

## Ph.D. DISSERTATION DEFENSE

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<b>Degree:</b>	Doctor of Philosophy
<b>School/Department:</b>	Charles V. Schafer School of Engineering and Science (SES) / Mechanical Engineering (ME)
<b>Date:</b>	Friday, April 24, 2026
<b>Time/Location:</b>	10AM – EAS 339
<b>Title:</b>	Multi-material Gradient Bioprinting of Low Viscosity Hydrogels via a Support Bath Printing Paradigm Guided by <i>in-situ</i> Viscosity Measurement
<b>Chairperson:</b>	Dr. Robert Chang, Department of Mechanical Engineering, SES
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### ABSTRACT

Advances in bioprinting enable complex tissue fabrication, yet controlling multi-material deposition of low-viscosity hydrogels remains challenging. To address this, this dissertation presents a novel platform integrating support bath printing with real-time *in-situ* viscosity measurement.

A primary contribution is a low-cost, open-source quad-extrusion bioprinter designed for seamless multi-material deposition. To understand the printing process mechanistically, tri-axial mechanical testing and inverse finite element modeling were employed, revealing how process parameters dictate structural integrity and cellular viability.

Furthermore, this research validated an In-Situ Viscosity Measurement System (IVMS). By providing continuous feedback to compensate for dynamic rheological changes, the IVMS significantly enhances print reliability. This integrated platform enables ongoing advanced biological applications, including multi-material gradient bioprinting to mimic native architectures and 3D bioprinted placental models to investigate trophoblast invasion.

Ultimately, this work outlines a translational roadmap for biofabrication. Driven by regulatory shifts toward FDA-approved New Alternative Methods (NAMs) for drug discovery, this research transitions the field toward intelligent, closed-loop process control utilizing physics-based machine learning. By establishing the scalable infrastructure needed to overcome current manufacturing limitations, these advancements lay the critical groundwork for unlocking full organ printing.