April 2012

CNMS User Newsletter

http://cnms.ornl.gov/

Important Dates:

- Call for Proposal deadline is May 2
- 2012 User Meeting: Sept, 12-14, 2012

Inside this issue:

We encourage feedback and suggestions for the content of future newsletters. We are especially interested in receiving research highlights from CNMS users that may be featured in future issues of this newsletter. Please email us any time you have an important paper that is accepted for publication.

REMINDER! Proposal deadline is May 2 for new user projects that will start August 1.

Message from the UEC Chair

Martyn McLachlan, Imperial College London

The CNMS is internationally recognized as a leading center of excellence in nanoscience. I think that the strength of the CNMS comes from a unique combination of equipment and facilities, the expertise and capabilities of the research staff, the direction of the senior management and *importantly* the unique collaborative and supportive user environment.

This year I am proud to be the elected chair of the User Executive Committee (UEC)– our role is to facilitate constructive exchange between you, the user community, and the center management. Together the UEC are an elected group of users – just like you. We would be more than happy for you to contact any or all of us with any suggestions or comments you may have about the user experience at CNMS.

Another task of the UEC is to assist in the planning of the annual user meeting in September – this event truly highlights the breadth and quality of research being carried out at the CNMS – and I hope to see as many of you as possible there, if not sooner at the CNMS. In the meantime I invite you to read through this and future newsletters and encourage you to become a more active user.

-Martyn

Proposal Calls

CNMS Call for User Proposals: High-Impact Nanoscience Research

Deadline: Wednesday, May 2, 2012

Submit your proposal *Now!*

The Center for Nanophase Materials Sciences is soliciting proposals for user-initiated nanoscience research that will make effective use of CNMS facilities and staff expertise. The CNMS nanoscience research program provides users with access to a broad range of capabilities for nanomaterials design, synthesis, characterization, and theory/modeling/simulation, in order to carry out studies that will significantly advance our understanding of nanoscale phenomena and develop functional nanomaterials systems. Access is provided at no cost to users for research that is in the public domain and intended for publication in the open literature.

The submission deadline is Wednesday, May 2, 2012. Approved projects will be granted access to CNMS facilities during the period August 1, 2012 through July 31, 2013.

The CNMS website provides detailed descriptions of specific CNMS Research Capabilities that are offered to users. Prospective users are invited and strongly encouraged to contact CNMS staff members in the respective research areas to discuss their proposal ideas and learn more about the specific capabilities of interest to them.

Call for User Proposals: Neutron Scattering Science

The next proposal deadline is Wednesday, September 5, 2012, to apply for user time at ORNL's neutron scattering facilities during January-July 2013. Visit neutrons.ornl.gov for more information.

2012 UEC Elections

News from CNMS

About the UEC
-Contact information
-Web links

CNMS users participating in an online election between October 27 and November 22, 2011, elected the following candidates to serve on the 2012 CNMS User Executive Committee (UEC), with 2-year terms that began on January 1, 2012.

Vice-Chair– Tony Hmelo (Vanderbilt U.)
Secretary– Milan Buncick (Aegis Technologies Group)
At-Large Members –
Nazanin Bassiri-Gharb (Georgia Tech)
Michael Hickner (Penn State U.)
IchiroTakeuchi (U. Maryland)

These newly elected UEC members will be joined by the following returning members in 2012:

Chair (succession from 2011 Vice-Chair)– Martyn McLachlan (Imperial College, London)
Past Chair, ex officio member– Mark Dadmun (U. Tennessee)
At-Large Members –
Nina Balke (ORNL/CNMS)
Marco Buongiorno Nardelli (North Carolina State U.)
Vivek Prabhu (NIST)
Colin Wolden (Colorado School of Mines)

In the months since the election, the UEC has been engaged in planning the user meeting, preparing this newsletter, and evaluating user survey results. The UEC is an elected body of users that is expected to make recommendations to CNMS management on matters affecting the user community. Users are encouraged to contact any member of the UEC to make suggestions for enhancing the benefits the research community receives from CNMS.

NEW! Evening food service at the SNS Café

The SNS cafeteria is now open for dinner from 6 to 8 p.m., Monday through Friday, serving hot entrees, hot sides and a limited grill menu. Deli sandwiches and pizzas are available on a preorder basis. Call-in orders are welcome and may be placed at 574-3932. The new café hours will be particularly convenient for users staying overnight at the Guest House adjacent to the CNMS and SNS. And don't forget the café is also open for breakfast from 6:30 to 9:30 a.m., Monday through Friday.

ORNL Guest House offers discounted rates

Did you know the ORNL Guest House offers discounted rates for academics and extended stays?

Academic Rate: $76 per night plus tax. Available for stays of four or more nights by students and faculty of colleges and universities, and high school teachers/administrators. Reserve your room at the Standard Rate and request the Academic Rate at check-in. College ID required.

Extended Stay Rate: $69 per night plus tax. Available for stays of 30 or more consecutive nights. Call 865-576-8101 to reserve your room at the Extended Stay Rate. Full payment by credit card is required in advance. If your stay fails to extend to the full 30 days, the rate will revert to the Standard Rate for your actual stay. If you cancel your reservation prior to 6 p.m. on the day of arrival, the deposit will be refunded in full via credit to the credit card. Any cancellation received after 6 p.m. will be subject to one night's lodging plus taxes.

Standard Rate: $91 per night plus tax. This is the GSA rate for Oak Ridge and is available to all, even without government ID.

The ORNL Guest House opened in August 2011 and is conveniently located near the CNMS on Nano Center Drive . Similar to a small hotel, it offers a comfortable room with amenities, such as a television, microwave, mini refrigerator and wireless Internet access. The facility also includes a lounge area, vending area, breakfast area, meeting room, fitness room, guest laundry room, and a prep kitchen.

More information and reservations are available online or by calling 865.576.8101.

National User Facility Organization Activities

On March 28-29, 2012, the National User Facilities Organization (NUFO) hosted its second User Science Exhibition on Capitol Hill, providing an opportunity for forty-five diverse user facilities to highlight the important role that these facilities play in science education, economic competitiveness, fundamental knowledge, and scientific achievements. The event consisted of back-to-back exhibits in the US House and Senate Office buildings for members of congress, their staff, and other interested stakeholders. The CNMS was represented by two members of its User Executive Committee, Milan Buncick (Aegis Technologies Group) and Vivek Prabhu (National Institute of Standards and Technology), along with User Program Manager Tony Haynes. NUFO also prepared a CNMS poster for the event (click graphic for high-resolution version of poster). Please see http://www.nufo.org/news.aspx?id=38 for a summary of the event.

Research Highlights

We are especially interested in receiving research highlights from CNMS users that may be featured in this section of future newsletters. Please email us if you have an important paper that has been accepted for publication.

New Technique Produces Free-standing Piezoelectric Ferroelectric Nanostructures from PZT Material

Ashley Bernal,[1] Alexander Tselev,[2] Sergei Kalinin,[2] Nazanin Bassiri-Gharb[1]

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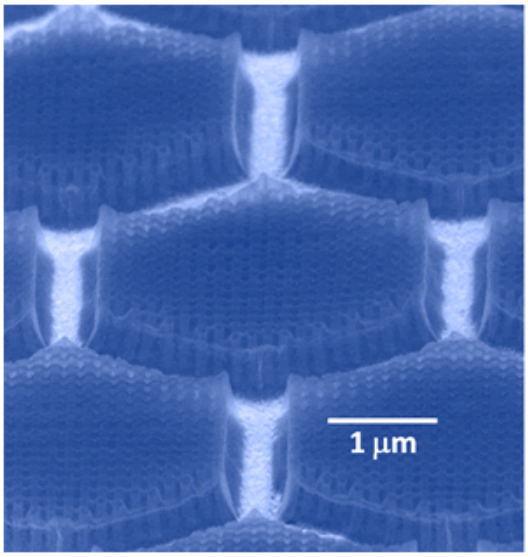
[2] Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, USA

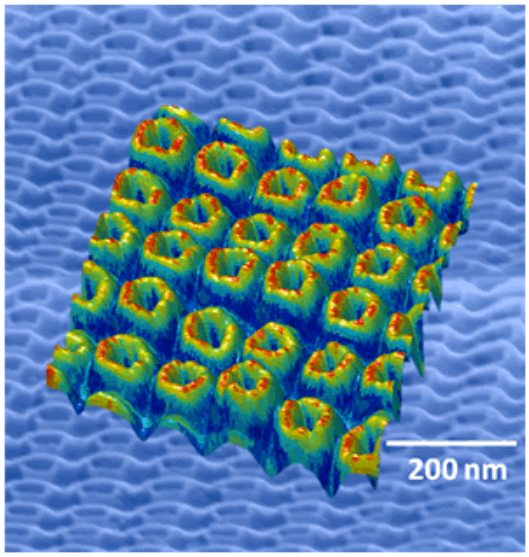
The ability to crystallize a ferroelectric oxide directly into nanoscale patterns could enable piezoelectric actuation and sensing at the nanoscale with much higher actuation power densities than with electrostatic and magnetoelectric approaches. For many important applications, a robust means of patterning ferroelectric (piezoelectric) materials such as lead zirconate titanate (PZT) in arbitrary shapes and on a variety of substrates (beyond single crystals needed for epitaxial growth) is required but the relatively high processing temperatures and difficult etching processes needed for conventional, top-down fabrication of these materials have substantially hindered their technological advancement in nanoscale applications.

CNMS users Ashley Bernal and Nazanin Bassiri-Gharb from the Georgia Institute of Technology have recently developed a bottom-up, soft-template infiltration technique for fabricating high aspect-ratio, free-standing, piezoelectrically active ferroelectric nanotubes and other nanostructures from PZT through the use of polymeric templates.

At CNMS, these researchers were able to use the novel technique of switching-spectroscopy piezoresponse force microscopy (SS-PFM) to perform high-resolution, in-situ measurements of the nanoscale piezoelectric properties of the structures. Electromechanical hysteresis loops were collected by measuring the PFM amplitude and phase associated with a single PZT nanotube, confirming for the first time the ferroelectric behavior of individual nanotubes *in situ* and demonstrating an extrinsic piezoelectric response comparable to that of PZT thin films of much larger dimensions.



SEM micrograph of hexagonal arrays of 100-nm diameter PZT nanotubes fabricated by soft-template infiltration.



Piezoelectric response signal (color-coded) superimposed on an SEM image of a PZT nanotube array.

The new nanopattering technique could ultimately lead to production of actively-tunable photonics and phononic crystals, terahertz emitters, energy harvesters, micromotors, micropumps and nanoelectromechanical sensors, actuators and transducers – all made from the nanostructured PZT material. Access to unique characterization capabilities and expertise at CNMS enabled the

Georgia Tech group to show that the resulting nanostructures have the desired ferroelectric response at nanoscale dimensions, as

well as observe ferroelectric size effects that had been previously undetected in ferroelectric nanotubes.

This research was first published online on February 24, 2012, and appeared in the March 2, 012 print edition of *Advanced Materials*. The research was supported by Georgia Tech new faculty startup funds and through a user project at CNMS.

Citation: "Ferroelectric Nanotubes: Free-Standing Ferroelectric Nanotubes Processed via Soft-Template Infiltration," A. Bernal, A. Tselev, S. Kalinin, N. Bassiri-Gharb, Adv. Mater. **24**, 1160–1165 (2012); doi: 10.1002/adma.201103993

User Spotlight

Nazanin Bassiri-Gharb

"My work is mostly concentrated on ferroelectric and multiferroic materials and their application to nano- and micro-electromechanical systems, as well as novel approaches to high-response piezoelectric ceramics. We try to integrate novel micro and nano-fabrication techniques and processes, with fundamental science of ferroics materials, and the news highlight in this issue of the CNMS newsletter is probably a good example of this approach. My group is specially interested in extrinsic contributions to the dielectric and piezoelectric properties, and specifically domain walls and phase boundaries and their interactions with point defects and crystallites, and size effects in thin films and nanostructures. Of course working at small scale means that you need to look at the local properties in addition to the global or macroscopic properties, so the expertise of the SPM group at the CNMS and their suite of Scanning Probe Microscopy-based techniques for local piezoelectric and ferroelectric characterization are a perfect match to my group's work at Georgia Tech. Specifically, the Band-Excitation Piezoresponse Force Microscopy (BE-PFM) that was originally developed at CNMS was what really attracted our attention for characterization of the high aspect-ratio ferroelectric nanostructures. This is not the first time that attempts have been made for looking at size effects in ferroelectric nanostructures. However, processing and characterization limitations (see technical highlights) have mostly prevented in the past a clear picture of the phenomena. Our current and future collaborations with CNMS include more detailed work on the switching behavior and size effect in ceramic and single crystalline ferroelectric nanostructure, as well as correlation of macroscopic and microscopic behavior of ferroelectric and ferroelastic micro/nano-structures under variable boundary conditions."

Dr. Nazanin Bassiri-Gharb is an assistant professor in the George W. Woodruff School of Mechanical Engineering at Georgia Tech, and holds a courtesy appointment with the School of Materials Science and Engineering. She obtained her Ph.D. in Materials Science from the Pennsylvania State University in 2005 and her laurea summa cum laude in Materials Engineering from University of Padua, Italy in 2001. Prior to her current appointment she was a senior research engineer at the MEMS Research and Innovation Center (MRIC) of QUALCOMM MEMS Technology, Inc. in San Jose, CA.

She is a member of the editorial board of Journal of Electroceramics, and an associate editor of IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control. Dr. Bassiri-Gharb is an elected member of the IEEE UFFC (Ultrasonic, Ferroelectrics and Frequency Control) Administrative Committee for 2010-2012, Oak Ridge National Lab's Center for Nanophase Materials Science (CNMS) User Executive Committee (2012-2013), and the IEEE Nanotechnology Council UFFC representative. She has received the IEEE UFFC/Ferroelectrics best student poster in Ferroelectrics (2004) Society of Women Engineers' General Motors Award (2005), and Bennett Aerospace Researcher of the Year Award (2011). She is married to Olivier Pierron (also an assistant professor at Georgia Tech) and they have a two-years old daughter, Liliana. She considers herself truly lucky in loving what she does. She also enjoys reading fiction, cooking (which she considers another form of materials science), spending time with her family, and catching up on lost sleep (which does not happen very often).

Correlating Electronic Transport to Atomic Structures in Self-Assembled Quantum Wires

Shengyong Qin,[1] Tae-Hwan Kim,[1] Yanning Zhang,[2] Wenjie Ouyang,[2] Hanno H. Weitering,[3] Chih-Kang Shih,[4] Arthur P. Baddorf,[1] Ruqian Wu,[2] and An-Ping Li[1]

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Quantum wires are extremely narrow one-dimensional (1D) materials where electron motion is allowed only along the wire direction, and is confined in the other two directions. Quantum wires, as a smallest electronic conductor, are expected to be a fundamental component in all quantum electronic architectures. The electronic conductance in quantum wires, however, is often dictated by structural instabilities and electron localization at the atomic scale. A CNMS team has recently reported on the evolution of electronic transport as a function of temperature and interwire coupling as the quantum wires of $GdSi_2$ are self-assembled on Si (100) *wire-by-wire*. Individual nanowires have a width of 16.7 Å, a height of 4 Å, and lengths of micrometers, and embody one of the closest realizations of 1D conductors. Amazingly, these nanowires can be grown either in the form of isolated nanowires or bundles with a number of constituent wires separated by an atomic interwire spacing. The researchers examined the correlation between structure, electronic properties, and electronic transport in the quantum wire system by combining nanoscale transport measurements, scanning tunneling microscopy, and density functional theory calculations. A metal-insulator transition (MIT) is revealed in isolated nanowires, while a robust metallic state is obtained in wire bundles at low temperature. The observations were interpreted as atomic defects leading to electron localization in isolated nanowires, and interwire coupling which stabilizes the structure and promotes metallic states in wire bundles.

In this paper, CNMS researchers and their collaborators have performed the first correlated study of electronic properties by utilizing both scanning tunneling microscopy and nanotransport measurements on the same nanowire as the nanowires are assembled *wire-by-wire*. The approach takes advantage of the team's developments in fabricating nanocontacts using a field-induced atom emission process to bridge the atomic wires and the mesoscopic transport electrodes. The competition of defect-induced localization and interwire coupling in 1D systems has been argued for decades. The 1D metallic phase is inherently unstable with respect to symmetry-lowering lattice deformation and defect-induced localization. Adding interwire coupling can often lead to the formation of change density waves. In both cases, the metallic state is not stable and a metal-to-insulator transition occurs at low temperature. These new results now indicate that robust metallic conductance can be stabilized by interwire coupling, while the isolated single nanowires exhibit a metal-to-insulator transition due to quantum localization. The results provide a rare glimpse of the intrinsic structure-transport relations and the influence of local environments at an unprecedented atomic scale.

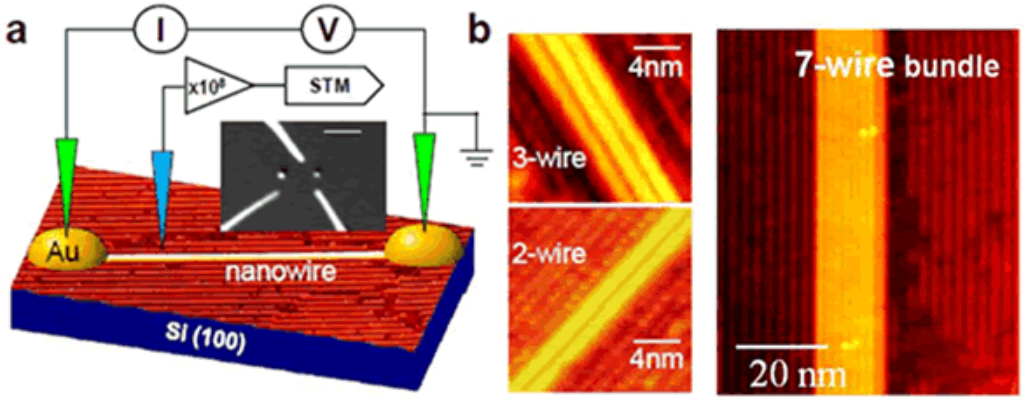

Fig. 1 (a) A cryogenic four-probe STM is used to probe both the electrical transport and the electronic structures of individual GdSi2 nanowires (b) STM images of self-assembled nanowires with different width.

This work was published online in Nano Letters on January 23, 2012. This research was conducted at the Center for Nanophase Materials Sciences, which is sponsored at Oak Ridge National Laboratory by the Scientific User Facilities Division by the Office of Basic Energy Sciences, U.S. Department of Energy. Theoretical work at UCI was supported by DOE grant DE-FG02-05ER46237.

Citation: "Correlating Electronic Transport to Atomic Structures in Self-Assembled Quantum Wires," Shengyong Qin, Tae-Hwan Kim, Yanning Zhang, Wenjie Ouyang, Hanno H Weitering, Chih-Kang Shih, Arthur P. Baddorf, Ruqian Wu, and An-Ping Li, **Nano Letters**, *DOI: 10.1021/nl204003s.*

CNMS Staff Spotlight

An-Ping Li

An-Ping Li is a research staff member at CNMS in Oak Ridge National Laboratory with an adjunct professor appointment in the Department of Physics and Astronomy of The University of Tennessee. He currently manages a cryogenic mutiple-probe scanning tunneling microscope at CNMS, a one-of-a-kind facility for nano-transport research. His primary research interests are the experimental determination of structure-transport relations at the nanoscale and electronic phase transitions in constrained dimensionality, including nanowires, nanojunctions, interfaces, defects, grain and domain boundaries, surfaces, and thin films. His research activities involve both the fundamental understanding of novel functionalities and the science-driven synthesis of artificially structured materials for energy applications.

An-Ping has published approximately 60 papers with over 2,350 citations, including 4 papers with more than 100 citations each. In the past 4 years, He has presented about 20 invited talks and colloquia. He is the founding chair of the AVS Topical Conference on Electron Transport, serving as organizing committee chair in 2011 and 2012 .