

## MS7014 MECHANICAL PROPERTIES OF POLYMERS, BIOMATERIALS, AND COMPOSITES

### Course Faculty:

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Lecture Time	9:30 – 12:30 pm Wednesday @ MSE B2-E-space	9:30 – 12:30 pm Wednesday @ MSE B2-E-space
Office Hours	11:00 – 13:00 Tuesday @ N4.1-01-29	By appt.

Date of printing	:	Fall <u>2023</u>
Academic Year	:	<u>2023/2024</u>
Study Year (if applicable)	:	<u>Graduate Course</u>
Subject Code & Title	:	<u>MS7014 Mechanical Properties of Polymers, Biomaterials, and Composites</u>
Academic Unit	:	[Lectures: 39 hrs; Academic Unit: 3]
Pre-requisites	:	<u>None</u>

### Supplemental Textbooks:

1. R. J. Crawford, Plastics Engineering, Third edition, Pergamon Press, 1990 [ONLINE]
2. Joel R. Fried, Polymer Science and Technology, Prentice Hall PTR, 1995.
3. B.D. Ratner, Biomaterials Science: An introduction to Materials in Medicine
4. B. D. Cullity and S. R. Stock, Elements of X-Ray Diffraction, 3rd Edition, 2001, Prentice-Hall, Inc.

### COURSE OBJECTIVES:

This subject is offered to first year graduate students. It aims to introduce important concepts in materials science, with a focus on viscoelasticity, hard/soft materials, non-destructive analysis, and methods of polymer/nanomaterial analysis.

### COURSE REQUIREMENTS:

- 1) Attend class session, take quizzes and continuing assessment exams, and study the relevant sections of the required course material as updated in the NTULearn <https://ntulearn.ntu.edu.sg/>.
- 2) Participate in class discussions and contribute to active learning projects used in class.

- 1. Hard/Soft Materials and Viscoelasticity** **9 hrs**  
Introduction to non-Newtonian flow behaviors and factors affecting viscous vs. elastic materials: molecular structures, molecular weight, pressure, temperature, shear history.
- 2. Measurements of viscoelastic behaviors** **6 hrs**  
Analysis of flow, cone and plate viscometers, capillary rheometers, and tensile testing.

**3. Hard/Soft Materials in Coatings** **9 hrs**

Employment and methods of state-of-the-art nanomaterials, additives, and polymers ceramics currently used in biomaterials. Examples of common materials, medical devices, and issues in development.

**4. X-Ray Characterization and Electron Microscopy** **9 hrs**

The topics include X -ray and e-beam characterization of polymers, biomaterials and composites, which cover the fundamentals, techniques, as well as case studies from the current literature.

<b>Week</b>	<b>Date 9:30-12:30 pm Wednesday</b>	<b>Online</b>	<b>IN-class</b>
<b>1</b>	Week 1		Syllabus and Lecture 1: Fundamentals: Hard Materials & Statics
<b>2</b>	Week 2	Lecture 2: Shear Viscosity & Non-Newtonian Fluids	Importing Data into OriginPro: Milk Chocolate Viscosity
<b>3</b>	Week 3	Lecture 3: Viscoelasticity & Power Law	Arrhenius Relationship and 3D graphics
<b>4</b>	Week 4	Lecture 4: Pressure Flow & Rheometry	Unknown Rheological Fluid
<b>5</b>	Week 5	Lecture 5: Polymer Additives: Autoxidation	Unknown Rheological Fluid
<b>6</b>	Week 6	Lecture 6: Polymer Additives: Stabilizers & Modifiers	Autoxidation
<b>7</b>	Week 7		Case Studies and Examples
<b>R</b>	Recess Week	No class	
<b>8</b>	Week 8	CA1 Exam	
<b>9</b>	Week 9	Lecture 8: X-ray Characterisation Techniques	X-ray analysis: Absorption & Radiography Absorption & Fine Structure Fluorescence Photoelectron
<b>10</b>	Week 10	Lecture 9: X-ray Characterisation Techniques	X-ray analysis: Diffraction Small Angle X-ray Scattering
<b>11</b>	Week 11	Lecture 10: Electron Microscopy and Techniques	Electron Microscopy: Instrumentation Electron Diffraction

			Contrast formation
12	Week 12	Lecture 11: Class Review	Lecture 11: Class Review
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## LEARNING OUTCOMES

Upon successful completion of the course, students will be able to:

- Understand the similarities and differences between the various engineering modes.
- Apply the concepts of shear and tensile deformation in the context of hard and soft materials.
- Understand the relationships between shear modulus and shear viscosity.
- Apply the concepts of shear deformation in the context of Newtonian fluids.
- Apply the theory of laminar flow in the context of viscosity and its application in industrial processing.
- Compare and contrast three types of Non-Newtonian fluids: pseudoplastic, dilatant, and Bingham plastics.
- Apply the concepts of Newtonian fluids and Hooke's solids in context to time-dependent viscoelastic materials.
- Model power law equations to predict Non-Newtonian, laminar flow of polymer melts.
- Mathematically describe the pressure flow along circular, slit, and annulus cross-sections using the relevant equations.
- Understand the difference between Steady-state testing and Dynamic-state testing.
- Choose characterization methods to quantitate apparent shear viscosity, zero-shear viscosity, dynamic viscosity, complex viscosity and yield point of various polymer resins.
- Describe the autooxidation cycle context of polymer processing, degradation, and long-term material properties.
- Understand various X-ray techniques for materials analysis, especially for the analysis of polymers, biomaterials and composites. Properly choose X-ray characterization techniques for different types of materials.
- Understand electron microscopy techniques for materials analysis. Properly combine the imaging, spectroscopy and diffraction methods in the e-beam analysis.

## COURSE EVALUATION:

Students will have an opportunity to evaluate the course on a date to be scheduled during the last week of the course at the beginning of the class.

Students will be assessed based on:

1. Continual Assessments (CA) exam. One CA exams forms up to 30% of the total subject grade.
2. Group participation including presentations and in-class assignments. 30% of the total subject grade.

3. A final term exam which forms the rest of the total subject grade (40%), which covers the entire course.

### **MAKE-UP EXAM POLICY**

Students must apply for medical leave if they cannot attend classes on the following occasions:

1. On days when continuous assessment, quizzes or in-class assignments are conducted during classes.
2. On any other occasions that tutor(s) or Lecturer(s) deemed as compulsory for students' attendance.
3. You may also approach the year coordinators and the Sub-Dean if you face other difficulties.

All medical certificates must be submitted not later than 7 working days after the medical leave to the School. If students submit the medical certificate after the deadline, they will be given zero mark for any test or quiz that they were absent from. Medical leave form is available at MSE General Office, #01-30.

For medical leave taken during examination periods, the medical certificate together with a Medical Report Form must be submitted to the Office of Academic Services not later than 48 hours after your medical leave during your examination.

For more information, please refer to Office of Academic Services web page on Leave of Absence and Medical Certificate.

**HONOR CODE:** By undertaking this course, the student agrees to abide by the Student Honor Code, located [here](#).

**Usage of Artificial Intelligence (AI) tools** in your report preparation and writing must be indicated. The act of taking words or ideas from other sources, including **ChatGPT and other AI technologies**, and present them as your own without proper citation of the source(s), will be treated as misconduct. AI tools may produce inaccuracies and introduce biases. Always check your facts from independent scientific sources, and critically evaluate any AI-generated output.