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NANOTECHNOLOGY NEWS FROM THE UNIVERSITY OF MINNESOTA

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NATIONAL NANOTECHNOLOGY INFRASTRUCTURE NETWORK FEATURED RESEARCH

Resolving 100 nm Features with Photolithography

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Patterning of nanometer-sized features is essential for a wide range of science and engineering applications. The usual candidate for patterning such small features is electron beam (e-beam) lithography, but this is a time consuming and expensive process. Our group previously developed a cheaper and faster alternative by using phase-shift photolithography [Meng and Wang, IEEE Trans Magn 2005] on a Karl Suss Mask Aligner. We recently adapted the process to the Cannon Stepper in order to exploit the benefits of that system. All of the phase-shift masks were fabricated on site in the Nanofabrication Center at the University of Minnesota. With these masks, we were able to resolve features below 100 nm.

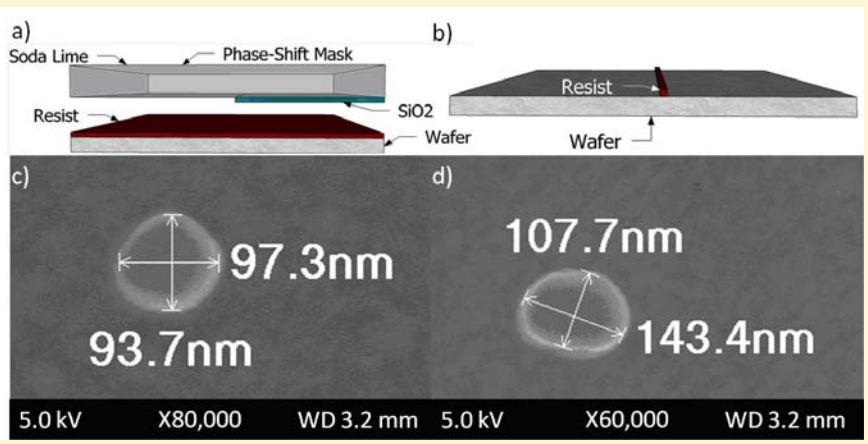

Fig 1. Schematic of phase-shift photolithography a) exposure and b) after development. SEM images of c) near circular and d) elliptical Shipley 1805 resist pillars.

Figure 1a shows a schematic of the setup used for phase-shift pattering. The phase-shift mask has patterned SiO_2 features on top of the underlying soda lime or quartz which modulates the phase of light by half a period with respect to the glass only areas of the mask. Consequently, the edges of the patterned SiO_2 create a destructive interference pattern that results in a local minimum in light intensity. If the sample is developed after just one exposure, then resist remains only at the SiO_2 edges as shown in Figure 1b. If instead the development is preceded by a second exposure with a different mask, then individual elements such as dots can be patterned with sizes below 100 nm as shown in Figure 1c. To test the process variability, a random sample of 50 elements selected across a 4 in wafer measured an average diameter of 106 nm with a standard deviation of 17 nm. In addition, we have been able to control the aspect ratio and pattern elliptical elements as shown in Figure 1d.

In summary, phase-shift photolithography on the Cannon Stepper allows 100 nm features to be patterned and aligned within 100 nm in a relatively fast and cheap method. These results hold great promise and have wide spread application as an attractive alternative to e-beam lithography methods.

Reminder: If your work uses the Nanofabrication Center please add the following in the acknowledgements section of any publication: "Parts of this work were carried out in the University of Minnesota Nanofabrication Center which receives partial support from NSF through the NNIN program."

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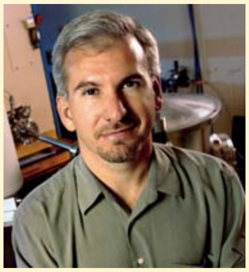
Characterization Facility News

CharFac Director's Message



CharFac Director,
Greg Haugstad

This past summer was busy with special events in the CharFac, most notably an educational experience for graduate students on complementary imaging techniques utilizing electron beams (+ cryo methods), confocal & Raman-scattered visible light, and proximal probes (atomic force microscopy and related). The practicum followed PowerPoint lectures spread over several Fridays introducing the techniques. Importantly, this developmental experience was in preparation for next spring's graduate course in correlative nanoscale imaging, a new era for graduate *curricular* activity in the CharFac. Historically several graduate courses have lightly utilized CharFac labs for demos and perhaps student analysis of generated data. Some dedicated courses in electron microscopy have covered a subset of EM imaging techniques, including some hands-on instrument usage. But in recent years other imaging techniques have had at most brief treatments within a survey course on (non-bio) materials characterization. One-on-one training in advanced methods has been on offer in the CharFac (and the St. Paul campus' Imaging Center) but rarely utilized; among likely reasons are cost and lack of credit towards formal graduate curricula. The materials, bio- and analytical *(continued, top right)* science that underpin advanced methods beg a lengthier period of focused study, akin to other topics within a graduate curriculum. The new course will endeavor to fill this gap. The description follows, taken from a proposal to the graduate school.

"This Graduate Minor program will provide integrative classroom and instrument education and training for graduate students to use complementary imaging and correlative techniques to dynamically probe the chemical and physical properties of natural and synthetic materials across the nanometer and micrometer scales. Our approach is transformative in that, for the first time, we will provide the pedagogical structure needed for the early PhD student to undertake systematic, concentrated study and training in a wide range of advanced nanoimaging techniques and applications. For many students (and advisors), this will be an attractive alternative to piecemeal training with little background coursework. This experience will better prepare the student to make effective choices for research and will instill an integrative approach that will enhance career-long contributions to science as techniques continue to evolve quickly." Students participating will be team-taught by faculty in the College of Science and Engineering, the College of Biological Sciences, and the Academic Health Center.

We have upgraded SPM3 to be equivalent to SPM4 in base AFM capabilities. This provides two systems with controlled humidity (1-95%) and sample heating (up to 250ºC). Maintaining low humidity can improve almost all modes of AFM in air, even if variable humidity per se is not relevant to a research question (as it can be in hygroscopic polymers, for example). Moreover both SPM3 and SPM4 have robust liquid cells. A single training certifies a user for basic operation of both Agilent systems. Importantly this will allow uninterrupted work when one system goes down for service (e.g., 1-2 months for scanners). Both systems now have the option to run the newer software Picoview or the previous Picoscan. Picoview has an improved user interface and allows for expanded data density (up to 4096x4096 pixel images). Both allow collecting a greater number of images in parallel than our Veeco Nanoscope systems. Picoview is needed to use the new multifrequency methods on SPM4 announced in the previous newsletter. SPM4 remains the system dedicated to advanced methods: close loop scanning, digital pulsed force mode, current sensing, Q control, shear modulation and setpoint ramping, as well as the multifrequency methods.

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Greg Haugstad, Director

NANOFABRICATION CENTER NEWS

NFC DIRECTOR'S MESSAGE

NFC Director,
Steve Campbell

This promises to be a very busy fall. NFC should receive three new pieces of equipment. In October we will take delivery on an Advanced Vacuum model 320 batch reactive ion etcher configured for dielectric etching. This system is similar to the existing STS etcher which is heavily used, but is no longer supported by the vendor. In November, we expect delivery of a new five-gun AJA sputtering system. This will have dedicated targets of the most commonly sputtered materials. The largest system we are expecting will also be delivered in November. This is the new direct write electron beam lithography system. Over the spring and summer, a faculty group evaluated three vendors. The selected vendor, Vistec, not only has an exceptional system, they provided a unique opportunity. They had a system on the floor that had been built for another customer, but that order was cancelled. We were able to use this situation to add capabilities to the system without exceeding our budget. The result is a 50 MHz tool, capable of writing 8 nm lines, that can be delivered much sooner than would otherwise be the case. The system is close to an order of magnitude better than the current Raith in resolution, overlay, and speed. We expect to decommission the Raith in late October to make

(continued, top right)

room for the Vistec. Contact NFC if you need details on the schedule.

We also have made two personnel changes. As you may know, John Schafer is out on leave. Matt Lowe is filling in for him, taking care of the information systems in NFC and CharFac. One of his projects in NFC will be to port our lab operating software, Coral, to a new and more reliable hardware platform. In addition, we have hired Dr. Bryan Cord. Bryan holds a PhD EE from MIT where he worked on electron beam lithography and e-beam resists. Bryan will be working with all of our users to ensure that they get the most out of the new lithography system. He is scheduled to start on October 11.

PHOTOMASK SERVICES

Many academic institutions and companies have some capability for thin film processing, such as deposition, etching and lithography. Photomasks, a key component of the lithography process, often consist of a glass plate with a patterned layer of chromium metal. The pattern corresponds to the design of the layer currently being processed. The fabrication of photomasks requires specialized equipment that is not available at many research labs. At NFC we have the capability to make photomasks with feature sizes down to 1.5 microns. The masks can be made on soda lime or quartz plates, with mask sizes as large as 8 by 10 inches (4 and 5 inch square plates are stocked). Both darkfield and lightfield masks can be fabricated. The cost for academic institutions for darkfield masks is $270 (higher for more complex designs), and lightfield masks cost $300. If you are interested in learning more about having photomasks made at NFC, please send an email to nfcmasks@umn.edu.

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Steve Campbell, Director
Greg Cibuzar, Lab Manager

SAFETY TRAINING

NFC is offering safety training for new users twice each month. On the first Thursday of every month, the training sessions begin at 1:00PM, and on the third Thursday of the month sessions begin at 10:00AM. The training includes watching our safety video and taking a brief quiz. Also, a NFC staff member provides a tour showing some of the safety related equipment and the gowning process used for the NFC cleanroom. Finally, there is training on using the Coral lab software. The safety training takes about two hours to complete, and must be done before users will be granted access to NFC facilities.

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Center for Nanostructure Applications

The primary mission of the Center for Nanostructure Applications is to seed interdisciplinary nano research projects that will go on to attract external support. Active nanostructures include applications of nano as diverse as energy conservation and production, large area displays and lighting, printed electronics, smart fabrics, electronic noses, drug delivery, cancer therapy, and new types of medical imaging.

These applications often require significant participation across traditional disciplines and the Center is designed to foster the cross-disciplinary research necessary to bolster the nano applications area at the University.

The Center also organizes workshops, speaker series, and short courses, as well as serving as a focal point for nano at the University.

For more information, visit http://www.nano.umn.edu/

The National Nanotechnology Infrastructure Network

The National Nanotechnology Infrastructure Network (NNIN) is an integrated networked partnership of user facilities, supported by the National Science Foundation, serving the needs of nanoscale science, engineering and technology. The mission of the NNIN is to enable rapid advancements at the nano-scale by efficient access to nanotechnology infrastructure. The NNIN supports the Nanofabrication Center at the University of Minnesota. As a node in NSF's National Nanotechnology Infrastructure Network (NNIN), the NFC provides access to advanced multi-user facilities to both industry and academic researchers, the latter at a subsidized rate.

For more information, visit www.nnin.org