Shofner Research Group

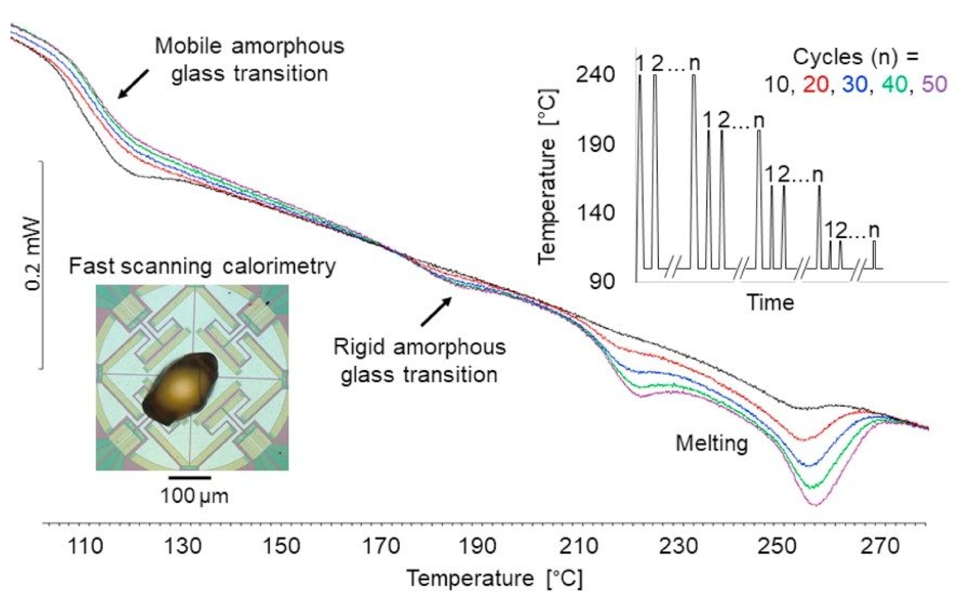
PI: Meisha L. Shofner, School of Materials Science and Engineering
Group Members: Malik Blackman, Tamara Bowman, Parker Campbell, Hazel Dhruve, Fariha Rubaiya (with L.M. Garten), Emily Ryan (with J.R. Reynolds), and Kaung Su Khin Zaw (with S. Nair)

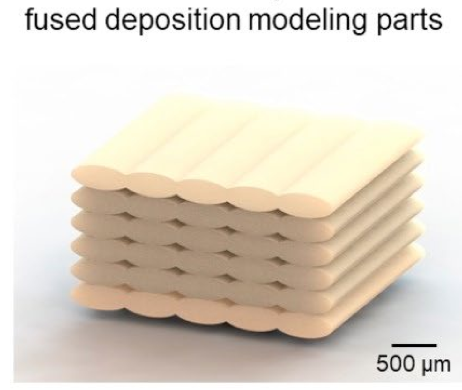
Overview

Our research concerns processing-structure-property relationships for polymers and composites. Much of our work examines how scalable processing strategies can be used to produce hierarchical structures, functional properties, and viscoelastic/mechanical performance.

Simulating the Processing Environment for Polymeric Materials in Additive Manufacturing

We are developing techniques to understand how polymer structure and properties develop during additive manufacturing as a function of the thermal environment, repeated and rapid heating/cooling cycles, and inherent polymer attributes. Our work has been focused on material extrusion and powder bed fusion, using fast scanning calorimetry and design/modeling techniques.



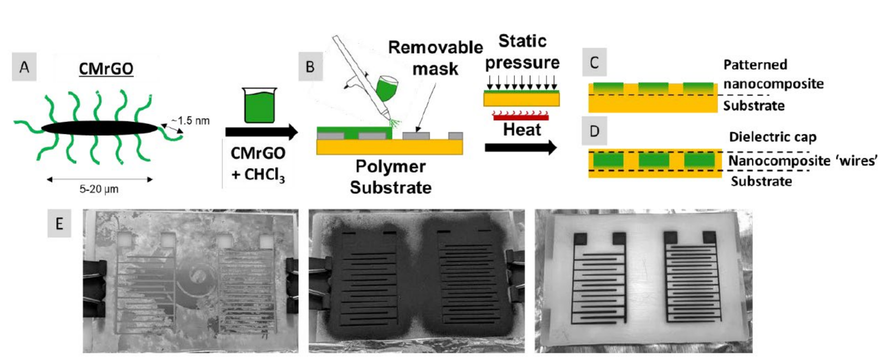


Cycles of heating and cooling from additive deposition in fused deposition modeling parts

Fitzharris, Watanabe, Rosen, and Shofner, Int J Adv Manuf Tech (2018)
Fitzharris, Watt, Rosen, and Shofner, *Additive Manufacturing* (2018)
Fitzharris, Rosen, and Shofner, *Polymer* (2019)

Polymer Composites for Radiation Shielding and Dust Mitigation

As part of the NASA-funded SSERVI Team at Georgia Tech, we are working to understand how polymer nanocomposites could be used to protect humans, equipment, and infrastructure during long-term space missions and habitation. Our current work involves developing strategies for manufacturing robust devices and structures using electrically-conducting polymer nanocomposites. Specifically, we are examining the capabilities of surface localized nanocomposites containing reduced graphene oxide to address hazards associated with lunar dust through active mitigation.



Fabrication of electrodynamic dust shield (EDS) devices for dust mitigation using chemically modified reduced graphene oxide (CM-rGO)

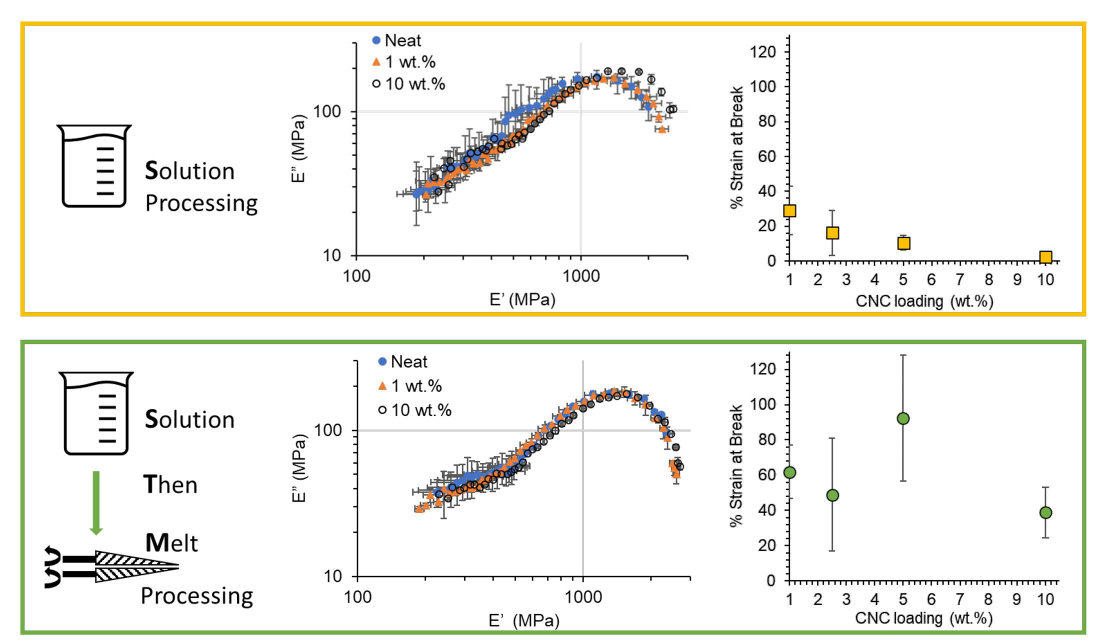
Seibers, Orr, Collier, Henriquez, Gabel, Shofner, La Saponara, and Reynolds, Polym. Eng. Sci. (2020)
Seibers, Brim, Pittelli, Beltran, Shofner, and Reynolds, *ACS Appl. Nano Mater.* (2020)
Schaible, Sjolund, Ryan, Shofner, Reynolds, Linsey, and Orlando, *Acta Astronautica* (2023)
Ryan, Seibers, Reynolds, and Shofner, *ACS Applied Polymer Materials* (2023)

Polymer Composites and Coatings Containing Bio-Based Nanofibers

To improve the environmental stewardship of polymers/plastics, bio-based materials are being increasingly investigated as replacement materials or as additives to synthetic materials. In line with these efforts, we are investigating the use of nanocellulose and chitin nanofibers (ChNFs) in polymer composites. Both types of nanofibers are derived from renewable resources, with nanocellulose sourced from precursors such as trees, plants, and organisms and ChNFs sourced from shellfish and fungi.

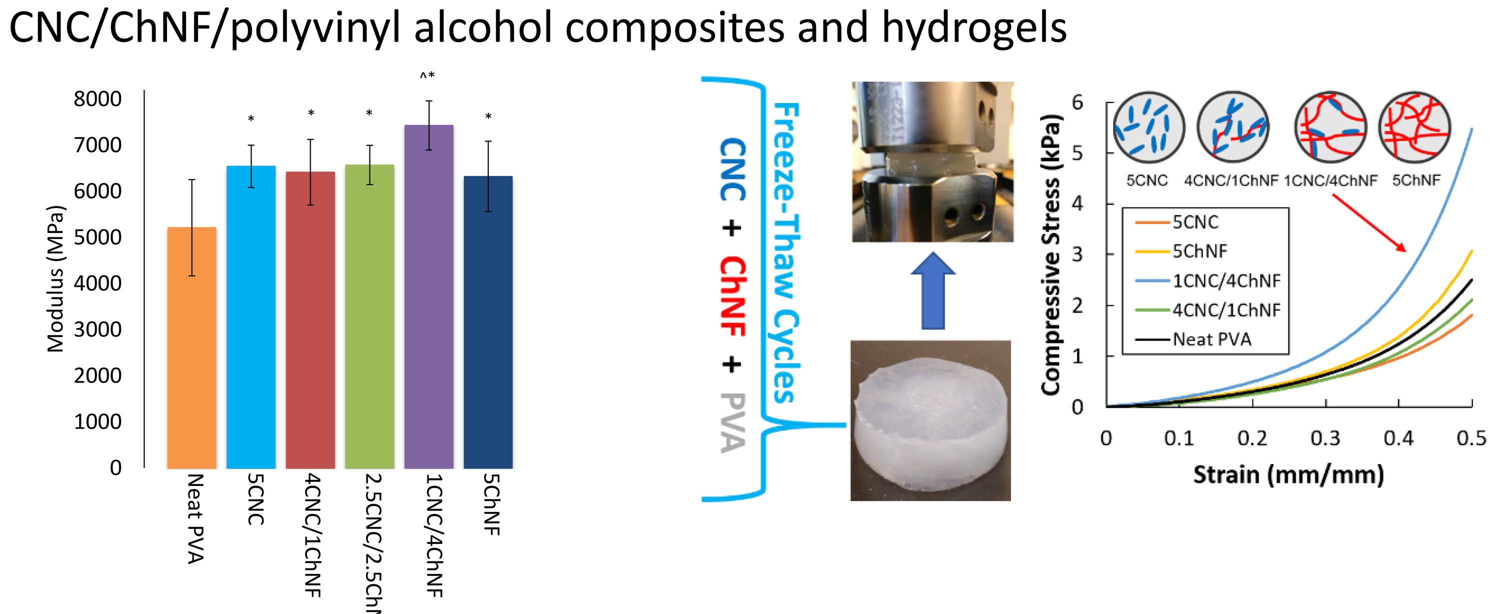
We are working with a variety of polymer matrices and processing techniques to understand how cellulose nanocrystals (CNCs, a type of nanocellulose) and ChNFs may provide thermomechanical reinforcement and to discover new routes for processing these systems, including methods for making bio-based barrier coatings.

CNC/poly(ethylene-*co*-vinyl alcohol) composites



Transmission electron microscopy image of CNCs.

CNC/ChNF/polyvinyl alcohol composites and hydrogels

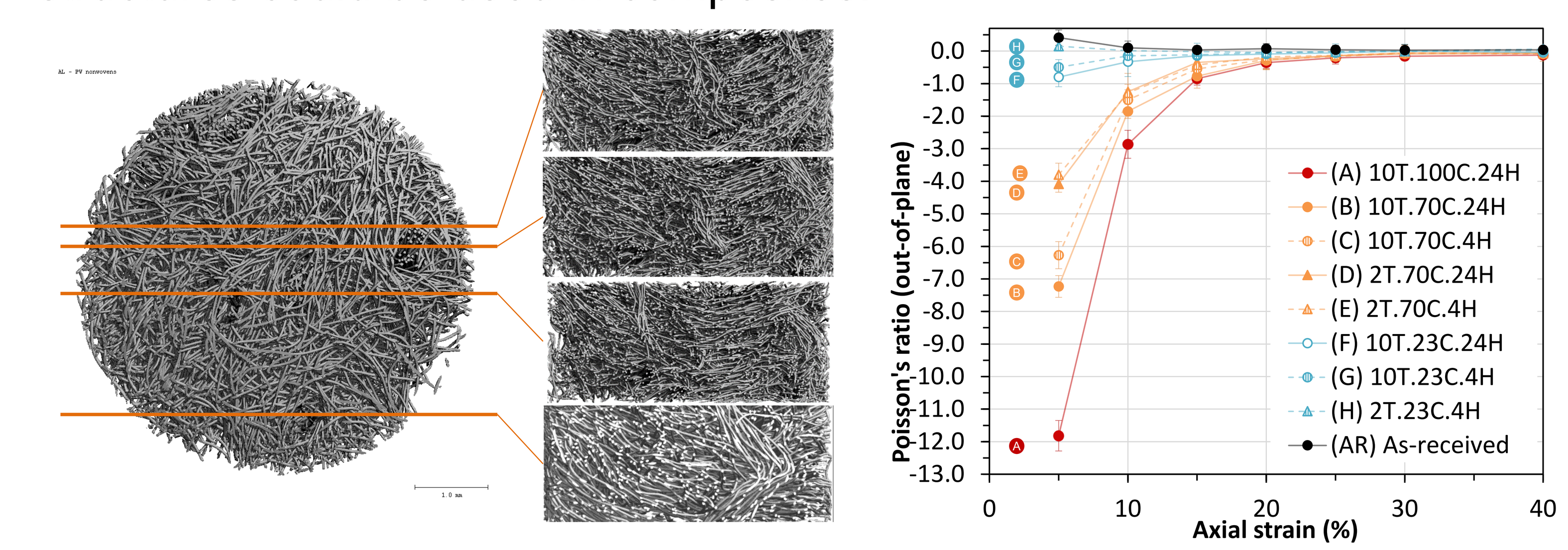


Xu, Girouard, Schueneman, Shofner, and Meredith, *Polymer* (2013)
Girouard, Schueneman, Shofner, and Meredith, *Polymer* (2015)
Girouard, Xu, Schueneman, Shofner, and Meredith, *ACS Appl. Mater. Interfaces* (2016)
Meree, Schueneman, Meredith, and Shofner, *Cellulose* (2016)
Orr and Shofner, *Polymer* (2017)
Irvin, Satam, Meredith, and Shofner, *Composites Part A* (2019)
Orr, Sonekan, and Shofner, *Polym. Eng. Sci.* (2020)
Dogan-Guner, Brownell, Schueneman, Shofner, and Meredith, *Progress in Organic Coatings* (2021)
Irvin, Satam, Liao, Russo, Breedveld, Meredith, and Shofner, *Biomacromolecules* (2021)
Dogan-Guner, Schueneman, Shofner, and Meredith, *Cellulose* (2021)
Dogan-Guner, Schork, Brownell, Schueneman, Shofner, and Meredith, *Polymer* (2022)
Ji, Waters, Lim, Lang, Ciesielski, Shofner, Reynolds, and Meredith, *ACS Sus. Chem. & Eng.* (2022)
Ji, Shen, Young, Goins, Reynolds, Shofner, and Meredith, *Materials Advances* (2022)
Irvin, Satam, Shial, Verma, Arroyo, Meredith, Shofner, *Journal of Applied Polymer Science* (2023)

Auxetic Behavior in Fibrous Structures

Materials with an auxetic response have a negative value of Poisson's ratio or similar behavior beyond the elastic regime. Auxetic behavior is unusual, though not necessarily rare, and hence it offers possibilities for unique applications.

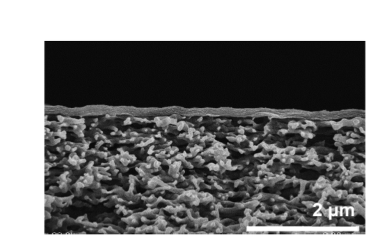
We are studying the auxetic behavior of non-woven fabrics and fiber networks to understand what materials and processing variables impact the magnitude of this response, its reversibility, and how these structures could be used in composites.



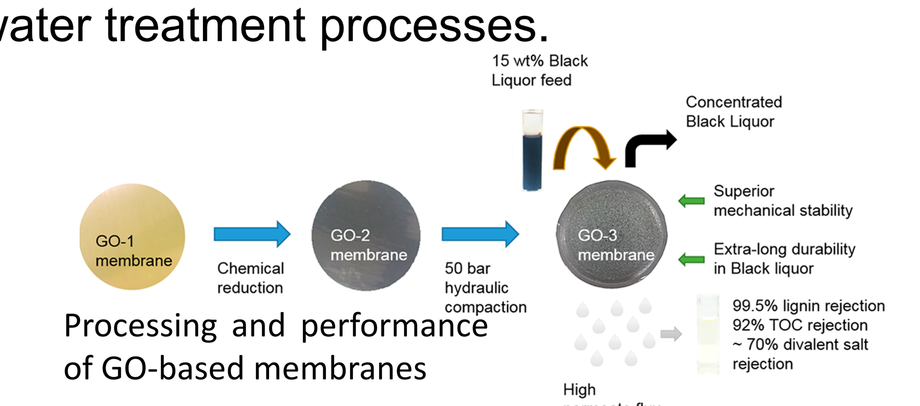
Verma, Shofner, and Griffin, *Physica Status Solidi B* (2014)
Verma, Shofner, Lin, Wagner, and Griffin, *Physica Status Solidi B* (2015)
Verma, Shofner, Lin, Wagner, and Griffin, *Physica Status Solidi B* (2016)
Verma, Smith, Griffin, and Shofner, *Engineering Research Express* (2020)
Verma, Smith, Griffin, and Shofner, *Materials Advances* (2022)
Verma, Wagner, Griffin, and Shofner, *Physica Status Solidi B* (2022)

Membranes for Concentration of Black Liquor and Industrial Water Treatment

GO and rGO are being used to form new membranes that will withstand the high pH (~12), temperature (90°C), and potential fouling species, present in spent pulping liquor (black liquor) leaving the digester in kraft pulp mills. Beyond improvements in the pulping process, these membranes can be used for separations relevant to biorefining. Current work is examining how these membranes can be used for other industrial water treatment processes.



GO-based membrane on a polyethersulfone support



Processing and performance of GO-based membranes

Rashidi, Kevlich, Sinquefield, Shofner, and Nair, *ACS Sustainable Chem. Eng.* (2017)
Wang, Ma, Sinquefield, Shofner, and Nair, *ACS Sustainable Chem. Eng.* (2019)
Wang, Ma, Xu, Sinquefield, Shofner, and Nair, *Nature Sustainability* (2021)
Ma, Sinquefield, Wang, Shofner, and Nair, *TAPPI Journal* (2023)
Zaw, Ma, Wang, Shofner, and Nair, *Chemical Engineering Science* (2023)

Acknowledgements

Our recent work has been supported by the NASA Solar System Exploration Research Virtual Institute, the National Science Foundation, the DOE-RAPID Institute, the Department of Energy, the USDA Forest Products Laboratory, P[3]Nano, the Renewable Bioproducts Institute at Georgia Tech, and industry sponsors.