face in obtaining grants from federal agencies, where success rates are typically 20% or lower. We have found that success often comes by coupling ourselves with other excellent researchers, both within UNL and without, to create an outstanding, nationally leading, team. It is likely that we would be well served by even more efforts at such teaming.

I want to close by welcoming new faculty (p. 4) and by acknowledging our great debt to the extremely dedicated staff members of NCMN, without whom we could not function. These include: Shelli Krupicka, Patty Fleek, Terese Janovec, Jaimie Iuranich, Karen Gildea, Zach Sun, Jim Li, Lanping Yue, Shah Valloppilly, Jiong Hua, and Steve Michalski. Thank you, NCMN staff!

***David J. Sellmyer***

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