BEST224: Polymeric Materials
Fall 2018

Class times

Lectures:
M, W 10:30am - 11:45am; GRAN-150.
Lectures will start promptly; *you are expected to arrive on time* to hear important announcements that include the learning objectives for each lecture.

Discussions:
W 1:30pm - 3:20pm; CLSSRM-288.

Course goals

You will apply your knowledge of physics, chemistry, mathematics and biology to develop a proficient understanding of how structure and processing affect the properties and performance of polymeric materials.

Learning outcomes

You will

- acquire and demonstrate sufficient polymer-related vocabulary to enable useful communication with practitioners in a diverse range of polymer-literate fields, including materials science and engineering, biomaterials engineering, solid state physics, and materials chemistry;
- acquire and demonstrate an understanding of how the connectivity and polydispersity of polymer molecules confer unique characteristics that set polymers apart from other classes of material;
- acquire and demonstrate insight into the complex interplay between molecular characteristics, thermodynamics, kinetics, microstructure and properties in the context of polymeric materials.

This course is also conceived as an opportunity for you to demonstrate a developing proficiency in the Core Knowledge, Communication Skills and Critical Thinking program learning outcomes that have been adopted by the BEST graduate group as a whole. Therefore the learning outcomes include:

- Core Knowledge – Graduates will possess a broad foundation in the fundamentals and current topics in either biological or materials science and engineering, as well as an in-depth understanding of their chosen research topic area.
- Communication Skills – Graduates will communicate both fundamental concepts and details of their own research effectively, both in written and oral form, including in a classroom setting to expert and non-expert audiences.

- Critical Thinking – Graduates will be able to critically evaluate the experimental design, data analysis and data interpretation of our peers.

You will practice the related skills – and hone the appropriate information-gathering, computational and data-handling proficiencies – in homework and discussion exercises. You will demonstrate your proficiency formally in the midterm and final examinations, and in the research paper that you will submit in the final week of the semester.

Lead instructor (lectures and discussion)

Christopher Viney
Office hours:
M 5:00pm - 6:00pm; GRAN-130
W 7:00pm - 8:00pm; GRAN-115
E-mail is not a substitute for attending office hours, and it is not a useful medium for obtaining help with homework.

Teaching assistant (TA)

Beatriz Morales Perez
Office hours:
R 10:00am - 11:00am; SE1-Atrium

Prerequisites

Graduate standing in Engineering or Natural Sciences.

Text

The scope of this class is not covered by any textbook. Your class notes will be your primary source of reference material. In addition, readings from current research, trade, and popular literature will be assigned.

Discussions

Learning a subject is enhanced by ***interacting with*** the subject – which includes discussing concepts and solving practice problems. Your discussion sections are designed to support your efforts to learn the course material by working with it in as many ways as possible. Attendance will be recorded.

Homework

Homework is a critical component of this course and is designed to help you learn, understand and practice the material. Seven sets of homework exercises will be issued during the semester. Homework is due on the dates indicated in the detailed schedule provided to course participants via CatCourses. **Late homework will not be accepted without proof of medical or similarly grave extenating circumstances.**

You are encouraged to work with your peers when doing homework. However, each student must turn in his/her own homework assignment and it must reflect his/her own work. You must explicitly identify all peers with whom you worked.

Exams

There will be one in-class midterm exam as indicated on the detailed schedule. There will also be a comprehensive final exam. There will be no make-up exams. If you are sick during a regularly scheduled exam, please bring a note from the university clinic or your own doctor verifying your illness. Your course grade will then be determined by the rest of your work.

Crib sheets will not be allowed during any of the exams. However, calculators will be allowed when necessary, provided that they are not used to store data or formulae pertaining to the course.

Research paper

You will write an in-depth, journal-length research paper on a polymer-related topic that you will select in consultation with the lead instructor. The topic will have some relevance to your field of research. Detailed guidelines will be provided.

Grade determination

Your final grade will be based on the following components:

- homework (20%).
- midterm (30%)
- research paper (10%)
- final exam (40%)

Note that grades will not be assigned on a curve, but will be based on an absolute measure of your work.

Dropping the course

Please see the UC Merced General Catalog and the Registrar's / Student First website for details.

CatCourses

The CatCourses site F18–BEST 224 01/MSE 114 01 will be used for periodic course announcements, and for the distribution of class notes, discussion exercises, homework sets, and (some) solutions. You can also check the scores that you have received on your homework assignments and exams.

Warning: pay no attention to any letter grade that is reported on CatCourses, *except* for the final grade.

Special accommodations

UC Merced is committed to ensuring equal academic opportunities and inclusion for students with disabilities based on the principles of independent living, accessible universal design and diversity. If you qualify for accommodations because of a disability, please submit a letter from the Disability Services Center to me in a timely manner (during the first three weeks of the semester, except for unusual circumstances) so that your needs may be addressed. Student Affairs determines accommodations based on documented disabilities.

We will make every effort to accommodate all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. Please speak with the lead instructor (CV) during the first week of class regarding any potential academic adjustments or accommodations that may arise due to religious beliefs.

Academic honesty and conduct

Students are expected to complete their own work and to abide by the UC Merced Academic Honesty Policy, which can be found on the Student Life website under the "Office of Student Conduct" link. Any work submitted by a student in this course for academic credit will be the student's own work.

You are encouraged to study together and to discuss information and concepts covered in lecture and the sections with other students. You can give "consulting" help to or receive "consulting" help from such students. However, this permissible cooperation should never involve one student having possession of a copy of all or part of work done by someone else, (for example) in the form of an email, an email attachment file, an online file in a shared folder, a diskette or external drive, or a hard copy. Should copying occur, both the student who copied work from another student and the student who gave material to be copied will both automatically receive a zero for the assignment. Penalty for violation of this Policy can also be extended to include failure of the course and University disciplinary action.

You must do your own work during examinations. Talking or discussion is not permitted during the examinations, nor may you compare papers, copy from others, or collaborate in any way. Any collaborative behavior during the examinations will result in failure of the exam, and may lead to failure of the course and University disciplinary action.

Note that most of the handouts provided in this course are protected by copyright, and are flagged accordingly on CatCourses. They are for your *personal* use only. Re-posting the files or their contents on sites such as (for example) "Course Hero" is an explicit violation of this copyright.

Students and instructors are expected to honor UC Merced's Principles of Community: http://www.ucmerced.edu/about-uc-merced/principles-community.

Resources

Counseling and Psychological Services
The mission of UC Merced Counseling and Psychological Services (CAPS) is to support the mental health and well-being of our students. It is the intention of all CAPS staff to provide a safe, confidential atmosphere of acceptance and accessibility to professionals in the field of psychology.

Contact Information (Confidential Help)
Phone: (209) 228-4266
counseling@ucmerced.edu
https://counseling.ucmerced.edu/

Discrimination & Sexual Violence Prevention
The University of California is committed to creating and maintaining a community where all individuals who participate in university programs and activities can work and learn together in an environment free of harassment, exploitation or intimidation.

Contact Information
Phone: (209) 285-9510
msalvador2@ucmerced.edu, Michael Salvador, Director of Compliance
https://dsvp.ucmerced.edu/

CARE Office
Campus Advocacy, Resources, & Education (CARE) provides prevention education for the UC Merced community to achieve an environment free from the threat of sexual violence, dating/domestic violence, and stalking. They provides free and confidential assistance for all UC Merced affiliates (including Undergraduate students, Graduate students, Staff and Faculty. Stop by KL 107.

Contact Information (Confidential Help)
Campus Advocate: Lynna (209) 386-2051
Valley Crisis Center: 24/7 Hotline (209) 722-4357
https://care.ucmerced.edu/

Food Assistance (CalFresh)
CalFresh is a monthly stipend system that allows you to purchase food for no cost at all on your part. If you qualify for work study you most likely qualify for CalFresh.

Contact Information
Phone: (209) 228-4187
calfreshoutreach@ucmerced.edu
https://healthpromotion.ucmerced.edu/calfresh-outreach

Final thoughts

If you are in trouble (behind in homework, doing worse in the course than you would like, etc.) for whatever reason, please let the lead instructor know. Help and advice are available.

Because this is a 4-unit course, you should plan to do *at least* 12 hours of work on it, per week. Here is one suggestion for how to spend this time effectively:

- reading assigned material: 1 hour/week
- attending lectures and office hours: 4 hours/week
- attending and participating in discussion: 2 hours/week
- homework: 3 hours/week
- review, and preparation of review notes: 2 hours/week

It is a good idea to explicitly block out time for all these activities in your schedule. The same is true for your other courses too!

MSE114 / BEST224 Fall 2018 Schedule

Week	Day	Date	Lecture (provisional scope and contents)	Discussion	HW
1	M	20-Aug			
	T	21-Aug			
	W	22-Aug	**Lecture 1: Introduction.** Why and when are polymers used – in Engineering and in Nature? Desirable properties and limitations of polymers. Polymers and sustainability.	No	
	R	23-Aug			
	F	24-Aug			
2	M	27-Aug	**Lecture 2: Basic polymer terminology.** Monomers, oligomers, polymers, high polymers; classification of copolymers; chemical and mechanical cross-links; rubbers, thermosets, thermoplastics; configuration, conformation; glassy & crystalline polymers; natural polymers, synthetic organic & inorganic polymers; bonding types, including the hydrophobic bond.		
	T	28-Aug			
	W	29-Aug	**Lecture 3: Generic synthetic routes to polymers.** Stepwise polymerization (condensation polymerization); addition polymerization (free radical polymerization, ionic polymerization, living polymers); ring-opening polymerization; natural sources of polymers; protein and polyester biotechnology.	D1	
	R	30-Aug			
	F	31-Aug			
3	M	3-Sep	Labor Day		
	T	4-Sep			
	W	5-Sep	**Lecture 4: Statistical aspects of polymerization.** Origins and quantitative description of molecular weight averages and distributions, polydispersity, and degree of polymerization. Controlling molecular weight in homopolymers and copolymers.	D2	HW1 due
	R	6-Sep			
	F	7-Sep			
4	M	10-Sep	**Lecture 5: Statistical aspects of polymerization (continued).** Statistics of step polymerization: number distribution function, number average molecular weight and degree of polymerization, weight average molecular weight and degree of polymerization, polydispersity. Statistics of chain polymerization.		
	T	11-Sep			
	W	12-Sep	**Lecture 6: Characterization of polymer molecules.** What common techniques can and cannot tell you. Methods of molecular weight determination: gel electrophoresis (SDS-PAGE), sedimentation equilibrium, end group analysis, colligative properties (osmotic pressure, vapor phase osmometry), light scattering.	D3	
	R	13-Sep			
	F	14-Sep			
5	M	17-Sep	**Lecture 7: Characterization of polymer molecules (continued).** Methods of molecular weight determination (continued): viscosity (relative, specific, inherent and intrinsic viscosities; Mark-Houwink equation), gel permeation chromatography (GPC), high-pressure liquid chromatography (HPLC). Molecular size: freely jointed chain model. Contour length. RMS end-to-end distance.		
	T	18-Sep			
	W	19-Sep	**Lecture 8: Characterization of polymer molecules (continued).** Molecular size (continued): chain with fixed bond angles, Eyring equation, hindered rotation, Gaussian chains. Radius of gyration. Displacement length. Polymers as fractal objects. Expansion factor, excluded volume effects, solvent effects. Measurement of displacement length by neutron scattering.	D4	HW2 due
	R	20-Sep			
	F	21-Sep			

Week	Day	Date	Lecture (provisional scope and contents)	Discussion	HW
6	M	24-Sep	**Lecture 9: Polymer solutions.** Relevance to processing. Ideal solutions. Hydrophobic effect. Inverse temperature transitions. Implications for self-assembly. Effect of molecular weight on solubility. Good solvents and theta-solvents. Liquid crystalline phases: description and classification.		
	T	25-Sep			
	W	26-Sep	**Lecture 10: Polymer solutions (continued).** Molecular origins of nematic order in an athermal system: qualitative and quantitative descriptions. Prediction of phase diagrams from thermodynamic first principles: calculation of free energy as a function of composition, common tangent construction.	D5	
	R	27-Sep			
	F	28-Sep			
7	M	1-Oct	**Lecture 11: Polymer solutions (continued).** Lyotropic behavior of increasingly complex systems: athermal systems, inclusion of enthalpic contributions, inclusion of flexibility, inclusion of polydispersity, inclusion of non-solvent. Practical relevance of phase diagrams for lyotropic systems. Why polymer solutions (and melts) can be drawn into fibers.		
	T	2-Oct			
	W	3-Oct	**Lecture 12: Thermodynamics and kinetics of polymer crystallization.** Crystallization and chain folds. Spherulites. Lamellar thickness. Isothermal thickening. Kinetics of crystallization: the Avrami equation. Kinetics of crystal growth.	D6	HW3 due
	R	4-Oct			
	F	5-Oct			
8	M	8-Oct	**Lecture 13: Melting and glass transitions in polymers.** Relevance to processing. Effect of flexibility, average molecular weight, molecular weight distribution, and crosslinks on melting temperature of crystalline polymers. Factors that affect polymer crystallizability. Definition of glass transition. Effect of bond flexibility, interchain bonding, degree of polymerization, branching, length of side chains, diluents and copolymerization on glass transition temperature. Solutions vs. melts in polymer processing.		
	T	9-Oct			
	W	10-Oct	**Lecture 14: Polymer processing – conventional and novel.** The goal of polymer processing: controlling the extension (shape), alignment (packing) and cross-linking (connectivity) of chain-like molecules. Fiber spinning: history, terminology (denier, tex, tenacity), melt spinning, solution spinning (wet and dry). Limitations of conventionally spun fibers. Extended chain crystals, superdrawing, crystallization from aligned solutions (stir crystals, shish kebab morphology).	D7	
	R	11-Oct			
	F	12-Oct			
9	M	15-Oct	**Lecture 15: Polymer processing – conventional and novel (continued).** Liquid crystalline polymers: thermotropic and lyotropic polymers. Gel drawing. Injection molding. Extrusion. Blow molding. Sheets and films: calendering and blown-film extrusion. Balance and degree of planar orientation. Vacuum forming and drape forming.		
	T	16-Oct			
	W	17-Oct	**Lecture 16: Polymer processing – conventional and novel (continued).** Additives that modify processability and properties. Joining polymers (and joining with polymers). Adhesion. **Characterization of polymer microstructures**. Use of x-ray diffraction / scattering to measure crystal thickness, percentage crystallinity, and molecular orientation. Density method for measuring percentage crystallinity.	D8	HW4 due
	R	18-Oct			
	F	19-Oct			

Week	Day	Date	Lecture (provisional scope and contents)	Discussion	HW
10	M	22-Oct	**Lecture 17: Characterization of polymer microstructures (continued).** Use of transmitted polarized light microscopy to measure molecular orientation in fibers: optical birefringence, optical anisotropy, optical indicatrix, vibration directions, interference colors, measurement of order parameter.		
	T	23-Oct			
	W	24-Oct	**Lecture 18: Characterization of polymer microstructures (continued).** Measurement of Tg, Tm, and thermodynamic data associated with microstructural change. Differential thermal analysis (DTA) and differential scanning calorimetry (DSC). Consequences of hierarchical microstructure: viscoelasticity, toughness, craze formation in glassy polymers, diversity and multifunctionality of natural polymers.	**Midterm**	
	R	25-Oct			
	F	26-Oct			
11	M	29-Oct	**Lecture 19: Mechanical properties of polymers.** Molecular / microstructural description of deformation. Elastic deformation of single chains. Crystalline polymers: deformation mechanisms of single crystals (slip, twinning, stress-induced martensite); deformation of bulk polymer (dependence on chains, fibrils, lamellae, stacks, spherulites & other elements of hierarchical microstructure)		
	T	30-Oct			
	W	31-Oct	**Lecture 20: Mechanical properties of polymers (continued).** Statistical theory of rubber elasticity.	D9	
	R	1-Nov			
	F	2-Nov			
12	M	5-Nov	**Lecture 21: Mechanical properties of polymers (continued).** Macroscopic description and quantification of mechanical properties. Phenomenology of linear viscoelasticity; the Boltzmann superposition principle; dashpot-and-spring models (constitutive equations, Maxwell model, Voigt / Kelvin model, standard three-parameter and four parameter linear solid models).		HW 5 due
	T	6-Nov			
	W	7-Nov	**Lecture 22: Mechanical properties of polymers (continued).** Temperature-time equivalence (static loading); temperature-frequency equivalence (dynamic loading); complex modulus and complex compliance. Non-linear viscoelasticity.	D10	
	R	8-Nov			
	F	9-Nov			
13	M	12-Nov	Veterans Day (observed)		
	T	13-Nov			
	W	14-Nov	**Lecture 23: Mechanical properties of polymers (continued).** Continuum theory of rubber elasticity: Rivlin equation, Mooney equation, Ogden equation. Mechanical failure: cold drawing, strain softening and orientation hardening, Considère's criterion, brittle / ductile transition, fatigue.	D11	
	R	15-Nov			
	F	16-Nov			
14	M	19-Nov	**Lecture 24: Electrical properties of polymers.** Origins of electrical conductivity in polymers: ionic conduction, conducting composites, electronic conduction. Applications of ionic conduction and conducting composites: anti-static polymers, electromagnetic shielding, re-settable polymer fuses, self-regulating heaters. Structure of electronically conducting polymers: conjugated chains, ladder polymers, doping, organometallic polymers. Processing considerations.		
	T	20-Nov			
	W	21-Nov	Non-Instructional day		
	R	22-Nov	Thanksgiving Holiday		
	F	23-Nov	Thanksgiving Holiday		

Week	Day	Date	Lecture (provisional scope and contents)	Discussion	HW
15	M	26-Nov	**Lecture 25: Electrical properties of polymers (continued).** Theory of electronic conductivity in polymers. Solitons (neutral, positive and negative). Polarons (n-type and p-type). Bipolarons (n-type and p-type). Additional applications of conducting polymers: "plastic batteries", electrochromic displays and "smart" windows, chemical sensors, plastic transistors, light emitting diodes, solid state plastic lasers.		HW6 due
	T	27-Nov			
	W	28-Nov	**Lecture 26: Natural polymers, and polymer self-assembly.** The formation of hierarchical, functional materials under near-ambient, environmentally benign conditions. Factors that favor liquid crystalline order, and other contributors to fiber self-assembly. Applications in the context of biomimetic materials and biomaterials.	D12	
	R	29-Nov			
	F	30-Nov			
16	M	3-Dec	**(Lecture 27)** Wiggle room / review		
	T	4-Dec			
	W	5-Dec	**(Lecture 28)** Wiggle room / review	D13	HW7 due
	R	6-Dec			
	F	7-Dec	(Instruction ends)		
		8-Dec	**Final Exam (8:00am–11:00am)**		