**MIE 1706: Manufacturing of Cellular and Microcellular Polymers (2025S)**

**Instructor**: Prof. Chul B. Park RS210 park@mie.utoronto.ca

**Lecture Hours**: M 3–4 pm (HS696) **and** F 2-4 pm (HS696). The lecture room for Feb 3 (M 3-4 pm) is HS618. See the detailed lecture schedules below. There are no lectures during the reading week.

**Final Exam**: Apr 7th, 2025 (most likely 2 hour open-book)

**Grading scheme**:

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| Reading Assignment: | 17 marks (1 mark for each paper). |
| Take-home Exam: | 12 marks (to be issued on Mar 7th, 2025, due on Mar 14th, 2025) |
| Term Project: | 20 marks (5 marks for the mid-term report due on Feb 24th, 2025 and 15 marks for the final report due on Apr 4th, 2025) |
| Final Exam: | 51 marks (Apr 7th, 2025) |

**Contents**

1. Introduction and Thermo-Physical Properties of Polymer/Gas Mixtures
    - Introduction to Foams and Foam Structure
    - Foaming Agents
    - Pressure - specific Volume - Temperature (PVT)
    - Surface Tension
    - Solubility
2. Cell Nucleation and Growth
    - Cell Nucleation - Homogeneous and Heterogeneous
    - Cell Growth, Cell Stability, and Simultaneous Modeling of Cell Nucleation and Growth
    - Visualization of Foaming
3. Foam Extrusion
    - Control of Cell Nucleation
    - Control of Cell Growth
4. Foam Injection Molding
    - Low-Pressure Foam Injection Molding (Structural Foam Molding)
    - High-Pressure Foam Injection Molding
    - MuCell Technology
5. Bead/Particle Foaming
    - EPP (Effect of Crystal on Foaming)
    - EPLA
6. Foam Compression Molding
    - Crosslinking and Foaming
    - Crystallization and Foaming
7. Open-Cell Foaming

**Lecture Contents and Reading Assignments**

| # | Day | Date | Lecture Contents | (Reading) Assignments |
|---|---|---|---|---|
| 1 | M | 01/13 | 1.1 Introduction to Foams and Foam Structure | |
| 2 | F | 01/17 | 1.1 Introduction to Foams and Foam Structure | Draw $v_f$ vs size |
| 3 | F | 01/17 | 1.2 Foaming Agents, (PVT and) Solubility | |
| 4 | M | 01/20 | 1.2 Foaming Agents, (PVT and) Solubility | J123 |
| 5 | F | 01/24 | 1.2 Foaming Agents, (PVT and) Solubility | J216 |
| 6 | F | 01/24 | 1.2 Foaming Agents, (PVT and) Solubility | |
| 7 | M | 01/27 | 2.1 Cell Nucleation - Homogeneous and Heterogeneous | |
| 8 | F | 01/31 | 2.1 Cell Nucleation - Homogeneous and Heterogeneous | J211 |
| 9 | F | 01/31 | 2.2 Cell Growth, Cell Stability | |
| 10 | M | 02/03 | 2.2 Cell Growth, Cell Stability | J144 |
| 11 | F | 02/07 | 2.3 Simultaneous Modeling of Cell Nucleation & Growth | J086 |
| 12 | F | 02/07 | 2.3 Simultaneous Modeling of Cell Nucleation & Growth | |
| 13 | M | 02/10 | 2.4 Visualization of Foaming | J191 |
| 14 | F | 02/14 | 2.4 Visualization of Foaming | J052 |
| 15 | F | 02/14 | 3.1 Foam Extrusion: Control of Cell Nucleation | |
| 16 | M | 02/24 | 3.1 Foam Extrusion: Control of Cell Nucleation. *Mid Term-Project Report due.* | |
| 17 | F | 02/28 | 3.2 Foam Extrusion: Control of Cell Growth | J060 |
| 18 | F | 02/28 | 3.2 Foam Extrusion: Control of Cell Growth | |
| 19 | M | 03/03 | 3.2 Foam Extrusion: Control of Cell Growth | J130 |
| 20 | F | 03/07 | 3.2 Foam Extrusion: Control of Cell Growth. *Take-home exam to be issued.* | J133 |
| 21 | F | 03/07 | 4.1 Foam Injection Molding: Low-Pressure Structural Foam Molding. | |
| 22 | M | 03/10 | 4.1 Foam Injection Molding: Low-Pressure Structural Foam Molding. | J257 |
| 23 | F | 03/14 | 4.2 Foam Injection Molding: High-Pressure Foam Injection Molding. *Take-home exam due.* | |
| 24 | F | 03/14 | 4.2 Foam Injection Molding: High-Pressure Foam Injection Molding | |
| 25 | M | 03/17 | 4.2 Foam Injection Molding: High-Pressure Foam Injection Molding | J285 |
| 26 | F | 03/21 | 4.2 Foam Injection Molding: High-Pressure Foam Injection Molding | J203 |
| 27 | F | 03/21 | 5.1 Bead/Particle Foaming: EPP | |
| 28 | M | 03/24 | 5.1 Bead/Particle Foaming: EPP | J247 |
| 29 | F | 03/28 | 5.2 Bead/Particle Foaming: EPLA | C314 |
| 30 | F | 03/28 | 5.2 Bead/Particle Foaming: EPLA | |
| 31 | M | 03/31 | 6.1 Foam Compression Molding | J080 |
| 32 | F | 04/04 | 6.1 Foam Compression Molding. *Final Term-Project Report due.* | |
| 33 | F | 04/04 | 7.1 Open Cell Foaming. | |
| 34 | M | 04/07 | *Final Exam* | |

**INSTRUCTION FOR THE READING ASSIGNMENTS**

· 1-page summary of the reading assignment due on the next lecture.
· Pay attention to the due date. Marks will be severely deducted for the late reports (20% for each day).
· The report will not be returned. Make your own copy before you submit it.

· Use the Times New Roman font, the font size 12, and single line spacing. 1 or 2 columns
· Type the report. Marks will be severely deducted for hand-written texts (except for the first homework).

**INSTRUCTION FOR THE TERM PROJECT**

**1. Purpose**

The purpose of the term project is to deeply understand the fundamentals of the foaming phenomena. You have to demonstrate that you have completely understood the cell nucleation theories, the equations used in the cell growth phenomena, and the coupled nature of the cell nucleation and growth phenomena, and the associated cell stability issue.

**2. Topic**

Any topic in the areas of cell nucleation, cell stability, cell coarsening, cell coalescence, cell growth, and simultaneous modeling of cell nucleation and growth, is acceptable. It does not have to have any unique and new contributions, but if you present any innovative ideas that do not violate the basic principles of the papers listed below, you will get some bonus mark. But please note that you need to first clearly demonstrate that you have fully understood the contents of these 8 papers. If you include the analysis of the cell nucleation phenomena in any of the actual foam processes such as foam extrusion, foam injection molding, bead foaming, or foam compression molding, it will be a feather in your cap. But again, too much emphasis on the application may not be impressive. I want to make sure that you fully understood the basic concepts. Warning: those who think that a part of these papers is wrong, and therefore develop a better theory or explanation of the phenomena, you had better first talk to me about your new concept. Most likely, you are wrong. If you do things on your own instead of demonstrating your understanding, your term-project mark may converge to zero.

Essential papers: J002, J086, J092, J144, J169, J190, J191, J205, J211 (note: The following statement in J205 "Furthermore, it is also hypothesized that the free volume within the amorphous regions was decreased due to polymer chain alignment under the applied $\varepsilon$, which caused a decrease in gas solubility." may be incorrect.)

**3. Reports** (20 marks)

· Mid-term project report due on Feb 24, 2025. 2-page limit including the title and references. 2 column format (see the attached example). 5 marks.
· Final project report due on Apr 4, 2025. 5-page limit including the title and references. 2 column format (see the attached example). 15 marks.
· Grading scheme

| | |
|---|---|
| Technical contents: | 70% |
| Communication skills: | 30% |

· Pay attention to the due date. Marks will be severely deducted for the late reports (20% for each day).
· I am attaching the Society of Plastics Engineers Annual Technical Conference paper template for your information. The Word file will be circulated to all.
· Make sure to include a formal bibliography at the end of the report.
· The report will not be returned. Make your own copy before you submit it.

· Use the Times New Roman font, the font size 10, and single line spacing. Please use the template format circulated by email.
· Type the report. Marks will be severely deducted for hand-written texts, figures, and tables. Equations, tables, and figures should be properly numbered. Proper captions should be attached to each table and figure.