INTRODUCTION TO POLYMERS – PHYS 751R Special Topics

Lectures: MWF 10:40 – 11:30 am, MSC E302 **FALL 2008**

Instructor: Prof. Connie Roth Email: cbroth@emory.edu
Office hours by appointment.

Course website: http://www.physics.emory.edu/faculty/roth/polymercourse/
(Summary of import information, link to 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.

Audience: Advanced undergraduates in physics and chemistry, and graduate students.

Required Textbook: P.C. Hiemenz & T.P. Lodge, POLYMER CHEMISTRY, 2nd edition, CRC Press (Taylor & Francis Group), 2007.

Additional Texts on Reserve 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. Stobl, 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 MATIERALS, 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.

Detailed Course Outline

Lectures	Topics
3	Introduction to polymers and molecular weight distributions (Chap 1)
4-5	Polymerization (selections of Chaps 2-5)
5	Polymer Conformations (Chap 6)
5	Thermodynamics of polymer solutions and blends (Chap 7)
1	MIDTERM
3-4	Dynamics of Dilute Polymer Solutions (Chap 9)
3-4	Polymer Networks and Rubber Elasticity (Chap 10)
5	Linear Viscoelasticity (Chap 11)
4	Glass Transition (Chap 12)
1	Presentations – Historical Papers
2	Crystallization (Chap 13)
2	Presentations – Current Topics in Polymer Research

Grading:

12% Homework Assignments (6 in total)

15% Midterm Test – **Friday, October 10th, 2008 in class**

28% Final Exam (2 hrs) – **Thursday, December 11th, 2008**. Time to be determined.

15% Review and Presentation of Historical Paper
10% for written review and 5% for presentation (see below for details.)
Presentations on Friday, November 14th, 2008 in class (5 min each).
Written reviews due at the beginning of this class.

30% Report and Presentation on Current Research Topic
20% for report and 10% for presentation (see below for details.)
Presentations on Wednesday, December 3rd, 2008 and **Friday, December 5th, 2008 in class (10 min each).**
Written reports due at the beginning of Friday's class (for everyone).

Homework Assignments are due at the beginning of class on the indicated due date.
50% credit will be given to homework submitted up to 24 hrs late (i.e., by 10:40 am the following day). Legitimate hardships will be considered on a case-by-case basis (contact instructor).

There will be a total of 6 homework assignments during the course (one roughly every two weeks). Each will be worth 2% for a total of 12% of the final grade.

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 (no scrap).

Midterm Test on **Friday, October 10th, 2008** will be in class and test the material covered in class up to that point. This will comprise Chapters 1, selected sections of 2-5, and Chapters 6 and 7. The midterm will make up 15% of the final grade.

Final Exam on **Thursday, December 11th, 2008** (time to be determined) will test all the material covered in class. The final will make up 28% of the final grade.

Content of Homework Assignments, Midterm Test, and Final Exam will be similar. In all cases, I will be stressing comprehension of concepts, not your ability to churn through math.

The purpose of taking this course is to develop:

1) Basic Understanding of the Fundamental Principles in Polymers
   Assignments and exams will test your comprehension of fundamental polymer concepts. A strong grounding in these basics should enable you to understand and evaluate research in polymers.
2) Develop an Appreciation of How Research Develops Knowledge in a Field
   By reviewing historical papers you will see how research contributed to our current knowledge base.
3) Practice Good Communication Skills
   Learn to present your ideas in a clear and concise manner, whether written or oral. Your knowledge and ideas are no good if you can't communicate what you know.

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 (24 pt spacing, equivalent to 27 lines per page)

- reference format:

Siatkowski, R. E.; Dunn, D. A.; Botto, R. E. Fundamental Geochemical Properties of Materials Relevant to Petroleum Research. *Journal of Obscure Chemistry* **2006,** 16, 200-215.

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.

Why such formal guidelines?

- Everyone's reviews and reports will be judged on the same footing (length and content).
- Good Practice. During the past few 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.)

Review and Presentation of Historical Paper (15% = 10% written + 5% 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?
- Who are the authors and where was the work carried out?
- 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 paper to the class on **Friday, November 14th, 2008**. Presenters exceeding 5 minutes will be asked to stop and graded accordingly. You may use a maximum of 3 Powerpoint slides to illustrate key ideas or figures.

Selection of Historical Papers:

Molecular Size Distribution in Linear Condensation Polymers
P. J. Flory, *Journal of the American Chemical Society* **1936**, 58, 1877-1885.

Molecular Size Distribution in Three Dimensional Polymers .I. Gelation
P. J. Flory, *Journal of the American Chemical Society* **1941**, 63, 3083-3090.

The Thermodynamics of High Polymer Solutions
P. J. Flory, *Journal of Chemical Physics* **1942**, 10, 51-61.

Theory of Solutions of High Polymers
M. L. Huggins, *Journal of the American Chemical Society* **1942**, 64, 1712-1719.

The Configuration of Real Polymer Chains
P. J. Flory, *Journal of Chemical Physics* **1949**, 17, 303-310.

Treatment of Intrinsic Viscosities
P. J. Flory, T. G. Fox, *Journal of the American Chemical Society* **1951**, 73, 1904-1908.

The Frictional Coefficient for Flexible Chain Molecules in Dilute Solution
L. Mandelkern, P. J. Flory, *Journal of Chemical Physics* **1952**, 20, 212-214.

A Theory of the Linear Viscoelastic Properties of Dilute Solutions of Coiling Polymers
P. E. Rouse, *Journal of Chemical Physics* **1953**, 21, 1272-1280.

Dynamics of Polymer Molecules in Dilute Solution – Viscoelasticity, Flow Birefringence and Dielectric Loss
B. H. Zimm, *Journal of Chemical Physics* **1956**, 24, 269-278.

2nd-Order Transition Temperatures and Related Properties of Polystyrene .1. Influence of Molecular Weight
T. G. Fox, P. J. Flory, *Journal of Applied Physics* **1950**, 21, 581-591.

The Glass Temperature and Related Properties of Polystyrene – Influence of Molecular Weight
T. G. Fox, P. J. Flory, *Journal of Polymer Science* **1954**, 14, 315-319.

Mechanical Properties of Substances of High Molecular Weight .19. The Temperature Dependence of Relaxation Mechanisms in Amorphous Polymers and Other Glass-Forming Liquids
M. L. Williams, R. F. Landel, J. D. Ferry, *Journal of the American Chemical Society* **1955**, 77, 3707-3707.

Viscosity of Entangling Polydisperse Polymers
W. W. Graessley, *Journal of Chemical Physics* **1967**, 47, 1942-1953.

Reptation of a Polymer Chain in Presence of Fixed Obstacles
P. G. de Gennes, *Journal of Chemical Physics* **1971**, 55, 572-579.

Dynamics of Concentrated Polymer Systems. 1. Brownian-Motion in Equilibrium State
M. Doi, S. F. Edwards, *Journal of the Chemical Society - Faraday Transactions II* **1978**, 74, 1789-1801.

Solutions of Flexible Polymers –Neutron Experiments and Interpretation
M. Daoud, J. P. Cotton, B. Farnoux, G. Jannink, G. Sarma, H. Benoit, C. Duplessix, C. Picot, P. G. de Gennes, *Macromolecules* **1975**, 8, 804-818.

Melting Point Depression and Kinetic Effects of Cooling on Crystallization in Poly(vinylidene fluoride)-Poly(methyl methacrylate) Mixtures
T. Nishi, T. T. Wang, *Macromolecules* **1975**, 8, 909-915.

Statistical Thermodynamics of Polymer Solutions
I. C. Sanchez, R. H. Lacombe, *Macromolecules* **1978**, 11, 1145-1156.

Gel Permeation Chromatography. I. A New Method for Molecular Weight Distribution of High Polymers
J. C. Moore, *Journal of Polymer Science: Part A* **1964**, 2, 835-843.

A Universal Calibration for Gel Permeation Chromatography
Z. Grubisic, P. Rempp, H. Benoit, *Journal of Polymer Science: Part B* **1967**, 5, 753-759.

Relative Reactivities in Vinyl Copolymerization
T. Alfrey, C. C. Price, *Journal of Polymer Science* **1947**, 2, 101-106.

Linear Method for Determining Monomer Reactivity Ratios in Copolymerization
M. Fineman, S. D. Ross, *Journal of Polymer Science* **1950**, 5, 259-262.

Narrow molecular weight resins by a free-radical polymerization process
M.K. Georges, R. P. N. Veregin, P. M. Kazmaier, G. K. Hamer, *Macromolecules* **1993**, 26, 2987-2988.

Polymerization of Methyl Methacrylate with the Carbon Tetrachloride/Dichlorotris-(triphenylphosphine)ruthenium(II)/Methylaluminum Bis(2,6-di-tert-butylphenoxide) Initiating System: Possibility of Living Radical Polymerization
M. Kato, M. Kamigaito, M. Sawamoto, T. Higashimura, *Macromolecules* **1995**, 28, 1721-1723.

Controlled/"Living" Radical Polymerization. Halogen Atom Transfer Radical Polymerization Promoted by a Cu(I)/Cu(II) Redox Process
J.-S. Wang, K. Matyjaszewski, *Macromolecules* **1995**, 28, 7901-7910.

Living Free-Radical Polymerization by Reversible Addition-Fragmentation Chain Transfer: The RAFT Process
J. Chiefari, Y. K. Chong, F. Ercole, J. Krstina, J. Jeffery, T. P. T. Le, R. T. A. Mayadunne, G. F. Meijs, C. L. Moad, G. Moad, E. Rizzardo, S. H. Thang, *Macromolecules* **1998**, 31, 5559-5562.

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.

Report and Presentation on Current Research Topic

(30% = 20% written + 10% presentation)

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

- Why are people studying this area? Emphasize motivation.
- What is the relevance to technological applications or society?
- What are the scientific issues? What are the outstanding questions people are trying to address?
- Historical timeline? How long have people been researching this topic? What have been the major breakthroughs?
- Explain the relevant science.
- What do you anticipate the future of this field to be?

Written report should be **no more than 5 pages double-spaced text**, 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.

Presentations – Each student will give a **10 minute** presentation highlighting their report to the class. Presentations will be in class on **Wednesday, December 3rd, 2008** and **Friday, December 5th, 2008**. Presenters exceeding 10 minutes will be asked to stop and graded accordingly. We will try and reserve 1-2 minutes after each talk for questions. Please hand-in a copy of your presentation slides (a "handout" of 6 slides/page is sufficient).

Possible Suggestions for Current Research Topics:

- 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
- …

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.