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	Nano-Structured Hierarchically Reinforced Biocomposites

Project Description

The MCML's biocomposite platform combines advanced hybrid nano-structuring with a strong focus on sustainability and industrial scalability. Through novel pre-processing, chemical modification, and forced/self-assembly techniques, the lab develops sustainable biocomposites from bio-based and biodegradable materials to replace petroleum-derived plastics in applications including packaging, biomedical devices, and consumer goods.

A major focus is the development of melt-blendable 1D and 2D lignocellulose-based reinforcing agents by templating lignocellulosic nanofibrils (LCNF) onto nanoclays of different geometries, using spray drying as a scalable forced-assembly process (see Figure 1). Surface treatment exposes hydroxyl groups on the nanoclay surfaces, promoting LCNF self-assembly during spray drying and producing dry powders compatible with existing melt-processing methods. By tailoring the surface chemistry of the nanoclay additives, the localization tendency of the clay along the LCNF surface can be controlled. Consequently, these self-assembled LCNF structures are expected to provide enhanced reinforcement due to their higher surface area and improved stress transfer, when blended with a polymer matrix as an additive in specific proportions, depending on the structure of the self-assembled LCNF. The approach also enables potential graphitization of the biomass into low-cost carbon nanotube and nanoplatelet analogs through a scalable, non-toxic process.

The platform also investigates biodegradable paper-based foams composed of recycled paper fiber, surfactant, and thermoplastic starch. These low-density foams exhibit improved compressive properties compared to conventional paper foams and, in some cases, outperform polyurethane and polystyrene foams of similar density. Ongoing work focuses on understanding composition–processing–structure relationships and incorporating cellulosic nanofibrils and nanocrystals to create hierarchically reinforced foam structures for applications ranging from food packaging to acoustic insulation.

Overall, the MCML's biocomposite research leverages expertise in nano-structuring and sustainable engineering to develop scalable, low-cost, and non-toxic alternatives to conventional materials, driving the next-generation of sustainable materials development.

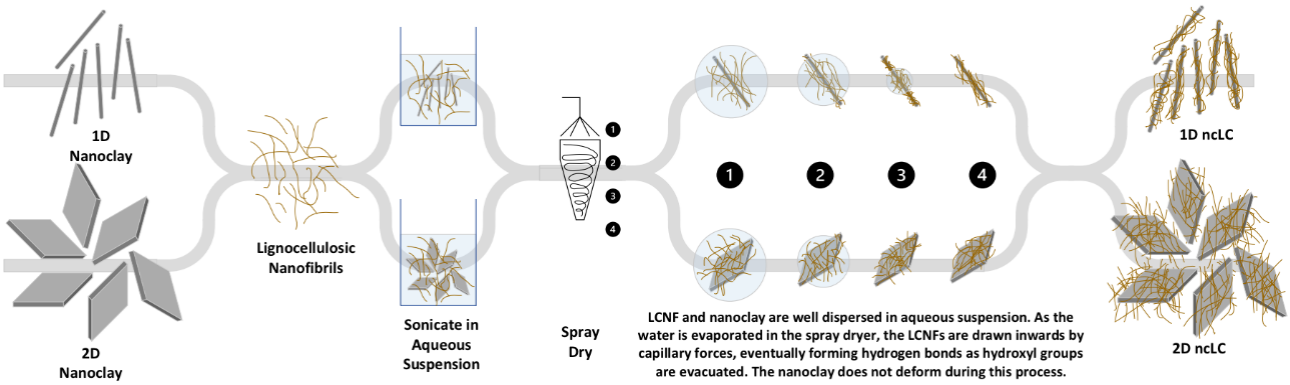

Figure 1: Pathway to preparing templated LCNF with nanoclays of different geometries, involving solution mixing, spray drying, and tailored self-assembly.

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