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Mechanics-guided 3D assembly of complex mesostructures and functional devices

Yonggang Huang

Departments of Civil and Environmental Engineering, Mechanical Engineering, and Materials Science and Engineering, Northwestern University,

ABSTRACT:

A rapidly expanding research area involves the development of routes to complex 3D structures with feature sizes in the mesoscopic range (that is, between tens of nanometres and hundreds of micrometres). A goal is to establish methods to controll the properties of materials systems and the function of devices constructed with them, not only through chemistry and morphology, but also through 3D architectures. Hwever, existing approaches of 3D assembly/fabrication are only compatible with a narrow class of materials and/or 3D geometries. In this talk, I will introduce a mechanics-guided assembly approach that exploits controlled buckling for constructing complex 3D micro/nanostructures from patterned 2D micro/nanoscale precursors that can be easily formed using established semiconductor technologies. This approach applies to a very broad set of materials (e.g., semiconductors, polymers, metals, and ceramics) and even their heterogeneous integration, over a wide range of length scales (e.g., from 100 nm to 10 cm). To enrich the class of 3D geometries accessible to the proposed assembly approach, we devised a set of mechanics-driven design strategies, such as kirigami/origami designs of 2D precursors, heterogeneous substrate designs and loading-path controlled shape morphing strategies. I will also introduce a series of mechanics models for the direct postbuckling analysis, as well as inverse design methods that map target 3D topologies onto unknown 2D precursor patterns, which could provide an important theoretical foundation of the rational 3D assembly. The compatibility of the approach with the state-of-the-art fabrication/processing techniques, along with the versatile capabilities, allow transformation of diverse existing 2D microsystems into 3D configurations, providing unusual design options in the development of novel functional devices. I will demonstrate a few examples in this presentation, including biomedical devices conformally integrated with organoids/tissues/organs, 3D MEMS capable of efficient energy harvesting of low-frequency vibration, bioinspired electronic systems, and 3D microfluidic devices.

BIOGRAPHY:

Yonggang Huang is the Jan and Marcia Achenbach Professor of Mechanical Engineering and Civil and Environmental Engineering at Northwestern University. He also holds a courtesy appointment in its Materials Science and Engineering Department. He is interested in mechanics of materials and structures, and has published 2 books and more than 700 journal papers and book chapters, including 12 in Science and 7 in Nature. He is a member of the US National Academy of Engineering, US National Academy of Sciences, and a fellow of American Academy of Arts and Sciences. His research awards include the Larson Award in 2003, Melville Medal in 2004, Richards Award in 2010, Drucker Medal in 2013, Nadai Medal in 2016, Thurston Lecture Award in 2019, and Honorary Membership in 2021, from American Society of Mechanical Engineers (ASME); Young Investigator Medal in 2006 and Prager Medal in 2017 from the Society of Engineering Sciences; International Journal of Plasticity Medal in 2007; Guggenheim Fellowship from the Guggenheim Foundation in 2008; Highly Cited Researcher in Engineering in 2009, in Materials Science since 2014, and in Physics in 2018; Bazant Medal in 2018 and von Karman Medal in 2019 from the American Society of Civil Engineers. His recognitions for undergraduate teaching and advising include the Most Supportive Junior Faculty Member from the Department of Aerospace and Mechanical Engineering, University of Arizona in 1993; on the "Incomplete List of Teachers Ranked as Excellent by Their Students", University of Illinois at Urbana-Champaign in 2003, 2004, 2005, 2006, and 2007; Engineering Council Award for Excellence in Advising from the College of Engineering, University of Illinois at Urbana-Champaign in 2007; Cole-Higgins Award for Excellence in Teaching, McCormick School of Engineering, Northwestern University in 2016; and on the Associated Student Government Faculty and Administrator Honor Roll, Northwestern University, 2018 and 2020. He is the Editor-in-Chief of Applied Mechanics Reviews, and was the President of the Society of Engineering Science in 2014, the Chairman of the ASME Applied Mechanics Division (2019-2020), and the Editor-in-Chief of Journal of Applied Mechanics (Transactions of the ASME) 2012-2022.