University of Minnesota

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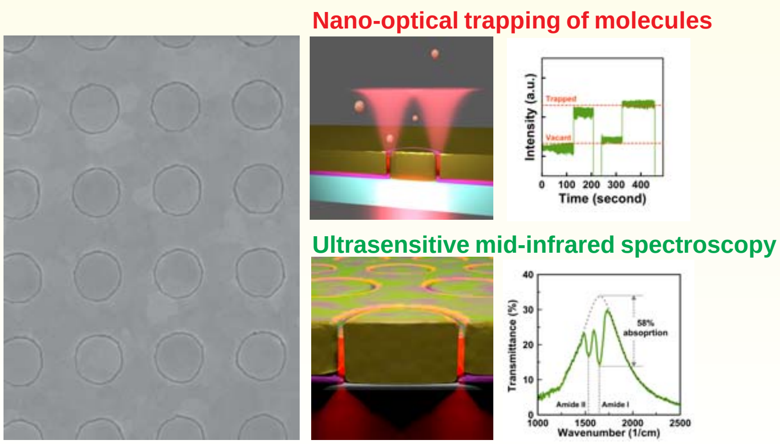
Gold Nanogaps Trap Light and Biomolecules

Prof. Sang-Hyun Oh's group in the ECE department at the University of Minnesota (http://nanobio.umn.edu) is developing a new generation of biosensors that can manipulate and detect biomolecules potentially down to the single-molecule level using ultrasmall gaps in gold films.

Atomic layer deposition (ALD) is one of the most advanced thin-film deposition techniques and is widely used in the microelectronics industry. As the name suggests, the ALD technique can deposit Angstrom-scale films with unparalleled thickness precision and conformality. Since 2009, Prof. Oh's team has pursued a new scheme to leverage the atomic-scale precision of ALD to define ultrasmall features (gaps, slits, rings, etc.) in metal films, a technique now called atomic layer lithography. The team has heavily used the ALD tools available in MNC and has been pushing the limit of the atomic layer lithography technique and finding novel applications in biotechnology and photonics. Recent papers from Prof. Oh's group (Yoo et al., 2018), led by a research associate Daehan Yoo, showed that annular nanogaps patterned in gold films via atomic layer lithography can trap light and dramatically boost optical near-field intensity, which can be used for optical trapping of biomolecules and even detect them with ultrahigh sensitivity (Fig 1).

With the newly acquired plasma-enhanced ALD (PEALD) tool, the team is trying to further improve the resolution and applicability of atomic layer lithography, which is a unique technology that was born in the MNC environment.

Daehan Yoo et al., Nano Letters (2018) 18, 3637
Daehan Yoo et al., Nano Letters (2018) 18, 1930



SEM image: A dense array of ring-shaped nanogap (10 nm width, 250 nm diameter) is created in a gold film via atomic layer lithography.

Upper right image: Upon laser illumination, individual gold nanoring can act as an optical trap. The trapping event for a single nanoparticle can be detected in real time.

Lower right image: When the ring diameter is enlarged, its optical resonance can be pushed to the mid-infrared regime. The team showed high-contrast and ultrasensitive mid-infrared spectroscopic detection of protein molecules with resonant gold nanogaps as narrow as 7 nm.

REMINDER: If your work uses the Minnesota Nano Center, please add the following in the acknowledgements section of any publications: "A portion of this work was carried out in the Minnesota Nano Center which receives partial support from the NSF through the NNCI program."

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CharFac Director, Greg Haugstad

CharFac is now the third imaging-intensive UMN core facility to be staffed with a resident data scientist. The U of M Informatics Institute (UMII), funded by the Office of the Vice President for Research, has hired Dr. Guichuan Yu to collaborate with CharFac staff scientists.

Much of Dr. Yu's work will develop matlab applications for data processing, visualization, analysis and modeling. Other work will develop custom scripting for usage in data acquisition. These efforts reflect the fact that commercial software, as provided by instrument vendors and 3rd party developers, is often insufficient to address many questions encountered in analytical research, whether through deeper data analysis, creative data acquisition algorithms, or both. Many potential datasets can contain rich information about sample structure and/or properties that cannot be accessed if lacking custom algorithms, data visualization and modeling. Here are examples from the early stages of Dr. Yu's work.

In collaboration with postdoc Mihee Kim from Prof. Frank Bates group, staff member Greg Haugstad has used mapping of AFM force-versus-distance curves to probe the strength of lipid bilayers. The bilayer rupture force is sensed as a first peak in each curve during approach whereupon the AFM tip penetrates through bilayer to supporting substrate. The force has both spatial variations and statistical fluctuations. Although commercial AFM software is adequate for *acquiring* the mapped dataset, it provides no way to *programmatically* (i) quantify rupture force, (ii) generate spatial maps of rupture force, and (iii) compile a population of rupture forces. Dr. Yu has written efficient matlab software to address all three needs (Figure 1).

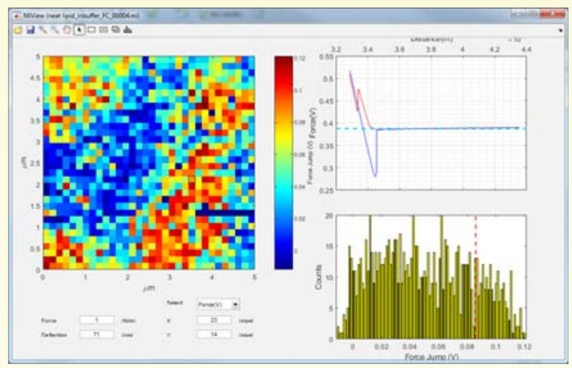

Figure 1. Custom matlab software for mapping rupture force values (left) obtained from force-distance curves (one example in upper right, red being approach data), and compiling a histogram of all rupture force values (lower right).

Dr. Yu also has worked with staff member Javier Garcia-Barriocanal to create universal X-ray scattering software for CharFac's X-ray diffractometers and small angle X-ray scattering instruments with 2D detectors. The new software simplifies experimental procedure and data reduction for thin film characterization employing reciprocal space mapping. It enables the characterization of in-plane structural correlations through the measurement of off-specular diffraction poles. This development allows new methodologies such as *crystal truncation rod* analysis.(See Figure 2.)

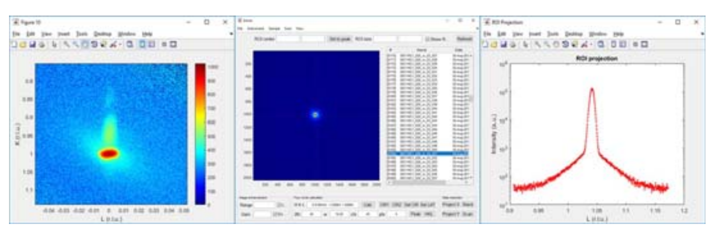

Figure 2. Data visualization and analysis software for X-ray scattering experiments. The software includes a reciprocal space calculator to help with the experiment design. It also unifies the software across different instruments from different vendors.

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Greg Haugstad, Director

MINNESOTA nano CENTER news

MNC Director, Stephen Campbell

Welcome back to the new school year. The Nano Center is pleased to announce several new systems, as Greg discusses in this newsletter. I recently returned from the annual National Nano Coordinated Infrastructure (NNCI) network meeting in Seattle. At this meeting NSF reviews the performance of the sixteen sites that it funds. Our work was very well received, but I need your help on one matter. We have been doing a very poor job of acknowledging NNCI support on our publications; only seven papers acknowledged it last year. While you must always acknowledge your primary sources of support, keep in mind that lab fees will increase by about 25% if we lose NNCI funding. Please use the following verbiage in all of your publications that use the lab in any way: "Portions of this work were conducted in the Minnesota Nano Center, which is supported by the National Science Foundation through the National Nano Coordinated Infrastructure Network, Award Number NNCI-1542202." You can also find this wording on the MNC website.

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Steve Campbell, Director
Greg Cibuzar, Lab Manager

Equipment Update

In the past year, there have been several changes to our equipment set. The Plasmatherm deep trench etcher received a full update to install the Cortex software, a much needed improvement to the operator interface and maintenance support. The MNC evaporators are getting updated to new deposition IC6 deposition controllers. For the CHA evaporator this involves a significant change to the PLC programming. Our workhorse RIE in the Keller cleanroom is the STS etcher, and it is over 20 years old, but still running well and heavily used. Earlier this summer we placed an order for a new Vision 320 etcher from Plasmatherm (pictured below) to complement the STS etcher, and it should be installed around the end of the year.

In the PAN cleanroom we installed a generous donation of a March Instruments oxygen plasma asher and Leitz Ergolux optical microscope from Anvik Corporation in New York. The O2 asher is especially needed in the PAN cleanroom to augment resist stripping capabilities.

New User Orientation

MNC is offering New User Orientation for new users twice each month. On the first Wednesday of every month, the session begins at 1:00pm, and on the third Thursday of the month the session begins at 10am. A MNC staff member provides a tour showing some of the safety related equipment and the gowning process used for the MNC cleanroom. There is also training on using Badger, the lab software. The safety training takes about one hour to complete, and must be done before users will be granted access to MNC facilities. See the 'For New Users' section of our website for complete information: www.mnc.umn.edu/newusers.php.

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Minnesota Nano Center and the National Nanotechnology Coordinated Infrastructure

The MNC is a state-of-the-art facility for interdisciplinary research in nanoscience and applied nanotechnology. The Center offers a comprehensive set of tools to help researchers develop new micro- and nanoscale devices, such as integrated circuits, advanced sensors, microelectromechanical systems (MEMS), and microfluidic systems. The MNC is also equipped to support nanotechnology research that spans many science and engineering fields, allowing advances in areas as diverse as cell biology, high performance materials, and biomedical device engineering.

In September 2015, the National Science Foundation funded the National Nanotechnology Coordinated Infrastructure (NNCI). MNC is part of this initiative, along with our partner facility at North Dakota State University. The NNCI aims to advance research in nanoscale science, engineering and technology by enabling NNCI sites to provide researchers from academia, small and large companies, and government with access to university user facilities with leading-edge fabrication and characterization tools, instrumentation, and expertise within all disciplines of nanoscale science, engineering and technology. The NNCI framework builds on the National Nanotechnology Infrastructure Network (NNIN), which enabled major discoveries, innovations, and contributions to education and commerce for more than 10 years.