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nanoTECHNOLOGY news
from the University of Minnesota
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Ecology-on-a-chip: Understanding marine ecology one drop at a time

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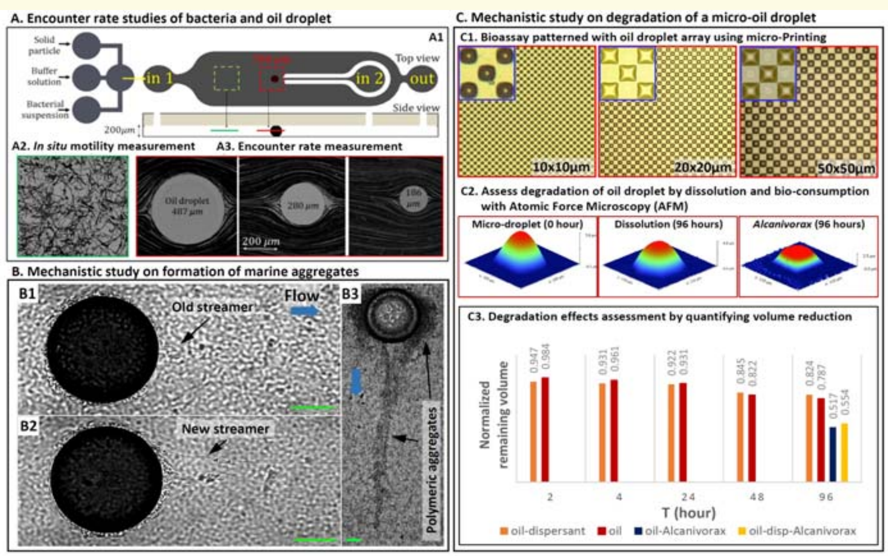
Every year a considerable amount of crude is released to marine environments via natural seeps or disastrous events like Deep Water Horizon, 2010. It is speculated that indigenous oil degrading microorganisms, including bacteria and planktons, consume released hydrocarbons at oil-water interfaces, which leads to wide spread usage of dispersant in oil spill remediation to break the oil plume into nano-droplets. However, contrary field observations have failed to provide supporting evidence and subsequently challenged this conventional wisdom. To reconcile these mechanistic disparities, Sheng's group (Texas A&M University, under grants: SA12-03/GoMRI-003 & SA15-06/GoMRI-011) using the Minnesota Nano Center have combined advances of micro-fabrication and microfluidics to develop novel *Ecology-on-a-chip* technology to identify and assess the pathways, processes, and mechanisms of the fate of oil involving microbial community and micro-droplets (Sample studies summarized in Fig. 1). The *Ecology-on-a-chip* allows us to generate exquisitely controlled chemical/mechanical microcosm environments, such as micro-transfer printing an array of immobilized oil drops with designed non-spherical shape over a substrate with ease (Fig 1C); generation of single pinned volume-controlled micro-droplet by micro-flow focusing and nano-particle induced self-pinning (Fig 1A &1B); and enable *in-situ* simultaneous microscopic observations over cell motility, flow, and the remodeling of the oil-water interface. It provides us with exquisite control over microcosms accentuating various ecological systems and at the same time direct observations of organism behavioral responses to these stimuli, which enables paradigm change discoveries. With the unique *Ecology-on-a-chip* technique, we have discovered, among many other things, that bacterial consumption of micro-oil droplets is not a prominent degrading pathway but rather microbial promoted EPS aggregation formation and subsequent sedimentation.



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

The Characterization Facility will be holding a late-summer, 2-day workshop on advanced nano- to micro-scale characterization methods, spanning all of our major instrumentation systems. The mornings will include lectures primarily by the CharFac staff while the afternoons will include instructive demonstrations of instrumentation, measurement methodologies and data analysis. This event is open to both our internal user base (students, postdocs, research staff, faculty) and external users and clients (whether from industry or academia). Although last summer's inaugural version of this event was well attended, we are striving for even higher participation from both internals and externals. For more information please follow the link under "Upcoming Events" on our home page. The afternoon demo will be limited to an attendance of ~25. In particular, seats will be reserved for industrial visitors and 2nd year UMinn grad students.

Other instructional events that CharFac has held in recent years have focused on particular kinds of instrumentation, such as cryo-electron microscopes, small-angle X-ray scattering systems, or nanomechanical probes. Please do not hesitate to contact me (cfac-dir@umn.edu) if you have an idea, or feel a need, for a particular theme of characterization workshop. Such events are driven by CharFac's mission to share intellectual resources for exploiting the full research capability of the instrumentation.

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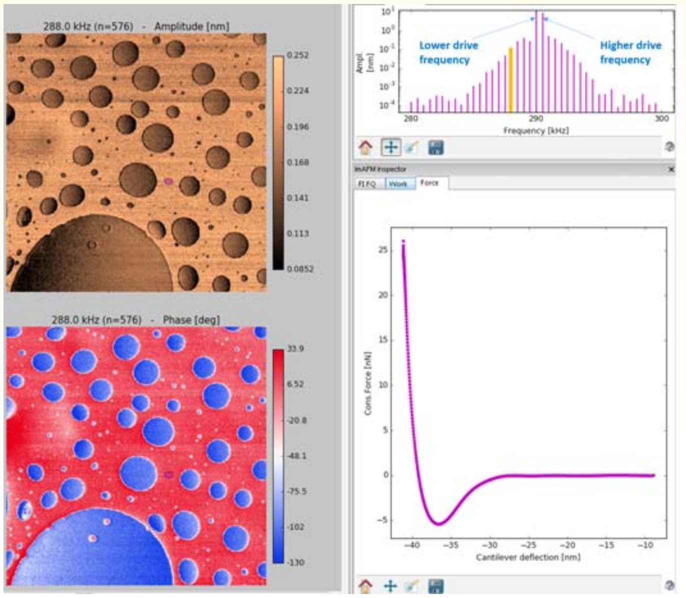
Greg Haugstad, Director

In equipment news, both of our major recent installations — the Phi Versaprobe III XPS/UPS and the FEI Helios dual-beam FIB — are now operational and open for training and services. Our staff members continue to develop expertise with these systems, and we encourage dialog with potential users (and sample donations).

Also in equipment news, we recently acquired an attachment to our Bruker scanning probe microscopes, a next-generation hardware and software system. It constitutes one of the newest and arguably most powerful "multifrequency" modes of atomic force microscopy (AFM) as have come to the fore in the past decade. The system utilizes a vibrating cantilever/tip — as in the well-known "tapping mode" — but is driven at *two* vibrational frequencies near the fundamental resonance of the cantilever instead of just one. The tip's nonlinear interaction (attractive + repulsive forces) with the sample surface spawns *intermodulation products* which are analyzed in frequency space to generate around 40 amplitude and phase images spanning a range of frequencies, and therein novel contrast mechanisms. Secondly, because the two drive frequencies produce a beat (timed once per pixel), the vertically oscillating tip explores a range of amplitudes at each site. This data is transformed from frequency to real space to generate point-by-point measurements of conservative and dissipative force versus distance (e.g., particularly elucidating for viscous materials), an unprecedented development. A screen shot of some of this information is shown below.



We are eager to try these new methods on complex, nanostructured materials, such as those containing three or more ingredients. Please contact me for more information. One can download a very recent review article entitled "Quantitative force microscopy from a dynamic point of view" in Current Opinion in Colloid & Interface Science (2017).

MNC Director, Steve Campbell

The much discussed transition metal dichalcogenide system is now installed in the PAN clean room, housed in a very large walk-in hood. Facilitation is complete and the manufacturer will be on site in mid-June to perform the start up. At that point we should be able to grow MoS_2 and WSe_2 for anyone who wants those materials. This has been an education in UL listing as it relates to the acquisition of foreign-built tools.

I want to thank Mo Li and Sarah Swisher, of the Electrical and Computer Engineering department, who wrote proposals to the Office of the Vice President for Research on behalf of MNC. Professor Li's proposal would fund an upgrade of the control and pattern generation software system (Beamer, by GenISys) to the latest version of v5.3.0. The new capabilities of the upgraded version include proximity effect correction, productivity improvement, and machine-specific enhancement, all of which are essential to improving nanopatterning resolution and fabrication throughput. Professor Swisher's proposal would fund a new thin film Parylene deposition. This tool deposits an ultra-thin conformal polymer coating with excellent moisture, chemical, and dielectric barrier properties. The coating is inert and biocompatible (approved by the FDA for external and implanted medical devices), and has a wide variety of uses including medical devices, electronics, and even military/aerospace applications. We should get the results of these submissions in the summer of 2017.

I hope that everyone has a productive and enjoyable summer.

Soft Lithography Capabilities

Soft lithography refers to a group of non-photolithographic methods that can be used to fabricate or replicate structures, using polymers such as PDMS. Examples include micro contact printing, replica molding, micromolding in capillaries and microtransfer molding. Many of these techniques were developed by George Whitesides at Harvard University. Applications include fabrication of microfluidic devices, patterning on non-planar surfaces, fabrication of complex optical surfaces, and stamps for selective application of biological materials. At MNC we have a soft lithography capability centered around SU-8 molding of PDMS. SU-8 is a commonly used molding material for PDMS, and can be formed into structures of a wide range of sizes and shapes. Optionally the masters can be formed by etching features into the surface of a silicon wafer. These masters can be made with nanoscale feature sizes using our new Vistec electron beam lithography system, or with larger sizes using conventional photolithographic processing. Please contact us if you are interested in learning how we can help you with soft lithography.

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.