



Summer 2019

## Flexible Electronics and Biomedical Sensors

Prof. Sarah Swisher's group in the ECE department develops materials and fabrication strategies to enable flexible electronics. The group's research focuses on thin, flexible sensors that will directly interface with the body. They formulate and synthesize electronic nanomaterial "inks", and then use high-precision additive manufacturing techniques (e.g. inkjet printing) to build flexible transistors and customizable electronic biosensors. As an example, Prof. Swisher's group has recently developed an implantable neural sensing device to explore communication paths between different regions of the brain using electrocorticography (ECoG). Prof. Swisher's group developed a process for patterning ECoG electrode arrays using inkjet printing on a thin (50  $\mu\text{m}$ ) transparent plastic film (Fig. 1). The completed ECoG array is bonded into a 3D-printed plastic frame (Fig. 2) to create a functionalized transparent polymer skull. In collaboration with Prof. Kodandaramaiah's group in Mechanical Engineering, this device will be chronically implanted in a mouse to record neural activity. This platform will enable chronic cortex-wide ECoG recording, and the additive manufacturing approach allows quick and easy modification of the electrode placement to target specific brain regions in different experiments.

Facilities at the MNC and CharFac were essential for the success of this work. The Parylene coating system acquired by the MNC in 2017 has been critically important. Parylene provides a conformal, impermeable, biocompatible polymer coating that electrically insulates and protects the ECoG arrays from physiological fluids during chronic implantation. In addition to flexible sensor fabrication, Prof. Swisher's group also develops custom nanomaterial inks for solution-processed electronics. They utilize a variety of tools for this work, including thin film metrology, etching, ALD, AFM, TEM, and XRD.

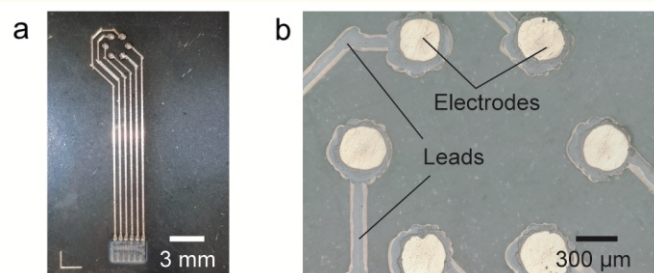


Figure 1. a) Optical image of completed inkjet-printed ECoG array. b) Close-up image of etched electrode surfaces and Parylene-encapsulated traces.

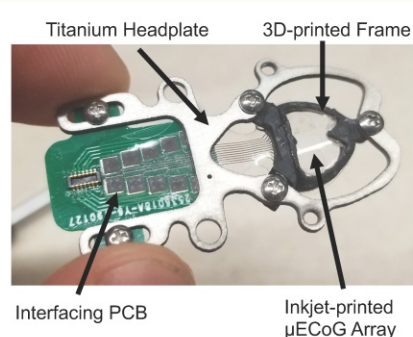


Figure 2. Inkjet-printed ECoG array ready for chronic implantation. The array is bonded into a 3D-printed frame and a titanium headplate, and connected to a PCB to interface the array with external electronics.

Donaldson *et al.*, IEEE EMBS Conference on Neural Engineering, 2019. doi: 10.1109/NER.2019.8717083

### 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*

We are excited to communicate a partial renovation of our Shepherd Labs basement facility containing the X-ray scattering labs and our large central spectroscopy lab. The decommissioning and removal of old SAXS systems has cleared space for wide-angle systems and bench space, such that we now have two labs dedicated to WAXS instead of one. The liberated space in our central lab provides a dedicated area for four data analysis stations, plus floor space for events organized by the technical staff (e.g., poster sessions, demonstrations, group software training). The converted-to-WAXS lab houses two new diffractometers (via an OVPR infrastructure award) and one older workhorse, as well as three sample stages for non-ambient work.

The first new instrument is the Rigaku Smartlab XE, which is a high resolution six-circle diffractometer ideal for the study of thin-films, single crystal and powder samples that would require angular resolutions as small as  $0.005^\circ$ . It is equipped with a copper sealed X-ray tube and a HyPix-3000 two-dimensional detector. This detector has a maximum count rate of at least 108 cps/mm<sup>2</sup> and a 15% energy resolution to reject spurious signals, reducing the overall background of the measurements and increasing the outstanding dynamic

range of detection. This instrument can adapt two of the non-ambient sample stages (Anton-Paar). The first is the DHS 1100 graphite dome that allows experiments from room temperature to 1100°C in vacuum, air and various other gases. The second is the DCS 500 graphite dome with electrical feedthrough to allow *in operando* measurements. It covers a temperature range from -180°C to 500°C and can operate under vacuum, in air or other inert gases. The Smartlab XE allows unique phase transformation studies and residual stress analysis as well as *in operando* and *in situ* experiments.



The Rigaku Smartlab XE to be installed in the X-ray Scattering laboratory of CharFac.

The second new instrument is the Rigaku Smartlab SE diffractometer. This instrument is configured as a powder diffractometer with Bragg-Brentano optics, copper X-ray sealed tube, computer controlled variable divergence slit and the D/teX Ultra one-dimensional detector. It will house the third non-ambient sample stage: the Oxford Cryosystems Phenix cryostat. This closed loop He cryostat allows a temperature range of measurement from 12 K to 290 K without consumables and is perfect for crystallographic studies of organics, inorganics, drugs, minerals and other materials at very low temperatures.

The decommissioning of the old SAXS beamlines also has allowed repurposing air-leg tables to other instrumentation in CharFac. One important result has been the elimination of an instability in our FTIR spectrometer's interferogram, which had required almost daily realignment of the mirror and moreover resulted in poor IR microscope signals.

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Greg Haugstad, Director





*MNC Director,  
Stephen Campbell*

I hope that this newsletter finds you enjoying our much delayed summer. I wanted to make you aware of a few new developments in the Center. We took advantage of the liquidation of the long-time supplier of “preowned” research equipment Bid Service, to acquire a few new systems. These will start arriving in mid-June. The first is a rapid thermal annealer, identical to the system that we have in Keller. After we get it here and installed, we will have the existing unit refurbished as it has experienced considerable downtime lately. The second is a thermal evaporator. By having two such systems we can reserve one for the deposition of relatively low vapor pressure materials like Al and Sn. The other system will be more of an “anything goes” tool. We hope to have both of these systems operating by the end of the summer. Finally, MNC and the Physics Department have teamed up to install some outdoor tables and chairs on the east side of the Physics and Nano Building. Facilities Management should be installing them in mid to late June, so stop by on a nice day and bring your lunch. Have a great summer.

Minnesota Nano Center at the  
University of Minnesota

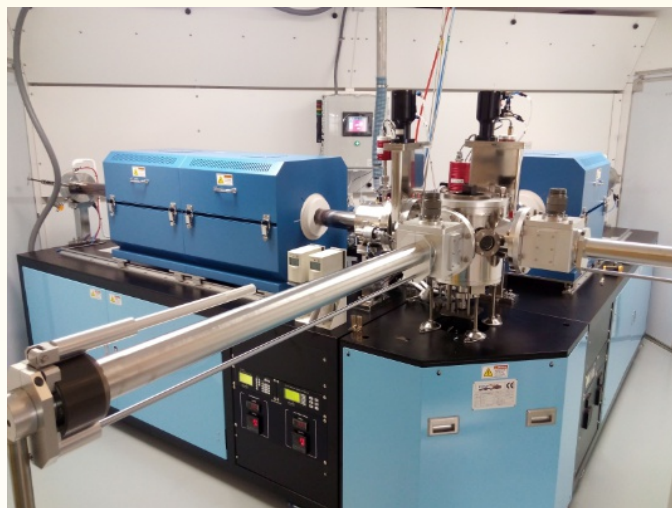
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Steve Campbell, Director  
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## 2D Materials Growth

The cleanroom in the Physics-Nanotechnology building has 2 tools for growing and manipulating 2D films. First is a CVD tool from Planartech used to deposit two dimensional (2D) transition metal dichalcogenide (TMD) materials (sulfides and selenides). The tool has capabilities for MoS<sub>2</sub> and WSe<sub>2</sub> films, with others to be added moving forward. The sulfide and selenide films each have their own growth tubes, and a loadlocked vacuum transfer chamber connects the tubes. This allows samples to be moved between the tubes without exposure to atmosphere. The second tool is a glove box that will contain equipment that will allow handling of oxygen sensitive 2D materials, including exfoliation of 2D films, transferring and positioning the film to a device substrate. These systems compliment the graphene on copper foil deposition system in Keller Hall.



TMD Deposition System at the  
Minnesota Nano Center

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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.

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