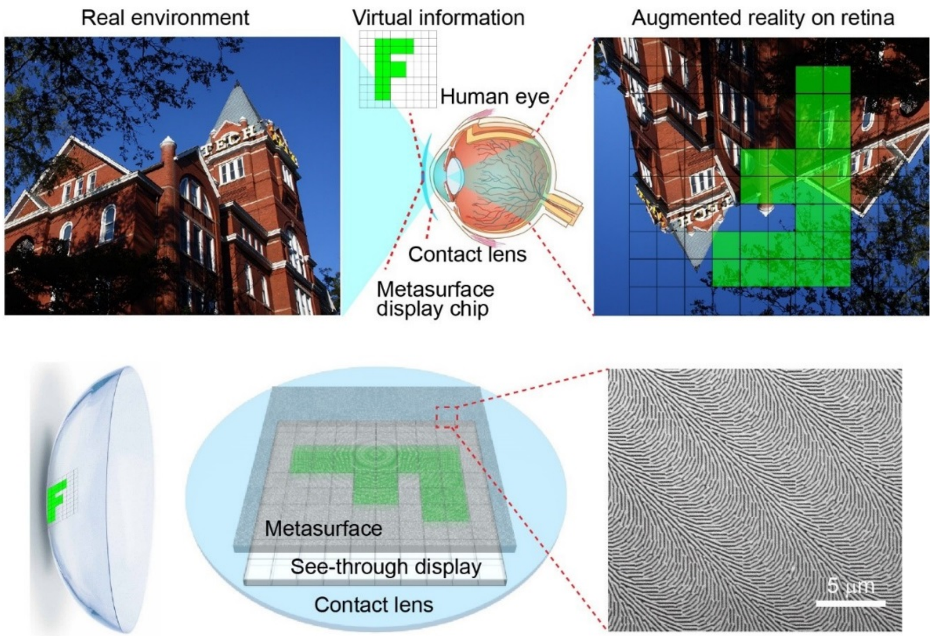
Southeastern Nanotechnology Infrastructure Corridor (SENIC)

Research and Education Highlights

Year 5 (October 2019 – September 2020)

Metasurfaces for Near-Eye Augmented Reality

This work proposes and experimentally demonstrates a holographic display technology that casts virtual information directly to the retina so that the eye sees it while maintaining the visualization of the real-world intact. The key to our design is to introduce metasurfaces to create a phase distribution that projects virtual information in a pixel-by-pixel manner. Unlike conventional holographic techniques, our metasurface-based technique, based on Pancharatnam-Berry phase elements made of silicon, is able to display arbitrary patterns using a single passive hologram. With a small form-factor, the designed metasurface empowers near-eye AR, excluding the need for extra optical elements, such as a spatial light modulator, for dynamic image control.



Schematic of metasurface enable device. The lower-right image is the SEM micrograph of a small portion of the metasurface comprises the predesigned distribution of silicon nanobeams.

Shoufeng Lan, Xueyue Zhang, Mohammad Taghinejad, Sean Rodrigues, Kyu-Tae Lee, Zhaocheng Liu, and Wenshan Cai, ECE, Georgia Institute of Technology. Work performed at Georgia Tech's Institute for Electronics and Nanotechnology.

This work was supported by NSF Award # ECCS-1542174. *ACS Photonics* 2019, 6, 864−870

National Research Priority: NSF-Future of Work at the Human-Technology Frontier

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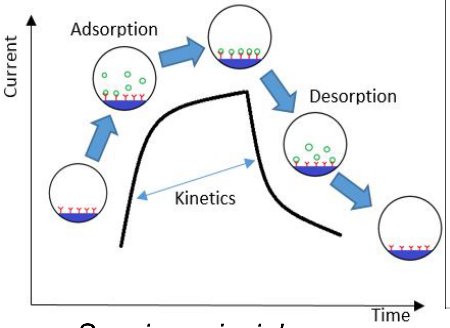
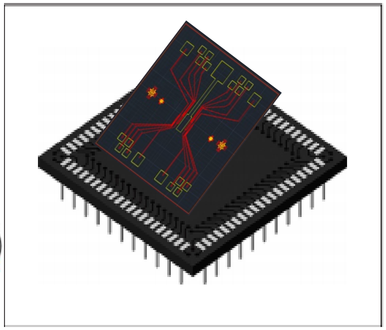
Nano Sensor Array for Methyl Salicylate Detection in Gaseous Form

This work targets a CNT-FET platform for the detection of Methyl Salicylate (MeSa) in the gaseous phase. Similar to the mammalian olfactory system, the MeSa molecules will be attached to a modified surface of the CNT channel and create a semi-specific recognition by changing the electrical current within it.

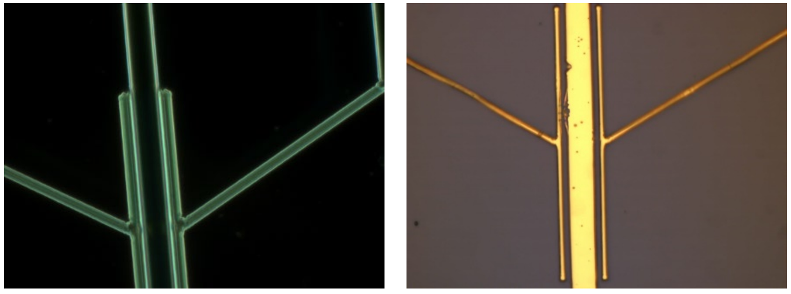
Each chip contain multiple separate sensors, that are modified by a different chemical recognition agent. The kinetics of coupling and decoupling of the target molecule and surface modification changes the current in a characteristic manner. Measuring the ratio between them gives an easy to analyze finger print. Cross referencing this ratios with several different modifications will allow accurate detection. The signal amplitude will give the information about the concentration of the analyte.



Sensing principle.



The Nano-sensor array design on a PCB.



Light microscope images at X500 magnification in DF (left) and (BF) right.

Or Zolti and Ramaraja Ramasamy, School of Chemical, Materials and Biomedical Engineering, University of Georgia.
Fabrication performed at Georgia Tech's Institute for Electronics and Nanotechnology.

National Research Priority: NSF-Growing Convergence Research

Characterization of particles emitted from aerosolized consumer products

This work focuses on understanding potential inhalation risks and hazards during the use of common aerosolized consumer products. Four de-identified consumer aerosolized cosmetic aerosols (AA4, AA8, S1, and S4) were assessed. Aerosols were generated, monitored and sampled using a novel aerosol generation system complete with aerosol monitoring instrumentation and animal exposure pods for in vivo toxicological evaluations. Aerosols were sampled onto aluminum substrates and evaluated using transmission electron microscopy coupled with energy dispersive X-ray spectroscopy (TEM-EDX)(Figure 1). Aerosols were multimodal consisting of micro-sized particles decorated with nanoparticles containing primarily titanium and iron.

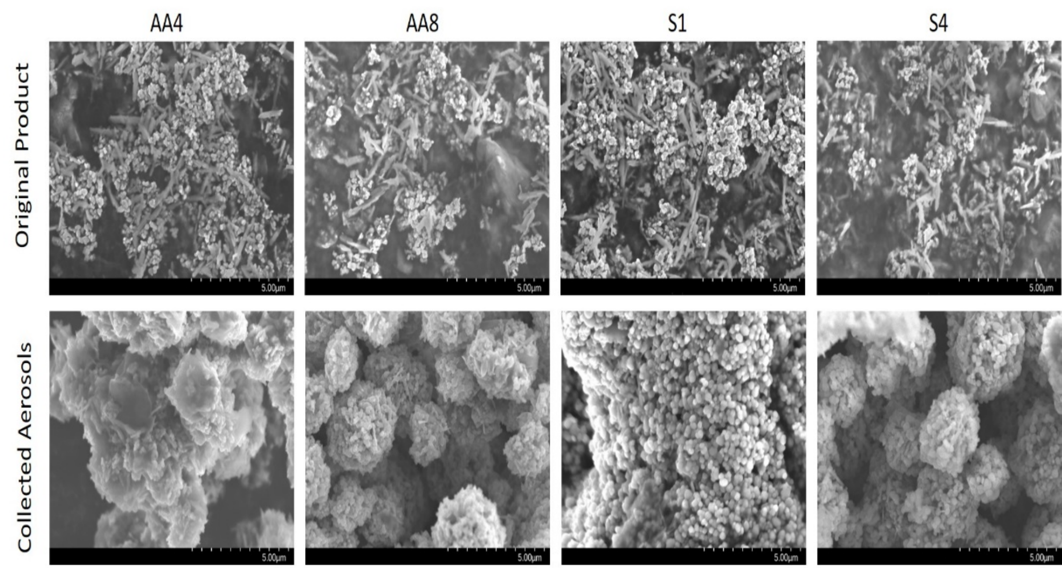


Figure 1. TEM micrograph consumer product aerosols emitted from aerosolized nano-enabled cosmetics.

Pearce, K.M., Goldsmith, W.T., Greenwald, R., Yang, C., Mainelis, G. & Wright, C., Dept. of Population Health Sciences, School of Public Health, Georgia State University, IEStechno, Institute for Electronics and Nanotechnology, Georgia Institute of Technology, Dept. of Environmental Sciences, Rutgers University. TEM-EDX work completed at IEN - Georgia Institute of Technology.

Inhalation Toxicology, DOI: 10.1080/08958378.2019.1685613

National Research Priority: Earth System Predictability and Meteorology (Federal R&D Research Priorities)

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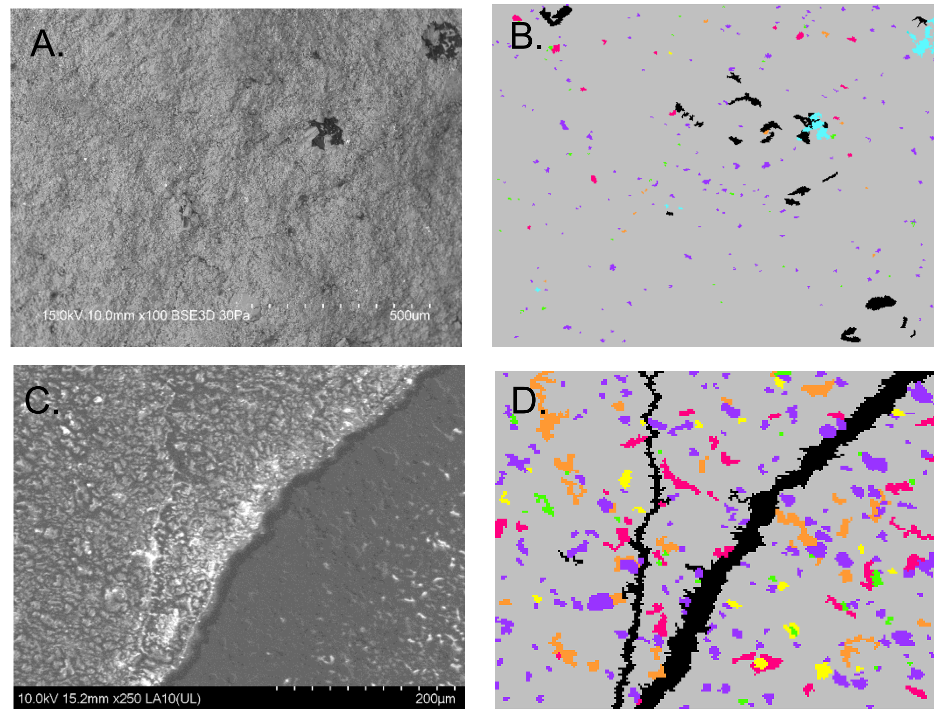
Role of Mineralogy in Controlling Fracture Formation

The overall goal of this work is to enhance understanding of reactive fracture evolution in the context of enhanced oil recovery from low permeability formations. Towards this, this work aims to evaluate the role of mineralogy in controlling fracture formation in shales. Shale samples from the Marcellus formation were fractured using unconfined compression. Scanning electron microscopy BSE and EDS images were then collected of fracture surfaces. Images were processed to infer the mineral composition of the fracture surface. Images were additionally collected of the matrix, processed to identify minerals, and compared with those collected of fracture surfaces.



SEM images (A, C) and processed images (B, D) of fracture surface (A, B) and formation matrix (C, D) for a Macellus shale.

Olivia Brunhoeber and Lauren Beckingham. Department of Civil Engineering, Auburn University, Auburn, AL. Work performed at Georgia Tech's Institute for Electronics and Nanotechnology.

Funding support from the American Chemical Society Petroleum Research Fund.

National Research Priority: NSF-Growing Convergence Research

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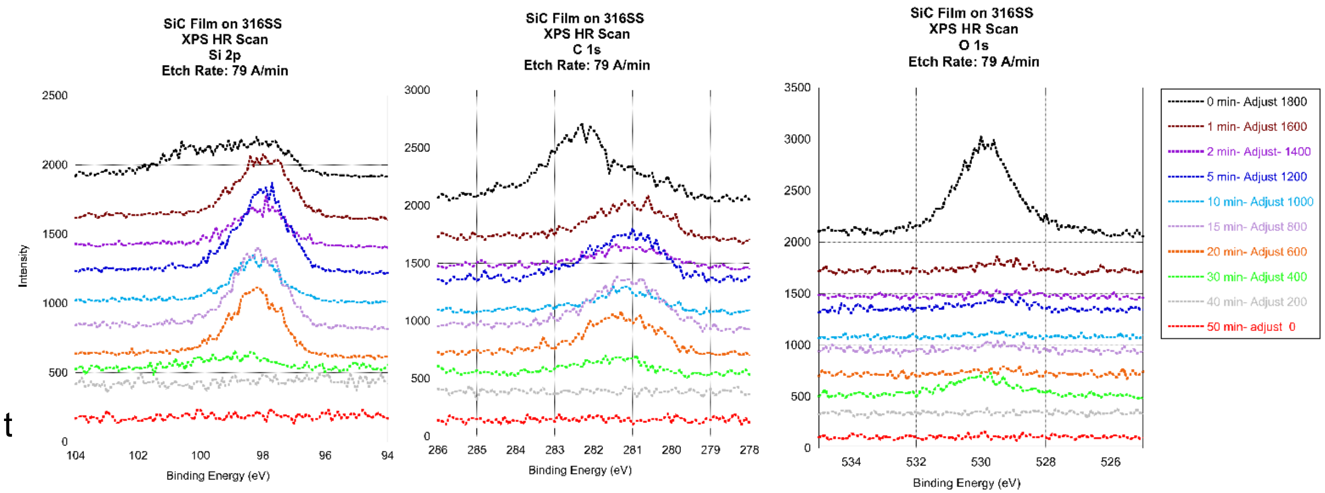
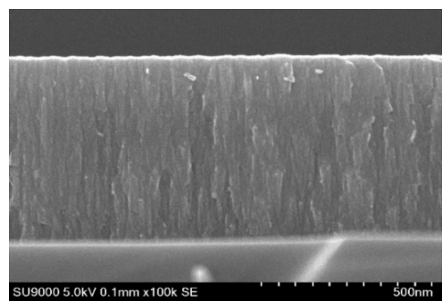
Fabrication of Silicon Carbide Thin Films for Permeation Studies

Objective: To deposit and confirm the quality of silicon carbide (SiC) coatings on stainless steel substrates.

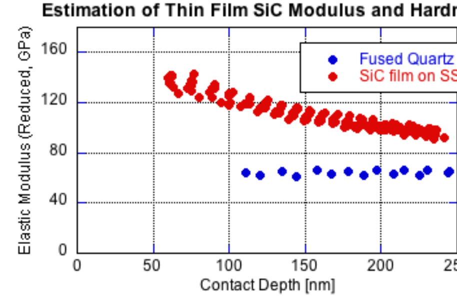
Motivation: SiC coatings have been found to control hydrogen permeation into stainless steel structures but require uniform coverage with minimal cracking t be successful.

Results: SiC films with no tensile cracks or delamination were successfully deposited. Indentation showed high surface hardness and XPS confirmed uniformity of film chemistry.





Estimation of Thin Film SiC Modulus and Hardness



M. Piness, M. S. Kennedy, and G. J. Pataky, Mechanical Engineering, Clemson University. Work partially performed at Georgia Tech's Institute for Electronics and Nanotechnology.

Funding through Savannah River National Laboratory.

National Research Priority: Advanced Manufacturing (Federal R&D Research Priorities)

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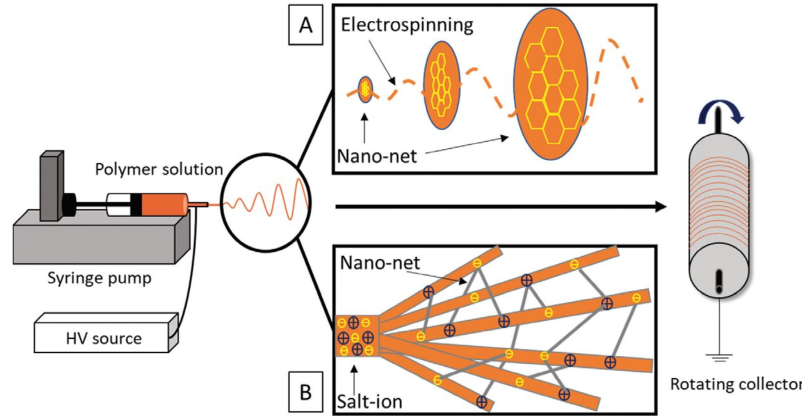
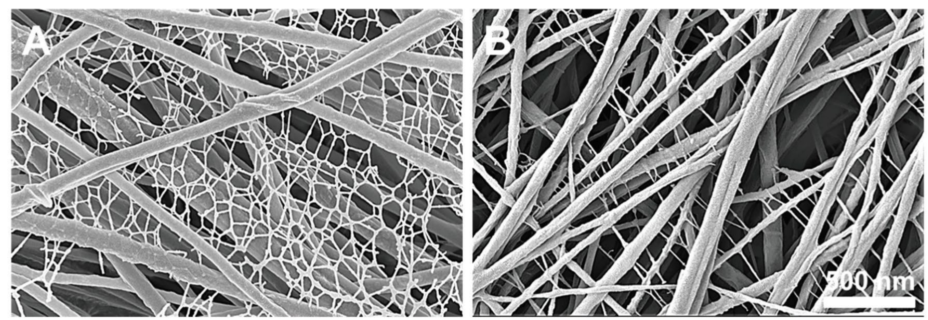
Controlled and extended drug release from Nanonet-nano fibers

In this work, for the first time nanonet-nanofiber electrospun meshes (NNEMs) of polycaprolactone (PCL)–chitosan (CH) were synthesized using electrospun nanofiber technology. The fabricated NNEMs were utilized for high payload delivery and controlled release of a water-soluble drug, namely Diclofenac Sodium (DS). High drug entrapment efficiency and concentration-dependent drug release patterns were investigated for up to 14 days. Results showed that the DS drug is a key contributing factor in the generation of nanonet-nanofiber networks during electrospinning. DS-NNEMs also enhanced cell adhesion, viability, and proliferation in the nanonet-nano fiber network through the controlled release of DS.



Schematic of a possible mechanism for nano-net formation



Nanonet electrospun mesh fiber. (A) Spider-nets with phase separation and (B) branched nano-net produced between the main fibers

Sheikh Saudi, Narayan Bhattarai et al., North Carolina A&T State University. Part of this work was performed at the Joint School of Nanoscience and Nanoengineering.

This work was supported by NSF Award# EEC-0812348. *Nanoscale,* 2020.

National Research Priority: NSF-Understanding the Rules of Life

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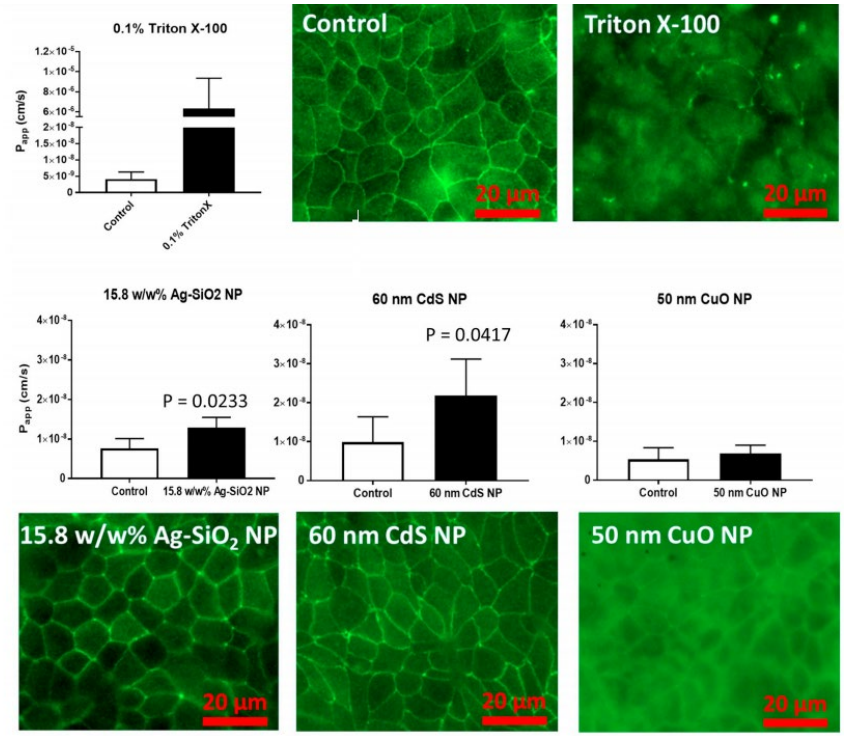
Investigation of gastrointestinal integrity on exposure to metal, metal oxide, and metal sulfide nanoparticles

Using fully differentiated Caco-2 cells, the perturbation of intestinal barrier function and cytotoxicity were investigated for 20 metal, metal oxide, and metal sulfide nanoparticles (NPs). Caco-2 cells were exposed to 50 µg/mL NPs for 24 h. NP formulations were characterized at 0 and 24 h, and In Vitro Sedimentation, Diffusion and Dosimetry Modeling was applied to calculate the effective dose of exposure during 24 h. Our results illustrate that while many metal, metal oxide, and metal sulfide ENMs do not adversely affect monolayer integrity or induce cytotoxicity in differentiated Caco-2 cells, a subset of ENMs may compromise the intestinal integrity. This study demonstrated the use of differentiated Caco-2 monolayer and Papp as an endpoint to identify and prioritize ENMs that should be investigated further.



Apparent permeability coefficient (Papp) of AF488-dextran (3,000 Da) and tight junction (ZO-1) staining following 24 hours exposure to NPs

Mortensen, Fennell et al., RTI International. Work performed at Joint School of Nanoscience and Nanoengineering.

This work was supported by NIH grant # U01ES027254 and NSF Award# CBET- 1604647. N*anoImpact,* 17, 100212, 2020

National Research Priority: NSF-Understanding the Rules of Life

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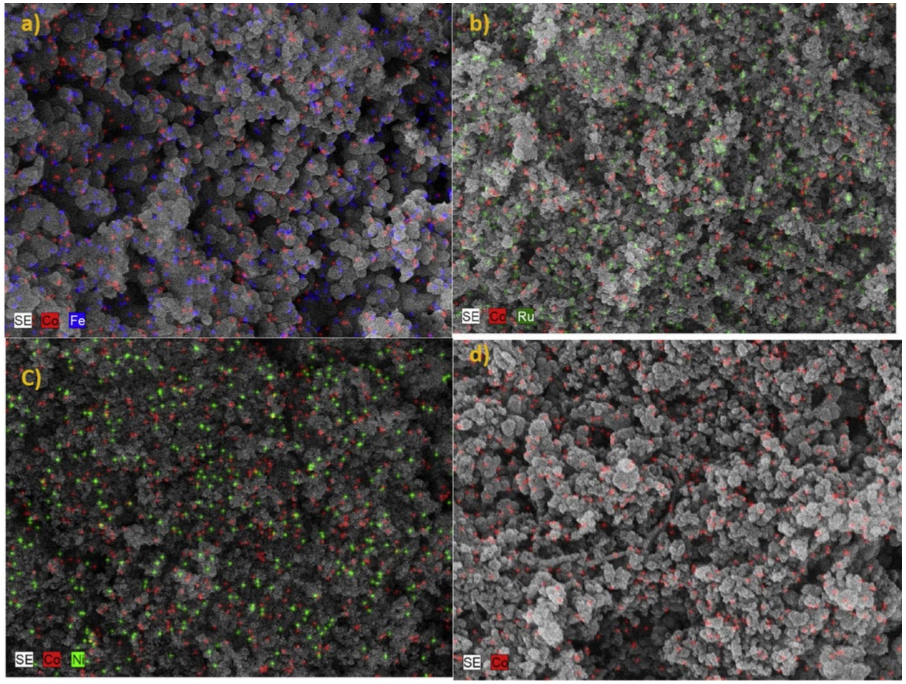
Fischer-Tropsch studies in 3D-printed stainless steel microchannel microreactor

In this work, 3D printed stainless steel microreactors was successfully used to study the effect of bimetallic M- Co-MCM-41 catalysts in FT synthesis at 1 atm. These catalysts were synthesized using one-pot hydrothermal procedure and resulted in high surface area MCM-41 matrix with an ordered mesoporous structure as-corroborated by low angle XRD and BET surface area studies. TEM and SEM-EDX results indicate a clear hexagonal matrix having porous surface morphology with uniform metal ion distribution. The highest CO conversion for CoFe-MCM-41 (65.5%), Co-MCM-41 (64%) and CoNiMCM-41 (72 %) was obtained at 210C, 240C and 240C respectively. The results from our experiments suggests that the addition of transition metals-Fe, Ni and Ru to Co-MCM-41 can play a vital role in FT synthesis



SEM-EDX images of different catalyst samples: a) CoFe-MCM-41 b) CoRu-MCM-41 c) CoNi-MCM-41 d) Co-MCM-41.

Mohammad, Kuila et al., North Carolina A&T State University. Characterization work performed at Joint School of Nanoscience and Nanoengineering.

This work was supported by NSF-CREST Award #260326. *Catalysis Today,* 358(1), 303, 2020.

National Research Priority: NSF-Growing Convergence Research

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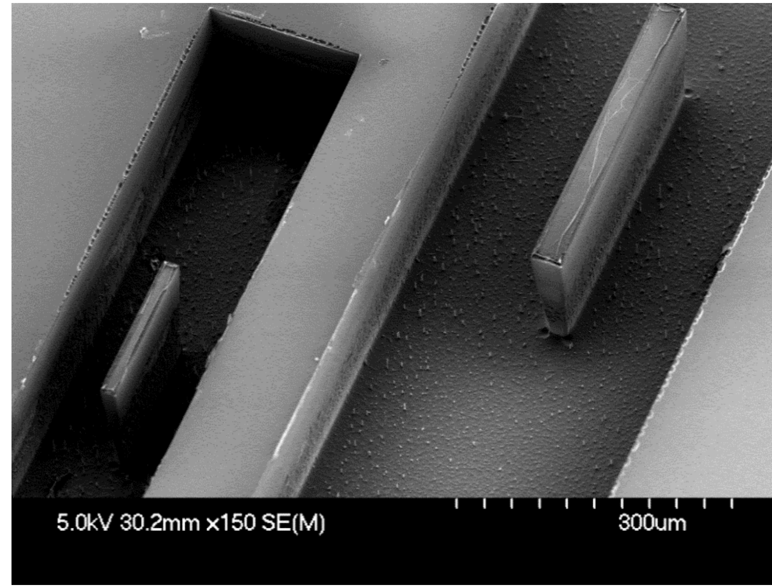
CTD-on-a-Chip: Enabling Polar In-Situ Ice-Ocean Data Collection

CTDs are oceanographic instruments that measure the conductivity, temperature, and pressure of a water parcel to calculate salinity. *In situ* salinity measurements can be used to estimate melt rates in ice-covered locales. This work looked at developing a highly-confined conductivity cell that used vertical electrodes to minimize the effects of nearby structures and materials to improve near-interface measurements. The trenches were etched with a DRIE Bosch process with a decoupling thermal oxidation layer. The Cr/Au electrodes were sputtered to improve sidewall coverage. Results showed promise in the formation of the structure down to central "fin" widths of 10um, and while sputtering improved step coverage, high roughness from the DRIE proved challenging for uniform metalization. Future work will look at reducing the roughness of the DRIE for improved coatings of the sidewalls.



SEM micrograph showing the channel and fin structure, with two different sizes shown.

Ben Hurwitz and Britney Schmidt, Planetary Habitability and Technology Lab, School of Earth and Atmospheric Sciences, Georgia Institute of Technology. Work performed at Georgia Tech's Institute for Electronics and Nanotechnology.

This work was partially supported by a SENIC Seed Grant (NSF ECCS-1542174).

National Research Priority: NSF-Navigating the New Arctic

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Fully Wireless, Nanostructured, Hemodynamic Sensor System for Continuous Monitoring of Blood Pressure and Flow Rate

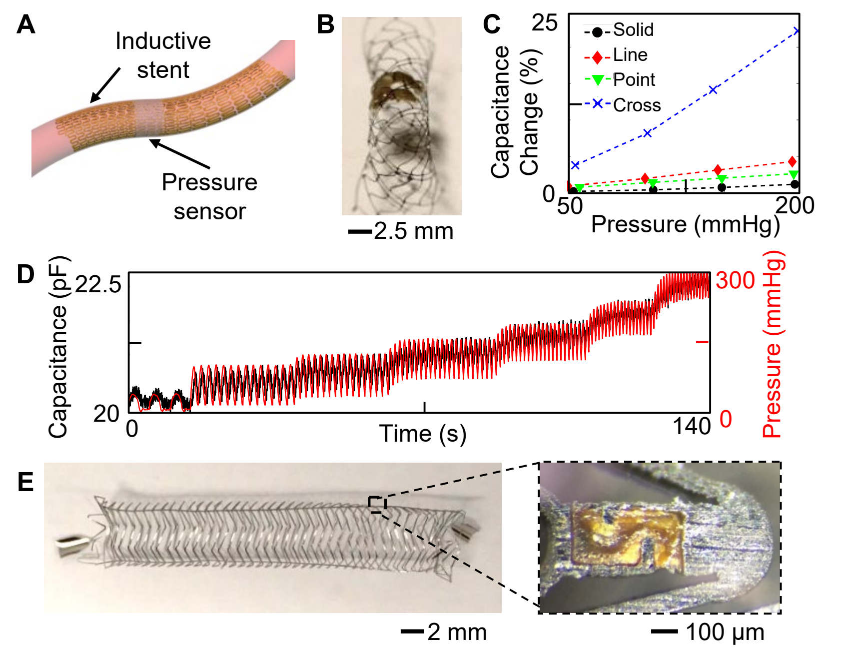
Hemodynamic conditions are used as indications for cardiovascular diseases, which account for over 30% of deaths worldwide

Focused on developing an implantable smart stent with two nanostructured, soft pressure sensors for wireless monitoring of blood pressure and flow rate

Stent is balloon expandable and employs a solenoid-like shape with polymer support links to maintain mechanical integrity and a high inductance (1.4 μH)

Fully printed, low-profile capacitive pressure sensors use a microstructured PDMS dielectric layer to achieve high sensitivity (3.8 fF/mmHg).

Future work will include wireless testing and in vivo demonstration



A) Illustration of implantable smart stent and sensor. B) Low-profile pressure sensor integrated on stent. C) Pressure sensitivity comparison of PDMS microstructures. D) Pressure sensor response to pulsatile flow in model blood vessel. E) Smart stent after balloon expansion with enlarged view of polyimide support link.

Robert Herbert and Woon-Hong Yeo, Mechanical and Biomedical Engineering, Georgia Institute of Technology. Work performed at Georgia Tech's Institute for Electronics and Nanotechnology.

This work was partially supported by a SENIC Seed Grant (NSF ECCS-1542174).

National Research Priority: NSF-Understanding the Rules of Life

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