Mechanical & Industrial Engineering
UNIVERSITY OF TORONTO

MIE498H1: Research Thesis 2026-2027

Supervisor	Prof. Patrick C. Lee
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Number of Positions	2
Open to	Undergraduate Mechanical Engineering Students
Term Offered	Full-year
Research Area	Materials
Research Topic	Bio-Inspired Laser-Induced Graphene And Micro–Nano Structuring For Advanced Functional Materials

Project Description

This research focuses on the development of multifunctional carbon-based materials through bio-inspired laser processing, graphitization, and hierarchical micro–nano structuring. By integrating laser-induced graphene (LIG), controllable crystallization, and morphology engineering, the work aims to establish scalable strategies for tailoring structure–property relationships for next-generation functional materials.

A major focus of this work is the fabrication of laser-induced graphene architectures inspired by natural hierarchical systems. Through controlled laser–matter interactions, polymeric precursors can be transformed into conductive turbostratic graphene networks with tunable porosity, surface chemistry, and morphology. Similar to biological systems that achieve multifunctionality through hierarchical organization, laser-induced graphitization enables simultaneous control of electrical, thermal, and mechanical properties within a single processing step. This approach provides a sustainable and efficient route for producing lightweight, high-performance carbon architectures without complex chemical synthesis.

The research further investigates how laser processing parameters-including fluence, pulse density, and scanning strategy-govern graphitization behavior, crystallization pathways, and micro–/nano-structural evolution. Laser-induced photothermal and photochemical effects are utilized to engineer porous graphene frameworks and anisotropic surface textures with enhanced conductivity, high surface area, and robust functional performance.

In parallel, this work explores bio-inspired porous architectures generated through laser-induced micro-/nano-structuring, where morphology and interfacial chemistry collectively determine material functionality. Advanced characterization techniques, including Raman spectroscopy, electron microscopy, thermal analysis, and electrochemical measurements, are employed to correlate processing conditions with structural evolution and bulk properties.

Overall, this research positions bio-inspired laser-induced graphitization and hierarchical structuring as scalable design strategies for advanced functional materials in applications such as flexible

electronics, sensors, energy storage systems, protective coatings, and multifunctional polymer composites.

Additional Information	N/A
Application Instructions	Please submit CV and unofficial transcript to Prof. Patrick Lee (**patrickc.lee@utoronto.ca**)