INTRODUCTION TO POLYMERS – PHYS 564 Spring 2019

Instructor: Prof. Connie Roth Email: cbroth@emory.edu

Lectures: Mondays & Wednesdays, 11:30 am – 12:45 pm, MSC N301

Course website: http://www.physics.emory.edu/faculty/roth/polymercourse/
(Summary of important information, this course outline, historical papers and PDFs)

Content: Polymer structures and conformations, polymer synthesis, molecular weight distribution and characterization; properties of polymer solutions, solubility and miscibility, polymer blends; properties of bulk polymers, glass and melt transitions, crystallization, rubber elasticity, viscous flow and viscoelasticity, time-temperature superposition; polymer dynamics, Rouse and reptation models. This course is intended to give students an overview of important concepts in polymer science, and highlight some of the current areas of research and how they relate to technological applications. The goal is to bring you up to speed such that you could then follow a research paper or presentation in this field.

Audience: Graduate students and advanced undergraduates in physics and chemistry.

Text: Paul C. Hiemenz & Timothy P. Lodge, *Polymer Chemistry*, 2nd edition, CRC Press (Taylor & Francis Group), 2007. (required)

Additional Texts on Available in the Library:

Classics

P.J. Flory, PRINCIPLES OF POLYMER CHEMISTRY, 1953.
J.D. Ferry, VISCOELASTIC PROPERTIES OF POLYMERS, 1961.
P.-G. de Gennes, SCALING CONCEPTS IN POLYMER PHYSICS, 1979.
M. Doi & S.F. Edwards, THE THEORY OF POLYMER DYNAMICS, 1986.

Introductory

M. Rubinstein & R. Colby, POLYMER PHYSICS, 2003.
G.R. Strobl, THE PHYSICS OF POLYMERS: CONCEPTS FOR UNDERSTANDING THEIR STRUCTURES AND BEHAVIOR, 2007.
S.L. Rosen, FUNDAMENTAL PRINCIPLES OF POLYMERIC MATERIALS, 1993.
C.E. Carraher, SEYMOUR/CARREHER'S POLYMER CHEMISTRY, 2003.
J.M.G. Cowie, POLYMERS: CHEMISTRY & PHYSICS OF MODERN MATERIALS, 1991.
L.H. Sperling, INTRODUCTION TO POLYMER SCIENCE, 2006.

Reference/Non-Circulating Materials in Chemistry Library

H.F. Mark, ENCYCLOPEDIA OF POLYMER SCIENCE AND ENGINEERING, 1985.

Electronic Online Access

J. Brandrup, POLYMER HANDBOOK, 1999.
L.A. Utracki, POLYMER BLENDS HANDBOOK, 2002.

(HW due dates) **Detailed Course Outline**

Lecture / Date	Text Sections	Topics
1 Mon, Jan 14	1.1–1.6	Course outline, Polymers in common products, Historical development, Terminology and Classification
2 Wed, Jan 16	1.7–1.8, 9.8	MW distributions and measurement techniques, GPC
	Monday, January 21	*MLK day – no classes*
3 Wed, Jan 23	2.1–2.4	Step-Growth polymerization and MW distribution
4 Mon, Jan 28	3.1–3.5	Chain-Growth polymerization steps
5 Wed, Jan 30	3.5–3.8	Kinetic chain length, Radical lifetime, MW distribution depending on termination
6 Mon, Feb 4	4.1–4.8, Chap 5	Controlled polymerization strategies (highlights)
7 Wed, Feb 6	6.1–6.3	Ideal chain conformation, methods to calculate R_g & R_{EE}
8 Mon, Feb 11	6.4–6.6	Semi-flexible chains, persistence length, more on R_g
9 Wed, Feb 13	6.7–6.8,7.7	Distributions of chains, scaling of $R_g \sim N^{\nu}$
10 Mon, Feb 18	R&C Chap 5	Overlap concentration, blobs, scaling in solutions
11 Wed, Feb 20	7.1–7.3	Entropy of Mixing, Flory-Huggins Theory
12 Mon, Feb 25	7.4,7.7	Osmotic pressure, excluded volume, theta solvent
13 Wed, Feb 27	7.5,–7.6	Phase diagrams, more on F-H χ parameter
	Mon/Wed Mar 4/6	*APS March meeting – class canceled*
	Spring Break, March 11 – 15, 2019	
14 Mon, Mar 18	Chap 8	Light scattering, Zimm plots, measuring R_g
15 Wed, Mar 20	9.2.2,9.3,9.8	Viscosity of dilute solutions, Mark-Houwink eqn (GPC)
16 Mon, Mar 25	9.5–9.7	Diffusion coefficients, hydrodynamic interactions
17 Wed, Mar 27	10.1,10.3–10.6	Elastic networks, force of entropy on a single chain, ideal network, shear modulus
18 Mon, Apr 1	11.1–11.3	Viscoelasticity, Silly Putty, Spring-dashpot models
19 Wed, Apr 3	11.4,11.6	Moduli curves, rubbery plateau, entanglements, Markovitz video
20 Mon, Apr 8	11.5,11.7	Microscopic picture, bead-spring model, reptation
21 Wed, Apr 10	**Presentations on Historical Papers**	
22 Mon, Apr 15	12.1–12.3,12.6	Glass Transition, DSC, MW dep. of T_g
23 Wed, Apr 17	12.4–12.5	T_g theory, Free volume, VFT, WLF, Time-Temp superp.
24 Mon, Apr 22	13.1–13.2,13.6	Crystallization in polymers, crystal structures
25 Wed, Apr 24	13.3–13.5,13.7	Nucleation & growth, melting, bulk kinetics
26 Mon, Apr 29	**Presentations of Current Research Projects**	(likely an extended 2 hour class)

Grading:

20% **Homework Assignments**

29% **Final Exam – Wednesday, May 8th, 2019 from 8:00 - 10:30 AM**
(Testing qualitative understanding of material taught.)

21% **Review and Presentation of Historical Paper**
14% for written review and 7% for presentation (see below for details)
Presentations in class on Wednesday, April 10, 2019 (5 min each).
Written reviews for everyone will be due at the beginning of that Wednesday class.

30% **Report and Presentation on Current Research Topic**
20% for report and 10% for presentation (see below for details.)
Presentations mostly in class Monday, April 29, 2019 (10 min each).
Written report for everyone due last day of class, Monday, April 29.

Homework Assignments are due at the beginning of class on the indicated due date.

Assignments handed in late can receive up to 50% credit. Legitimate hardships will be considered on a case-by-case basis (contact instructor).

Group discussion on homework problems is encouraged, but students must write up their own solutions. Scores for assignments will not only be based on the correct answer, but also that the solution is clearly presented. (Convince me that you understand the material and didn't just copy somebody.) Homework solutions should be clearly written on clean sheets of 8½ x 11 paper.

Final Exam will qualitatively test all the material covered in class. I will be stressing comprehension of concepts, not your ability to churn through math. The idea is that there is a basic conceptual understanding of polymers that I think you should be getting out of this course such that you can understand a research seminar or paper in the field. The final exam will aim to test if you understood these basics.

Format for all written reviews and reports:

- 8 ½" x 11" paper with 1" margins all around
- 12 point serif font (e.g., Times New Roman)
- True double spaced text (exact 24 pt spacing, or 27 lines per page)

Written reviews and reports not conforming to format guidelines or exceeding length requirements may be returned without grading.

In all work submitted for this course, I reserve the right to deduct marks for spelling, grammar, and unclear, incomprehensible, or illegible writing.

Review and Presentation of Historical Paper (21% = 14% written + 7% presentation)

Each student will choose an important historical / landmark paper in polymers. They must do a literature search and write a short review placing the work into context.

The review should address the following questions:

- What was the major finding of the paper?
- How did it advance the field?
- How has the paper been cited?
- Is work in that area still ongoing or has it been resolved?

Written reviews should be **no more than 2 pages double-spaced**. Work exceeding this limit will not be graded. This is an opportunity for you to practice writing well-constructed and concise sentences.

Presentations – Each student will give a short presentation (**5 minutes in length)** reviewing their historical paper to the class. Presenters exceeding 5 min. will be asked to stop and graded accordingly. You may use a maximum of **5 Powerpoint slides** to illustrate key ideas or figures. There will be 2 minutes after each talk for questions.

Selection of Historical papers available on the course website:

http://www.physics.emory.edu/faculty/roth/polymercourse/

(Or another paper selected by the student that meets the instructor's approval.)

No two students will review the same paper. Papers will be assigned on a first come, first serve basis. So choose early.

The purpose of this project is to:

- Develop an appreciation for how scientific research goes from being published, cited, to eventually accepted as scientific knowledge and thus incorporated into textbooks and courses.
- Learn the uses of citation searching through **Web of Science**: **http://isiknowledge.com/WOS**

Why such formal guidelines for report and presentation length?

- Everyone's reviews and reports will be judged on the same footing (length and content).
- Good Practice. During the past several years I've had to:
  - Write various parts of journal manuscripts and grant proposals to different length requirements (150, 250, 300, 1500, 1700, 2500 words), or fixed number of pages with set margins and font size.
  - Give presentations of various lengths (3 min, 10 min, 15 min, 20 min, 30 min, 45 min).

(So you might as well get practice playing this crazy game called research.)

<u>Report and Presentation on Current Research Topic</u>

(20% = 20% written + 10% presentation)

Each student will select and report / present on a current area of research in polymers:

1) Give us the basic background to understand why are people studying this area.
   - What is the relevance to technological applications or society?
   - How long have people been researching this topic? What are the scientific issues?
   - What have been the major breakthroughs? Explain the relevant science.
   - What are the outstanding questions people are trying to address currently?

2) Give us an example of a recent study (paper) in which you feel the authors have tried to address one of these issues.
   - What did they do and how have they contributed to our scientific understanding?

<u>Written report</u> should be **no more than 5 pages double-spaced text (~ 1500 words)**, not including abstract, references, or figures. Work exceeding this limit will not be graded.
- Cover page should include: Title, Name, Date, and Abstract (max 250 words)
- References: minimum of 7, with at least something current within the past 3 years
- Figures: Should be discussed within the body of the text, not just added into parentheses within the text.

<u>Presentations</u> – Each student will give a **10 minute** presentation highlighting their report to the class. Presenters exceeding 10 min will be asked to stop and be graded accordingly. There will be an additional 3 min after each talk for questions. Please submit a copy of your presentation slides (a "handout" of 6 slides/page is sufficient).

<u>Possible Suggestions for Current Research Topics</u>:
- polymers for fuel cell applications
- polymers in solar cells
- polymers for organic light emitting diodes
- polymers for solid electrolyte batteries
- polymer recycling
- green chemistry (e.g., super-critical CO_2 processing)
- bio-based composites
- polymer nanocomposites
- polymer blend compatibility
- polymers in microelectronics
- controlled polymerization techniques
- … other topics that may interest you… talk to instructor…

Students are free to choose any current area of polymers that interests them provided it meets the instructor's approval. Again, **no two students will report on the same topic.** Topics will be assigned on a first come, first serve basis; so choose early. This is an opportunity for you to explore another research area besides your own; take advantage of it.

Homework Schedule – Spring 2019 **Introduction to Polymers (Phys 564)**

Homework 1 – due Wednesday, January 30	MW distributions
Homework 2 – due Wednesday, February 13	Polymerization
Homework 3 – due Wednesday, February 27	Chain conformations
Homework 4 – due Wednesday, March 20	Miscibility & Phase diagrams
Homework 5 – due Wednesday, April 17	Elasticity of polymers
Homework 6 – due Wednesday, April 24	Viscoelasticity

(Homework due at the beginning of class.)