Mechanical & Industrial Engineering
UNIVERSITY OF TORONTO

MIE498H1: Research Thesis 2025-2026

Supervisor	Axel Guenther
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Number of Positions	1
Open to	Mechanical Engineering Students
Term Offered	Full-year
Research Area	Mechanics & Design
Research Topic	Automated Roll-to-Roll (R2R) Processing of Ultrathin Collagen Sheets using MATLAB

Project Description

Collagen type 1 is the extracellular matrix material that allows human tissues such as blood vessels, the heart, and skin physiological loading forces. Increasingly, additive manufacturing approaches can recapitulate the hierarchical organization of collagen in native tissues. In our laboratory, we use ultrathin collagen sheets that are ~2 microns thick and 10mm wide for the preparation of load-bearing composite structures [1,2]. Our current artisan setups allow us to prepare ~10cm long sheets, sufficient in length to prepare blood vessel and bile duct structures for evaluation in miniature human tissue laboratory or in small animal models. However, hundredfold longer sheets and automated approaches are required to routinely prepare human-tissue scale structures.

To address this need, we have prepared a roll-to-roll (R2R) system that involves extruding collagen solution onto a conveyer belt before collection onto a large drum followed by post processing. As of now, all the electrical components (pumps, motors) are manually operated, which requires experiments to be conducted by 2-3 operators, introduces human error and uncertainty, limits throughput and prevents truly continuous operation and scalability. Automating the entire R2R production promises consistent, sterile fabrication of aligned collagen sheet substrates at throughputs of up to 1.7 km per day, while providing real-time control over processing parameters.

Goals:

- Control extrusion flow rates (3 pumps), roller speed (stepper motor), PEG bath water levels and (stretch goal) stage temperature via MATLAB GUI.
- Implement clogging-free startup via sequential initiation of extrusion via separate computer-connected syringe pumps (i.e., buffer solutions, collagen solution).
- Incorporate real-time image acquisition of collagen sheet width, thickness (if possible) and length via camera recording under controlled lighting conditions.
- Log all process parameters for documentation (e.g. by identifying batch via QR

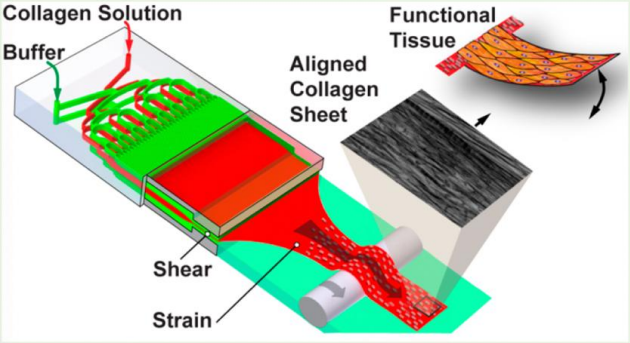
code on roll) and feedback control in future versions.

Expected Outcomes:

- Automate R2R collagen sheet formation with continuous length tracking and in situ imaging/characterization.
- Display and record sheet metrics and process parameters in real time.
- Provide basis for future additive manufacturing via layering or multi-material sheet stacking.

Prerequisites:

- Interest in robotics, mechatronics, additive manufacturing
- No prior knowledge in biofabrication required



References:

[1] Y. Zhang, S. Malladi, B. Wang, D. O. Son, B. Hinz, E. L. Chaikof, A. Günther, Microfluidic Production of Ultrathin, Handleable Collagen Sheets Exhibiting Toe-heel Tensile Behavior. *Adv. Mater. Technol.* 2025, 2401810. https://doi.org/10.1002/admt.202401810

[2] S. Malladi, D. Miranda-Nieves, L. Leng, S. J. Grainger, C. Tarabanis, A. P. Nesmith, R. Kosaraju, C. A. Haller, K. K. Parker, E. L. Chaikof, and A. Günther Continuous Formation of Ultrathin, Strong Collagen Sheets with Tunable Anisotropy and Compaction *ACS Biomaterials Science & Engineering* 2020 *6* (7), 4236-4246, https://doi.org/10.1021/acsbiomaterials.0c00321

Additional Information	N/A
Application Instructions	Please submit CV, unofficial transcript, to Prof. Axel Guenther, e-mail: axel.guenther@utoronto.ca