NREC
Nanotechnology Research & Education Center

Nano Wired

VOLUME 1, ISSUE 2 SPRING/SUMMER 2011

NREC MISSION

- Enabling multidisciplinary nano-related research for faculty at USF
- Providing professionally-managed facilities for fabrication and characterization
- Providing training programs for faculty and students
- Enabling industrial and academic collaboration for commercialization of technology

INSIDE THIS ISSUE:

Director's Note

Dr. Ashok Kumar, Director, NREC

Welcome to the second edition of our newsletter from the Nanotechnology Research and Education Center (NREC). The new name 'Nanotechnology Research and Education Center' is working in true sprit to focus on both research and education related activities. The NREC is enabling our faculty, students, and industrial partners to carry out state-of-the-art research and development work. The NREC is promoting truly multidisciplinary research, which advances knowledge in addition to fostering relationships that enhance the transition of basic research results to devices and other applications.

In the spring 2011 semester, our Center educated graduate students, post doctorial and industrial researchers through our training programs that center around our characterization tools and processing techniques using our equipment. A new, state-of-the-art high resolution scanning electron microscope was installed and our first group of students completed training on this instrument. The technical staff contributed to several engineering formal classes as guest lecturers and they performed demonstrations in our laboratories for these classes. The NREC hosted over ten seminars and talks from visiting faculty and industry that pertain to nanotechnology related topics. Periodic tours were given to K-12 programs as well as visiting prospective students, parents, new USF employees, and administrators from other universities as part of our outreach activities.

Recently, I attended the 10th anniversary of the National Nanotechnology Initiative (December 8-10, 2010) and came to know the investment from 25 federal agencies and many industries focused on producing revolutionary and transformative technologies and breakthroughs. The future of nanotechnology looks promising and its rapid development worldwide is a testimony to the transformative power of identifying a concept or trend and laying out a vision at the synergistic confluences of diverse areas. To this end, the NREC looks forward to a productive summer working with our faculty users and students and serving our industrial researchers.

New Tools

High Resolution Scanning Electron Microscope

The NREC is excited to announce that the new Hitachi SU-70 High Resolution Scanning Electron Microscope has now been installed in Nanotech I.

Numerous new scientific investigations will be enabled with the new equipment including imaging, elemental analysis and the fabrication of nanostructures by both electron beam lithography (EBL), and direct write electron beam induced deposition (EBID).

• EBL is a resist-based lithography similar to optical lithography. Pattern designs are scanned onto the resist using the electron beam of the SEM. The resist is developed leaving behind a copy of the pattern.

• EBID is a direct-write lithography which uses a Gas Injection System (GIS) to deposit nanostructures by Chemical Vapor Deposition (CVD). The electron beam induces deposition of the injected gas on the substrate directly, avoiding the need for a mask. Both etching and deposition can be performed depending on the gas used.

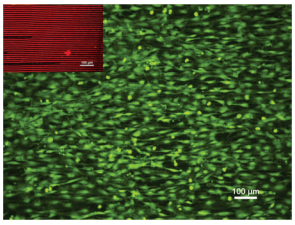
Research Awards

Assistant Professors Gallant and Lusk receive NSF CAREER Awards

Dr. Nathan Gallant is designing and building micro-patterned structures to study the effects of mechanical inputs on the behavior and bio-chemical responses of cells.

Development of combinatorial materials on a substrate, such as a gradient of protein density deposited perpendicularly to a gradient of a varying mechanical property (such as shear or strain), allows a range of multiple inputs to be tested and any synergistic effects revealed.

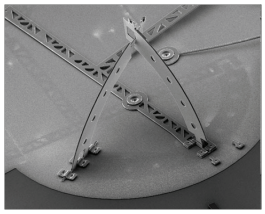
Cell alignment on thermally responsive polymer surface extrusions direct tissue organization and permit intact tissue release (below). Micro-patterning of the surfaces can influence cell spreading and adhesion. The ultimate goal is to design optimal bio-materials for medical implants or tissue regeneration.



The use of the cleanroom, photolithography equipment and electron-beam evaporator in the NREC helps Dr. Gallant in his research.

Dr. Craig Lusk specializes in the design and implementation of Shape-Shifting Surfaces. These are three-dimensional arrangements of plates and flexures that form a continuous, two-dimensional surface. These arrangements can expand, shift, or contract in response to external forces without introducing gaps in the surface.

Dr. Lusk has created macro-sized models in geometric shapes such as square and triangular. Typically, a model consists of four layers connected to a pivot point at each corner. Every layer has a component that contributes to the 2-D surface, and compliant mechanisms or "flexures" that provide connections, help hold the shape, and deflect with spring rates based on the construction material properties and the physical design.



Applications for this technology include structural, electrical, and bio-medical. Dr. Lusk's research group uses equipment in the NREC cleanroom and will use the HR-SEM for this project.

Professors Kumar and Morgera elected Fellows of the American Association for the Advancement of Science (AAAS)

Dr. Ashok Kumar was elected as a Fellow of AAAS for his "pioneering research in the field of thin film technology for multifunctional applications and for service to the broader materials community." Dr. Kumar's group heavily uses the NREC facilities (including cleanroom and materials characterization) for various projects funded both from public and private sources.

Dr. Salvatore Morgera was elected as a Fellow of the AAAS for "pioneering research in structured estimation theory, adaptive communications, and pattern analysis and for academic program development in undergraduate Engineering Leadership and graduate Bioengineering." Dr. Morgera is directing an NSF-funded Industry & University Cooperative Research Program (I/UCRC) and many of the associated faculty with this project use NREC facilities.

Founded in 1848, the AAAS is an international non-profit organization with the mission of world-wide advancement of science, engineering, and innovation. It also publishes the journal *Science*, which has the largest paid circulation of any peer-reviewed journal in the world (over one million).

Staff Spotlight

Dr. Yusuf Emirov, Metrology Scientist

Originally from the Russian city of Makhachkala on the shore of the Caspian Sea, Dr. Emirov attained his Ph.D. from the Institute of Semiconductors in Kiev (Ukraine) and later the highest Russian scientific degree, the Doctor of Science, from the world famous Physics Institute of Russian Academy of Science (in Moscow), which has produced six Nobel Prize winners.

At that time, he studied copper migration in semiconductors in addition to photoluminescence and photoconductivity of semiconductors and structures. He is the author and co-author of more than 90 scientific publications.

Joining the NREC staff in 2003, Yusuf has extensive experience in metrology techniques for macro- and nano-dimensional material characterization. He has become proficient in the operation of several nanotechnology tools for materials characterization: Atomic Force Microscope (AFM), Transmission Electron Microscope (TEM), and the sometimes challenging art of sample preparation for TEM using the Focused Ion Beam (FIB).

Dr. Emirov trains users on all of these tools: AFM, FIB, TEM, which over 250 student researchers have successfully completed.

Faculty Spotlight

Nathan Crane, Ph.D.
USF Dept. of Mechanical Engineering

Completed his Ph.D. at the Massachusetts Institute of Technology in 2005. Dr. Crane's research interests include micro and nanoscale assembly, additive manufacturing/rapid prototyping processes, and manufacturing process development.

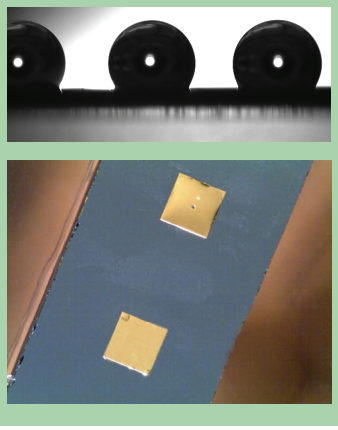
The two main thrusts for Dr. Crane's research are self-assembly of electronic structures at the micro/nano scales and controlled electrowetting of surfaces for actuation at the meso and micro scale.

For micro-assembly, methods have been developed for using surface tension forces to control the assembly of small components. This work has been demonstrated with the fabrication of miniature thermoelectric coolers and microscale photovoltaics.

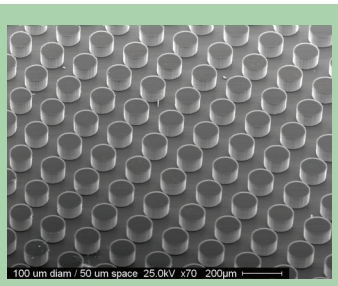
The other research focus of electrowetting involves the control of fluid in small volumes (such as droplets) using externally applied electric fields to alter interfacial tension, causing a change in the contact angle and/or motion of the droplet. Dr. Crane has demonstrated continuous droplet motion at velocities of up to 50mm per second using DC voltages. Applications include lab-on-a-chip, micro-lenses, tunable filters, and display devices.

Some of the NREC equipment that is used in Dr. Crane's research includes: electron beam lithography, e-beam evaporator, chemical vapor deposition, deep reactive ion etch (DRIE), wafer dicing saw, and various metrology instruments.

http://www.eng.usf.edu/~ncrane



Water droplets on surface (top), conforming to patterned electrowetting areas (middle). Micropillars formed via DRIE (bottom)



Jing Wang, Ph.D.
USF Dept. of Electrical Engineering

Completed his Ph.D. at the University of Michigan in 2006 . Research areas of interest: functional nanomaterials, micromachined sensors and actuators, RF/microwave/THz devices.

Dr. Wang is currently an Assistant Professor in the Department of Electrical Engineering at USF. To date, Dr. Wang's core technical contributions relate to the application of advanced nanotechnology and micro-fabrication methods for the development of RF/microwave devices. This work includes: the synthesis and utilization of magnetic nanoparticles, design and fabrication of MEMS resonators and filters, and developing injection-moldable polymer nanocomposites for ultra-high density interconnects.

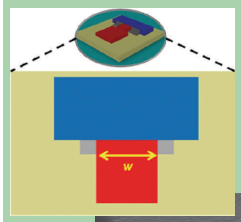
Two of the REU students from his group received Second Place in the *Student-Built Vacuum Systems Design* Poster Competition during the American Vacuum Society's (AVS) 57th International Symposium in October 2010.

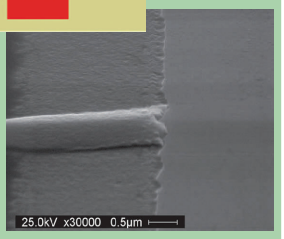
Recently, Dr. Wang received an NSF GOALI award for "Antenna-Coupled ALD-Enabled Metal-Insulator-Insulator-Metal Diodes for High Responsivity and High Resolution THz/Infrared Focal Plane Arrays" along with co-PI Dr. Mumcu (Elect. Eng.). The research objective is to develop and integrate room temperature M-I-I-M tunnel diode detectors within miniature antenna focal plane arrays for high resolution THz/infrared imaging and energy harvesting. The approach is to enhance diode nonlinearity by using dual tunnel junctions and system level design to address impedance mismatch, antenna size and bandwidth.

The novelty of this work is not only to improve responsivity of individual MIIM diodes by employing double tunnel junction with enhanced nonlinearity and asymmetry, but also to develop an array of detectors that are optimally tuned by addressing issues of impedance matching, compact antenna size, diffraction limits, and interelement electromagnetic (EM) couplings.

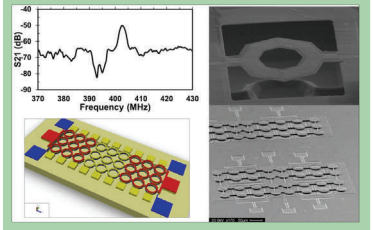
Dr. Wang's research group fully utilizes all aspects of the NREC, from photolithography and deep reactive ion etching in the cleanroom to various types of thin film deposition, along with the entire suite of metrology equipment in the facility.

http://transducers.eng.usf.edu/

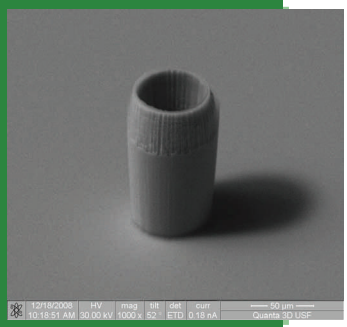




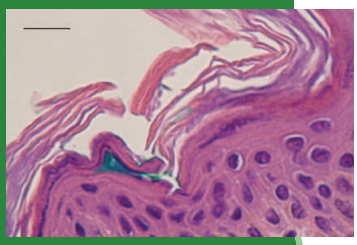
The schematics and SEM photos of micro-fabricated MIIM diode with nano-scale junction (top) and on-chip micromechanical resonators (bottom)



Student-Alumni Profiles



SEM image of SiO_2 Micro-needle (top) and cross-section of punctured skin layer (below).

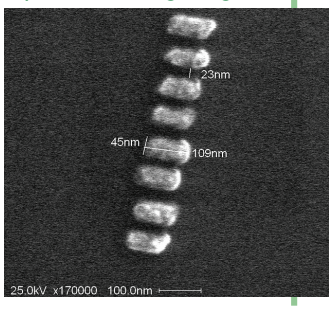


Puneet Khanna, Ph.D. - Receiving his degree in 2009, Dr. Khanna's research centered on the fabrication and optimization of silicon dioxide-based micro-needles for painless punctures of human skin. This has many applications such as real-time diabetes monitoring, drug delivery for inexpensive, disposable, self applied vaccinations.

In addition to a reduction in pain, SiO_2 micro-needles offer other advantages such as reduced insertion force due to tip shape, increased reliability (lateral force resistant), and enhanced biocompatibility.

Puneet has started the next phase of his career at Global Foundries in Fishkill, NY. His experiences in the NREC cleanroom, operating various tools such as the Deep Reactive Ion Etch (DRIE), have given him valuable skills that he described as the "Art of Fabrication". These skills will be useful as he performs Front End Of Line (FEOL) processes as a principal engineer.

Javier Pulecio, Ph.D. - A 2010 graduate, worked in Dr. Sanjukta Bhanja's Nano-Computing Research Group on Field-Coupled Nano-Magnetic Logic Systems, which is the use of nano-sized magnets (below) fabricated in specific patterns to produce logic gates capable of computation through single domain magnetic dipolar coupling. Unlike traditional computers which utilize the "movement" of electrons, magnetic logic uses the magnetic moments of electrons to implement Boolean functions with the promise of scaling down to atomic scale and creating ultra low power devices.



Many pieces of equipment in the NREC were used in this research including the cleanroom, SEM for electron-beam lithography, evaporator for metal deposition, and Scanning Probe Microscope for Atomic and Magnetic Force Microscopy.

After graduation, Javier accepted a position as a Research Associate in the department of Condensed Matter Physics and Materials Science at Brookhaven National Laboratory in New York.

Congratulations to former NREC user Shyam Aravamudhan on becoming Assistant Professor at Joint School of Nanoscience and Nanoengineering at North Carolina A&T State University.

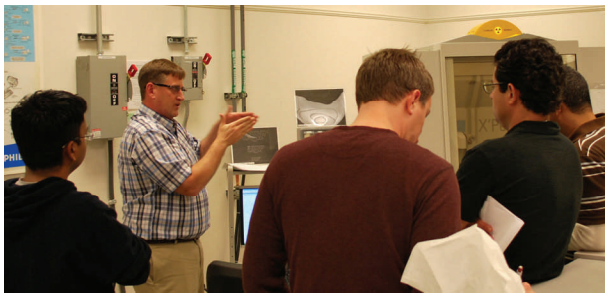
Education

NREC has trainings for faculty, students and industrial users to teach proper operation of the tools that are in the facility. Recently, various graduate students were trained on the Focused Ion Beam tool (all three phases) and the new SU-70 Scanning Electron Microscope.

Last semester, Dr. Lucille Giannuzzi was invited by the NREC to give a two-day workshop on Transmission Electron Microscope (TEM) and Focused Ion Beam (FIB) tools and techniques. The workshop was well-attended by an interdisciplinary group of faculty and students who learned about 3-D characterization, nano-prototyping, cross-sectioning and specimen preparation, crystallography, interface investigation, and biomaterial applications

Dr. Stephen Fonash, from the Nanotechnology Applications and Career Knowledge (NACK) Center at Penn State University, was a guest speaker this semester giving an inspiring talk on "Post-Secondary Nanotechnology Education and Workforce Development in the US," in addition to a technical talk "Exploration of Light and Carrier Collection Management Solar Cells."

Again this semester, the NREC staff provided support for the "Characterization of Materials" course by providing guest lecturers and laboratory demonstrations.



Industry Spotlight

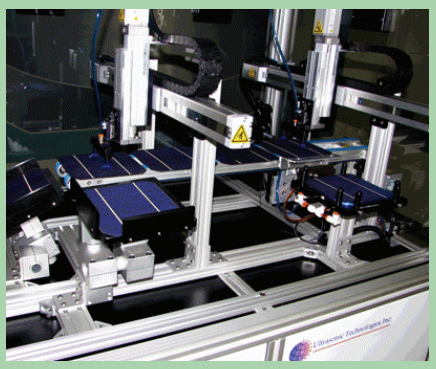
Ultrasonic Technologies Inc.

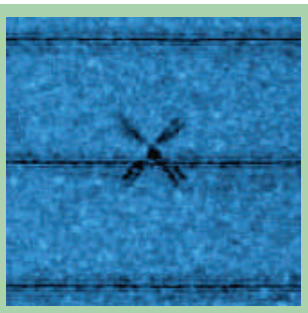
Founded by Sergei Ostapenko, Ph.D., in 1997, Ultrasonic Technologies Inc. specializes in crack detection in Si solar cells and solid oxide fuel cell (SOFC) substrates using Resonance Ultrasonic Vibration (RUV) Technology (www.ultrasonictech.com).

The RUV technique is developed as a real-time quality control automatic system for off-line and in -line non-destructive crack detection in full-size silicon wafers, solar cells and SOFC substrates. The RUV methodology relies on deviation of the resonance frequency response curve measured on a wafer with a peripheral or bulk millimeter-length crack compared to non-cracked standard wafers. A proprietary statistical algorithm provides up to 95% accuracy of crack inspection with throughput rate of 2 seconds per wafer.

Detection of mechanical defects is important in solar wafer manufacturing to avoid in-line breakage and reduce costs associated with processing a pre-damaged wafer with seed mechanical flaws.

Dr. Ostapenko is the sole-inventor of RUV technology protected by the 2002 US patent. He performed with a group of graduate and undergraduate USF students fundamental study of the RUV methodology under support of DOE, NSF and private solar companies. Dr Ostapenko was associate professor working at CMR/NNRC/NREC in the CoE since 1993.





RUV Machine (top) and pinhole defect in solar cell (bottom)

Industry Spotlight

MUSTANG VACUUM SYSTEMS

Edward Gillman, Ph.D.

Ph.D. from Florida State U. in 1997

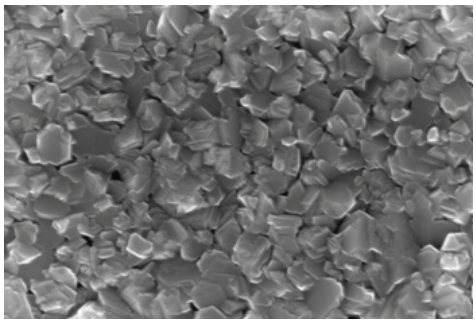
Senior Scientist at Mustang Solar, Sarasota, FL

Work at Mustang is focused on the large scale production of Copper Indium Gallium Selenide (CIGS) photovoltaic materials. Our technologies are designed to optimize the solar cell manufacturing process with excellent uniform coatings, able to be produced in less time, with minimum waste of materials along the way.

This helps today's solar cell producers to maximize profits while playing an important role in preserving our global environment. Mustang Solar is a wholly-owned subsidiary of Mustang Vacuum Systems; a global leader in thin film technologies.

The facilities at the University's Nanotechnology Research and Education Center such as X-ray and SEM allows Mustang Solar to rapidly characterize the latest developments at Mustang's Research and Development Center and adapt them for the lowest device cost and maximum productivity of CIGS solar cells.

Processes under development include Front Contact – TCO, Window Layer CdS, Absorber and CIGS Back Contact, which are deposited by physical vapor deposition (PV, PVD, PE-PVD), sputtering (DC, RF, AC or pulsed DC power) and evaporation.



Crystalline CIGS film produced with a Mustang Solar deposition system

Having facilities available in a shared-user facility like the NREC, allows Mustang to concentrate its R&D effort on production, rather than duplicating these resources at its Sarasota location.

This project is in collaboration with Dr. Don Morel and Dr. Chris Ferekides from the University of South Florida Department of Electrical Engineering.

Nanotechnology Research and Education Center

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We're on the Web
www.nrec.usf.edu

Conferences and Seminars

Anton Paar

The NREC, in partnership with Anton Paar GmbH, is organizing a one-day seminar on rheology — measuring the deformation, shear, and viscoelastic behavior of materials under different conditions.

Applications include: polymers (polymer melts and solutions), biotechnology (biomaterials, pharmaceuticals, etc.), materials science, paints and coatings, adhesives, energy-curable resins (UV, light. etc.), food science (academic and industrial), lubricants, metallurgy (for example metal melt rheology), electro and magneto-rheological fluids, nanotechnology (interaction of nanoparticles with polymers, for example), building materials (e.g. cements and grouts), asphalt testing (primarily for highway applications) and many others.

Mr. Thomas Mezger completed a degree in Chemical Engineering at Stuttgart University, Germany. He has gained a wealth of experience in the field of practical rheology during his years with rheometer manufacturers Contraves, Physica, and Anton Paar. For over 10 years Mr. Mezger has held seminars for employees of companies and institutes from a wide range of technical branches.

Using his experience in the field, Mr. Mezger wrote The Rheology Handbook, which was published in 2002.

Rheology one-day seminar
Friday, May 20th, 2011
8:30am, CUTR Room 102
www.nrec.usf.edu for more info

Donations

The Nanotechnology Research and Education Center is a vital component in the development or cutting-edge research. Your financial contributions supplement state and grant funding, and make an enormous difference in our efforts to further research capabilities and improve our infrastructure. Equipment donations are also encouraged. All gifts are tax deductible. If you have any gift/tax questions please contact Brett Woods, Director of the USF's College of Engineering Development Office at (813) 974-9199 (or e-mail, bwoods@usf.edu). Thank you for your generous contribution to the USF NREC!

Ashok Kumar, Director, NREC

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