Programmable Composites: From Lightweight, Strong Aerospace Structures to Soft, Shape-Reconfigurable Robotic Surfaces

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Monday, February 21st, 2022
12:30 PM

MAE Seminar Series

Creating engineered materials that have not only unprecedented, but also dynamically tunable physical properties remains an ultimate pursuit by many scientists and engineers. Although novel manufacturing breakthroughs, most notably additive manufacturing, have greatly expanded our ability to manipulate material compositions and architectures across a wide range of length scales, many of these technologies still face limitations in scalability, material compatibility, and design versatility, among others. In addition, most advanced materials and structures are "static" – i.e., unable to reprogram post fabrication. In this talk, I will discuss new materials, manufacturing methods, and characterization techniques that enable an integrated pathway towards creating dynamically reprogrammable, multifunctional materials with unusual capabilities. First, I will describe the design, fabrication, and characterization approaches that exploit aligned carbon nanotubes and in situ synchrotron radiation computed tomography for creating a hierarchically engineered, aerospace composite with enhanced laminate-level strength and toughness. Next, I will present a soft, robotic surface that incorporates liquid metal networks in low-modulus elastomer matrices, capable of fast, reversible shape-morphing into a diverse set of complex 3D shapes on demand. I will conclude by discussing new possibilities in developing future material systems with unique programmable functionalities by integrating these enabling concepts with artificial intelligence and data-driven approaches.

Dr. Xinchen Ni is currently a postdoctoral researcher in the Querrey Simpson Institute for Bioelectronics at Northwestern University, where he works with Prof. John A. Rogers on developing multifunctional programmable material systems for applications in bioelectronics and healthcare. He received his Ph.D. in Mechanical Engineering at the Massachusetts Institute of Technology in 2020, working with Professor Brian L. Wardle on aerospace advanced composites, and his M.S. in Mechanical Engineering, also at MIT, with Professor Mary C. Boyce in 2014. He is the recipient of the Graduate Student Silver Award from the Materials Research Society in 2018.

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