UNIVERSITY OF MINNESOTA

nanoTECHNOLOGY news

from the University of Minnesota

Fall 2019

Imprint Lithography Enables Roll-to-Roll Printed Electronics

Lorraine Francis, Dan Frisbie, and their graduate students in Chemical Engineering & Materials Science use the fabrication facilities in the MNC to support their research efforts in roll-to-roll (R2R) printed electronics. Their patented printing process called SCALE, for Self-Aligned Capillarity-Assisted Lithography for Electronics, combines R2R imprint lithography with ink jet printing of electronic inks. The SCALE process for creating conductor lines is illustrated in Figure 1. The process begins by creating a master template on a silicon wafer using photolithography and reactive ion etching steps (not shown). The completed master template is then replicated into an elastomeric rubber. The elastomeric stamp is peeled away from the template and attached to an imprint drum, Figure 1a. A continuous plastic 'web' coated with a UV curable liquid is brought into contact with the drum. UV light shining on the contact zone crosslinks the liquid and produces a micro-molded replica of the Si master features on the flexible web. The features consist of ink reservoirs and capillary channels. In the second step, Figure 1b, ink jet printheads dispense silver ink into the reservoirs and capillary forces draw the ink into the channels. The ink dries and is sintered, Figure 1c, creating silver-lined capillary channels. To build up solid metal lines, the web is immersed in a plating bath and copper plates out on top of the silver, Figure 1d. An example of the completed copper lines is shown in Figure 1e and a SEM image of the cross-section is in Figure 1f.

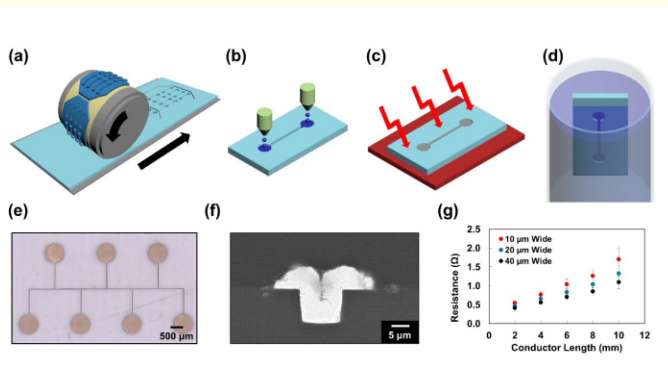

Figure 1. (a) R2R imprinting on a plastic web. (b) Ink jet delivery of silver ink to reservoirs. (c) Sintering of the silver. (d) Plating of copper on the silver lines. (e) Image of completed copper interconnects. (f) Cross-section of a copper line. (g) Resistance measurements demonstrating near bulk copper conductivity.

The advantage of the SCALE process compared to other printing methods is that the resolution and edge-roughness are dictated by the imprinting step, which has sub-micron capability. Also, the print and plate approach produces high aspect ratio metal lines whereas in normal printing the aspect ratios are generally not better than 1:10 (height-to-width). The SCALE process can be employed to build discrete devices such as resistors, capacitors, diodes, and transistors, from conducting, semiconducting, and insulating inks.

ACKNOWLEDGEMENT REMINDER

If your work uses the Minnesota Nano Center, please add the following in the acknowledgements section of any publications: "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."

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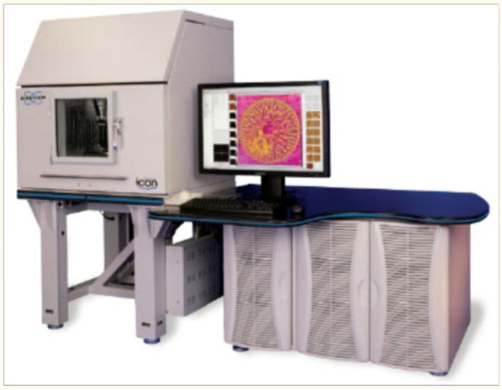
characterization FACILITY news

CharFac Director,
Greg Haugstad

In late August CharFac held an all-day open house in Shepherd including AM/PM poster sessions on common instrumentation and methods plus "lunch & learn" talks on recent or upcoming additions. We intend to repeat such events multiple times per year, including departmental venues. The poster session is a great opportunity to have casual discussions with staff experts, whether for introduction to capabilities, questions of feasibility, or to engage in brainstorming. Among the lunchtime slides was a comprehensive list (charfac.umn.edu/instruments/instrument_suite_2019.pdf) of data-generating instrumentation. Highlighted therein are systems added since 2017, an unprecedented period for both additions and replacements, in some cases leaping forward several instrument generations. Staff experts are eager to discuss both new frontiers in analytical methods and improvements to familiar work as provided by modernized systems.

We are particularly excited to announce the planned installation of two new atomic force microscopy instruments this fall (in addition to upgrades to current Bruker Nano V Multimode 8's from Win7 Nanoscope v9.3 to Win10 v9.7). One addition will be the first large-sample/motorized stage system in CharFac's 30-year history, the Bruker Dimension Icon. In addition to a vacuum chuck that can secure many samples at digitally defined locations, the Icon features a low-noise, fully closed-loop XYZ scanner with a 12-micron Z range. Importantly this scanner removes the artifacts of nonlinearity and cross coupling generated by its piezo-elements. Older vintage scanners often require ill-defined, nonlinear post-processing of data, for example to quantify small changes in surface height (e.g., film edge) that are spread over micron-scale lateral distances (e.g., when a film-deposition mask is not near the substrate). More egregiously, the measurement of large vertical changes over small lateral distances can be *erroneous* due to Z scanner nonlinearity (in addition to being *difficult* due to less-accommodating Z range). A past workaround required using a (noisy) Z sensor option on our Keysight AFMs (supported for a limited time due to exit from market).



Bruker Dimension Icon scanning probe microscope

The second major addition is truly novel: an "AFM-IR" system, the Bruker/Anasys NanoIR3. This system uses infrared laser light focused around the tip-sample interface, along with photoabsorption-induced sample response (e.g., expansion) *sensed* at the tip-sample interface, to provide IR absorption images down to ~10 nm spatial resolution. Mapped chemical information can be collected in a hyperspectral way (spectrum per measurement site) or more quickly/densely by imaging a particular absorption line. We anticipate users from multiple colleges within the university as well as external clients and collaborators from industry and academia.

CharFac at the
Univeristy of Minnesota

12 Shepherd Labs
100 Union Street SE
Minneapolis, MN 55455

Website: www.charfac.umn.edu
Email: charfac@umn.edu
Telephone: 612-626-7594

Greg Haugstad, Director

MINNESOTA nano CENTER news

MNC Director,
Stephen Campbell

Welcome back to a new school year. It is always great to see the new students. The 2020 academic year finds MNC in a very good position. Expenses have been decreased slightly and income from both internal users and external users is up. Also, we are delivering on our promises to the National Science Foundation through their NNCI program. This bodes well for our renewal application that will be submitted in the spring of 2020. To help us be successful, please remember to acknowledge NSF support of the laboratory in your papers. You can find the required verbiage by going to our web site and clicking on the "Current Users" tab.

This past summer Gary Olin, an MNC staff member for the past 15 years passed away suddenly at the age of 52. Gary's skills in equipment maintenance and facility operations will be difficult to replace. He was a good friend and will be missed by many.

Minnesota Nano Center at the
Univeristy of Minnesota

140 Physics & Nanotechnology Bldg
115 Union Street SE
Minneapolis, MN 55455

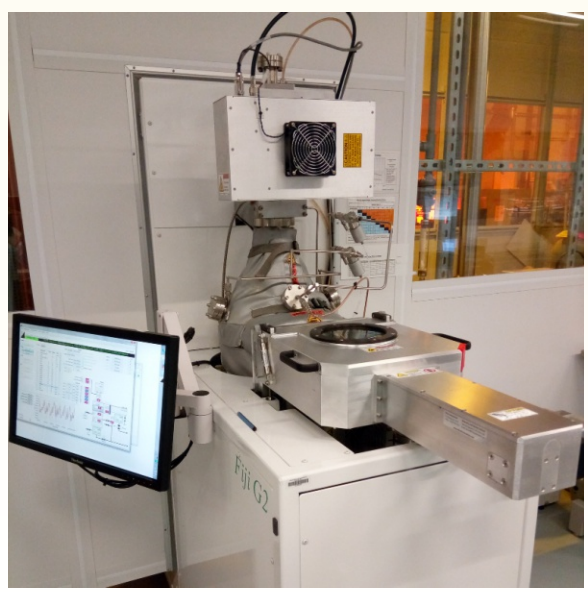
Website: www.mnc.umn.edu
Email: mnc@umn.edu
Telephone: 612-624-8005

Steve Campbell, Director
Greg Cibuzar, Lab Manager

Processing Capability: ALD Tools

Atomic Layer Deposition (ALD) systems allow very well controlled growth of extremely thin films, even over highly nonplanar structures such as nanopores, nanowires, and nanoparticles. Typical films are metal oxides, metal nitrides and metals. The process involves the sequential exposure of the substrate to two gases. The gases are chosen such that at least one of them saturates the surface at one monolayer of coverage and the process conditions are such that neither gas, by itself, will decompose to form a solid. After exposure to the first gas, the system is flushed, but one monolayer of this gas remains on the substrate where it can react with the second gas to form a monolayer of the desired film. The process is repeated until the desired film is grown.

MNC has two ALD systems, a standard thermal tool with ozone as well as a plasma-enhanced tool (PE-ALD). The thermal ALD currently has source materials for the deposition of HfO_2, Al_2O_3, SiO_2, TiO_2, and ZnO. The PE-ALD tool uses a plasma instead of thermal energy to drive the process, and this allows depositions to be done at lower temperatures. This tool currently has these films: HfO_2, HfN_2, Al_2O_3, Al_2N_3, TiO_2, and TiN_2. Due to increasing demands, MNC is in the process of adding a second thermal ALD system later this year.



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140 Physics & Nanotechnology Building
115 Union Street SE
Minneapolis, MN 55455

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.

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Direct requests to Becky von Dissen, 612-625-3069/vondi001@umn.edu.
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