UNIVERSITY OF MINNESOTA
nanoTECHNOLOGY news
from the University of Minnesota

Summer 2020

Particles, Droplets, and Bubbles in Microfluidic Flows

The Dutcher Lab (Professor Cari Dutcher, Rana Bachnak, Yun Chen, Maggie House, Shihao Liu, Iaroslav Makhnenko, Athena Metaxas, Ben Micklavzina, Shweta Narayan, Vishal Panwar, Priyatanu Roy, and Nikhil Sethia) studies the dynamics of complex fluids such as aerosols, emulsions, foams and blends. These interface-rich fluidic materials are all around us in our everyday lives, and the way in which they evolve over time or respond to processing conditions depends on the local dynamics at the many soft interfaces throughout the material. Advanced two-phase microfluidic platforms can be used to probe these interfacial dynamics, at length- and time-scales of many important applications. We design, fabricate, and use the platforms to enable new measurements of chemical microphysics of atmospheric aerosols, fluid dynamics and rheology of polymeric solutions, and interfacial phenomena of emulsions and foams. Currently, our active project areas explore (1) dynamic interfacial tension and phase change of aerosol droplets (Figure 1) and agricultural sprays, (2) surfactant transport and interfacial rheology of oil-in-water and water-in-fuel emulsions, and aqueous fire-fighting foams, (3) high-speed detection and sorting of particles and soft materials, and (4) extensional rheology of fibril-forming polymer solutions. Often, we generate droplets, bubbles, and filaments on-chip, and measure their dynamic responses to changes in flow field through a variety of optical methods. Our methods also incorporate multilayer channel designs, on-chip pressure sensors, RTD-based temperature controllers, and IDT-generated surface acoustic waves. To create these advanced lab-on-a-chip devices, we take advantage of many MNC tools for photolithography and thin-film deposition including photomask fabrication, sputtering, vapor deposition, and high temperature annealing.

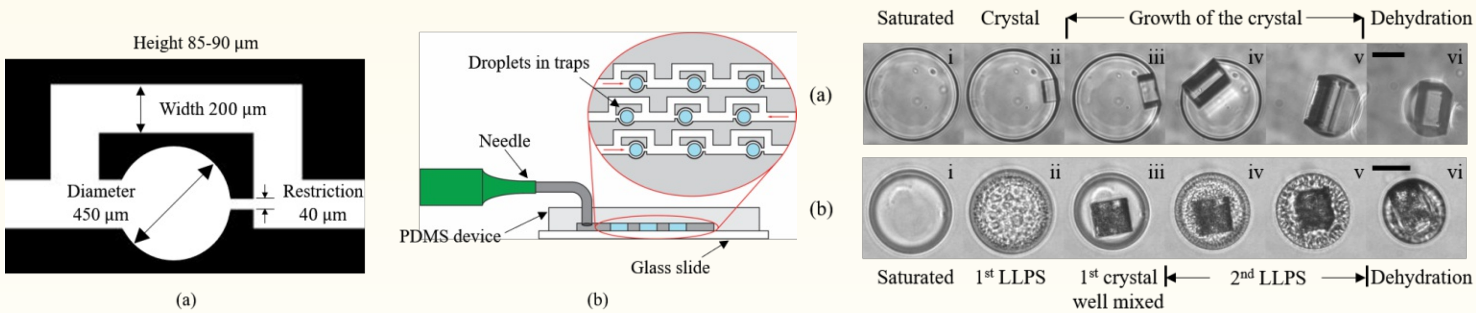

Figure 1. (Left) Schematic of trapped droplets in microfluidic wells (side view, and enlarged top view) for observing phase transitions of aerosol droplets and sprays, and (right) examples of complex series of transitions, including liquid-liquid phase separation (LLPS), observed in aqueous salt-organic mixture. Scale bar: 50 μm. Reprinted with permission from Nandy, Liu, Gunsbury, Wang, Pendergraft, Prather, and Dutcher. *ACS Earth and Space Chemistry* 3(7), 1260-1267. Copyright (2019) American Chemical Society.

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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CharFac Director,
Greg Haugstad

In partnership with experts at Penn State, Illinois and Wisconsin, CharFac recently (April-May) delivered webinars viewed by hundreds of academic and industrial registrants across the US. Both broad introductions and specialized methods were included, and subject matter ranging from theoretical foundations to practical tips. Techniques included photoelectron, Auger and chemical spectroscopies; nanoindentation and atomic force microscopy; wide- and small-angle X-ray scattering; transmission and scanning electron microscopy; focused ion beam and ion scattering; and more. CharFac scientists spoke on confocal Raman microscopy, Rutherford backscattering & related methods; multifrequency AFM / AFM-IR; electron backscatter / transmission Kikuchi diffraction; cryo-electron microscopy / 3D reconstruction. These and other recorded webinars can be viewed at https://www.mri.psu.edu/materials-characterization-lab/webinars/playback-recorded-webinars.

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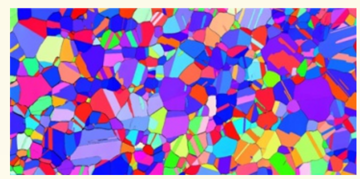
Greg Haugstad, Director

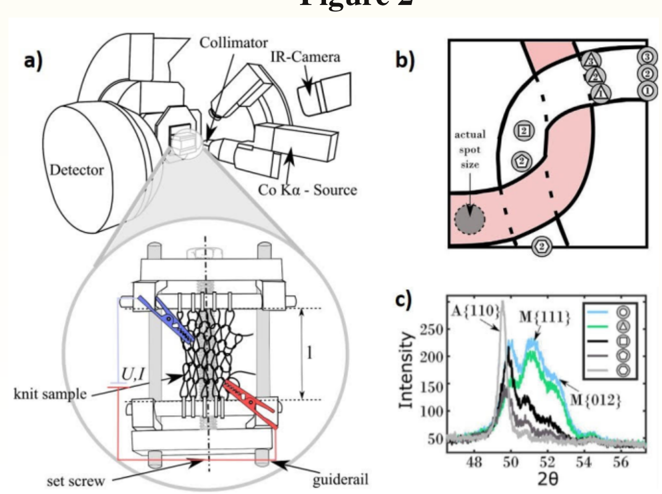
In developmental news we highlight two ancillary methods. The first is electron backscatter diffraction (EBSD), an SEM-based technique to analyze crystal orientations on polished polycrystalline samples. As the electron beam scans across a sample, a diffraction pattern is collected at each point; the computer indexes patterns and determines crystal phase and orientation. Maps of phase, grain size/shape/orientation and twinning can be produced, as exemplified in Figure 1 for the case of steel. A larger map was collected in under 1 hour with new technology (Oxford Instruments) but would have required ~100 hours on our old system. Please contact staff member Nick Seaton with questions.

Figure 1



The second method was a custom development for studying reversible phase transformations in Nickel-Titanium alloys. The method positions a 300 um X-ray beam on a knitted architecture *under controlled temperature and mechanical strain*. Figure 2a depicts part of the setup, a mounted straining device in our Bruker D8 Discover. Variable micro-beam positioning (2b) revealed relationships between local stress and volume fraction of phases (2c). See Eschen, Garcia-Barriocanal and Abel, *Materialia* **11** (2020) 100684, or contact staff member Javier Garcia-Barriocanal.

Figure 2



MNC Director,
Stephen Campbell

The following message is from the incoming MNC Director, Dr. Steven Koester.

It's my pleasure to announce that I have been appointed the new director of the Minnesota Nano Center, effective July 1, 2021. I am currently serving in the role of Director Designate until that time. I am excited to be assuming this position, and having the opportunity to build upon the strong legacy established by Steve Campbell and the entire world-class MNC staff.

For those who may not know me, I received my Ph.D. from the University of California at Santa Barbara, working on III-V-semiconductor nanoscale devices, and spent over 14 years at the IBM T. J. Watson Research Center as a research staff member and manager. I was fortunate to work on a range of projects at IBM, including silicon-germanium materials integration, optoelectronic devices, 3D integration and advanced transistors for digital logic technology. I have been a professor in the ECE Department at the U. for over 10 years, and my research group focuses on novel device technologies based upon emerging materials, and has spanned the gamut of electronic, photonic, spintronic, and biosensing technologies. I have been involved with the MNC for the past 5 years as co-PI on the NSF-funded Midwest Nano Infrastructure Corridor, and have helped to develop the 2D materials process infrastructure and related outreach activities.

As the incoming director, I look forward to continuing to expand the role of the MNC as a world-class nanotechnology facility. By working and interacting with other University facilities and institutes, as well as other nanofabrication facilities across the country, I am confident that we can ensure the competitiveness of the MNC and secure its capability to be a center that can enable the next "big idea". I am especially interested to expand the nanoscale biotechnology offerings of the center, particularly given the critical need for technology related to the diagnosis, testing, and treatment of covid-19. I also will strongly commit to support the core U. value of diversity and equity to advance our research community in all aspects of the MNC mission.

In summary, I look forward to working with our entire community of internal and external users, and am confident that the MNC will continue to help you achieve your new research breakthroughs, educate your students, and make a positive impact in terms of the search for knowledge for all facets of society.

Sincerely,
MNC Director Designate
Steven Koester

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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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