IOWA STATE UNIVERSITY
Department of Mechanical Engineering

Aerosol Jet Printed 3D Microarchitectures: From Process Development to Real-World Applications

Prof. Rahul Panat

Department of Mechanical Engineering

Carnegie Mellon University

Faculty host: Ethan Secor

Seminar on October 17th, 2023 at 11:00 AM in 2004 Black Engr.

Abstract

In this research, we develop a novel nature-inspired droplet-based nanoparticle printing method using the Aerosol Jet (AJ) technology that extends ink-based printing into 3D space. A balance between inertia forces and surface forces for the microdroplets (each containing nanoparticles), along with rapid solvent evaporation are used to create highly complex 3D microarchitectures of metals and polymers without auxiliary support and with near-fully dense truss members. Highly intricate 3-D micro-lattices, pillars, interconnects, and spirals are demonstrated.

We then use these structures to: (i) study fundamental material science, and (ii) demonstrate device applications with extraordinary performances that cannot be achieved by any other method. For (i), a temperature-gradient-driven mass transport is shown as a new mechanism of 4D printing. For (ii), novel 3D geometry of electrodes enable detection of pathogen antibodies and antigens in 10-12 seconds at femtomolar sensitivities - the fastest detection of disease biomarkers yet reported! This technology is validated through human trials. In addition, the 3D microarchitectures in our lab enable fully customizable brain-computer interfaces (BCIs) that record electrical signals between neurons at densities of thousands of electrodes/cm2, which is 5-10× the current state-of-the-art BCI technologies. The technology was validated through animal testing via recording of the action potentials from the mouse brain. We also demonstrated the printing of high-capacity Li-ion batteries and thin flexible robotic skins with embedded sensors. Lastly, our ongoing work on creating manufacturing digital twins of the AJ printing process is also discussed.

Prof. Rahul Panat is the Russell V. Trader Professor of Mechanical Engineering at Carnegie Mellon University (CMU). He is courtesy faculty in the Materials Science and Engineering and the Biomedical Engineering Departments at CMU. He is also the Associate Director of Research at the Manufacturing Futures Institute at CMU, which is focused on bringing the latest advances in digital technologies to advanced manufacturing. Prof. Panat completed his PhD in Theoretical and Applied Mechanics from the University of Illinois at Urbana in 2004. He joined Intel Corporation's R&D unit in Chandler, AZ, where he worked for 10 years on microprocessor packaging R&D; specifically on 3D heterogeneous integration. At Intel, Dr. Panat led a team of engineers that developed the manufacturing process for world's first halogen-free IC chip. He was part of a team that introduced the first Si chip with a billion transistors. He returned to academia in 2014 and joined CMU in fall 2017. His research is focused on microscale 3D printing and its applications to biomedical engineering, stretchable electronics, and Li-ion batteries. His research is funded by NIH, DOE, NSF, US Army, US Air Force, and federal intelligence agencies, in addition to industry and several foundations. Prof. Panat is recipient of several awards, including MRS gold medal, Mavis Memorial Award, an award at Intel for his work on the halogen-free chip, Struminger Teaching Fellowship, and the Russell V. Trader chair professorship at CMU. .

This seminar counts towards the ME 600 seminar requirement for Mechanical Engineering graduate students.

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