Mechanical & Industrial Engineering
UNIVERSITY OF TORONTO

MIE498H1: Research Thesis 2026-2027

Supervisor	Prof. Patrick C. Lee
Supervisor email	patrickc.lee@utoronto.ca
Number of Positions	2
Open to	Undergraduate Mechanical Engineering Students
Term Offered	Full-year
Research Area	Materials
Research Topic	Polymer Processing, Aerogels, and Stereocomplexation-Driven Materials Design

Project Description

This research focuses on controlling structure-property relationships in polymer systems through processing, architecture, and intermolecular interactions, with particular emphasis on stereocomplexation as a versatile route to enhance material performance.

A major theme of this work is the use of stereocomplexation in poly(lactic acid) (PLA)-based systems as a platform for designing high-performance, sustainable materials. Stereocomplexation arises from the co-crystallization of enantiomeric poly(L-lactide) (PLLA) and poly(D-lactide) (PDLA), forming a densely packed crystalline structure stabilized by strong intermolecular interactions. As widely noted in literature, this "peculiarly strong interaction between L- and D-lactyl sequences" enables substantial improvements in thermal resistance, mechanical performance, and hydrolytic stability relative to conventional PLA systems.

Building on this foundation, our work explores how stereocomplexation can be deliberately induced, controlled, and integrated into complex polymer systems. It is well established that stereocomplex crystals exhibit melting temperatures exceeding those of homocrystals by more than 50 °C, providing a powerful route to overcome the intrinsic thermal limitations of PLA. We leverage this phenomenon across a range of processing strategies, including co-gelation, reactive blending, and nanostructuring, to create materials with enhanced thermal stability, mechanical robustness, and functional performance. This methodology is also applicable to other complexable polymer systems (e.g., poly(methyl methacrylate), see Figure 1).

In parallel, we investigate polymer aerogels formed through co-gelation approaches, where phase behavior and intermolecular interactions dictate the evolution of porous architectures. By integrating stereocomplexation into these systems, we aim to couple nanoscale ordering with macroscopic porosity, enabling lightweight materials that do not sacrifice strength or thermal performance. This approach reflects a broader perspective in which stereocomplexation is not only a crystallization mechanism, but also a design tool for structuring materials across multiple length scales. Across these systems, advanced characterization techniques are used to link processing conditions to molecular interactions, crystallization behavior, and bulk performance.

Overall, this work positions stereocomplexation as a unifying principle in polymer design: one that enables the transition from conventional biodegradable polymers to advanced, multifunctional materials with tunable properties. By combining controlled processing with molecular-level design, we aim to develop scalable strategies for next-generation polymer systems in applications ranging from insulation and coatings to biomedical and sustainable materials.

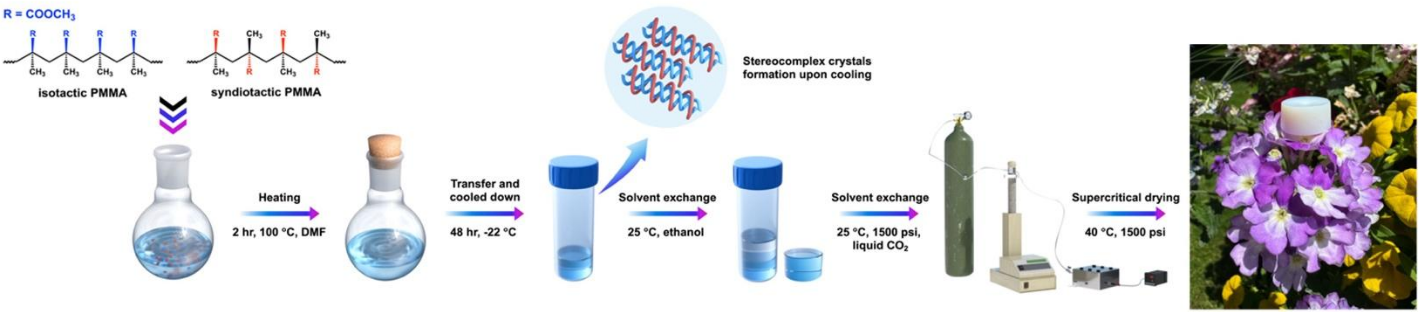

Figure 1: Schematic illustrating the process used to fabricate aerogel monoliths comprised of polymethyl methacrylate stereocomplex crystals.

Additional Information N/A

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