MatSE 444: SOLID STATE PROPERTIES OF POLYMERIC MATERIALS

Course Designation: Formerly designated PLMSE 407 ; this is a required course in Polymer Science and Engineering, and an elective course for other options.

Catalog Description: Structure/property relationships in the bulk solid state of polymers. Characterization of bulk properties and structure.

Course Description: (Extended description required by Penn State's Faculty Senate for inclusion on the course website)

Understanding relationships between structure and properties in the bulk solid state of polymers is important in designing and utilizing polymers in many applications. In trying to understand 'structure' we also need to define what is meant by and important in 'structure', and review tools used to measure desired structural features. Two thirds of the course addresses accepted general features of the polymeric solid state, with particularly emphasis on characterization of semicrystalline polymers since semicrystalline polymers represent approximately 75% of industrially important polymers. In this portion of the course we will be particularly concerned with defining and measuring percentage crystallinity and with defining and measuring orientation in polymers. Both of these parameters play important roles in establishing physical characteristics of polymers, in particular in mechanical properties. Mechanical properties continue to be an important feature for polymers since polymers posses the widest available range of mechanical properties of any material. The remainder of the course covers either new and/or continuing topics selected from composition-branching distribution; barrier properties of thin films and recycle-degradation of polymers.

The course is offered annually, in the spring semester, in the Department of Materials Science and Engineering.

Prerequisites: MATSE 443 (PLMSE 406)

Textbook: Non required. Course materials provided on the web as PDF files, Flash® movies and Flash® Virtual Instruments.

Course Objectives: The objectives of the course shall be to enable students to:

1) Provide a detailed view of morphology in semicrystalline polymers, the procedures that produce these structures and the molecular level construction of such structures. To start to relate properties to structure.
2) Understand various practical means to measure the degree of crystallinity and rate of crystallization in polymers, and simple theoretical basis for crystallization. To understand the relationship between various molecular and process parameters, and the degree and rate of crystallization, and melting.
3) Understand the basic 'free volume' concept as it applies to Tg and the influence of various molecular and process parameters on free volume and therefore on measurement of Tg.
4) Teach students the importance of molecular orientation and how it's measured in semicrystalline polymers; to distinguish between crystalline and amorphous components to molecular orientation.
5) Ensure that students integrate information from several sources and extrapolate to conclusions regarding structure and properties in a meaningful way.
6) To provide students either with selected state of the art advances, and/or continuing challenges to the polymer industry, so students may better understand future trends and concerns for the industry as a whole.

Topics Covered:

1) Review of applicable material from PLMSE 406; in particular a brief introduction to glass, crystallization and melting transitions, and states of matter.
2) Morphology in semi-crystalline polymers from simple single crystals to shish-kebabs (row nucleated) and the procedures that produce these structures.
3) Various crystallization theories, with emphasis on the kinetic theory, including a molecular level description of these processes as well as the annealing process.

4) Define and measure how much crystallinity is present in a semicrystalline sample (the degree of crystallinity) using a variety of methods. Included is an in depth review of thermal analysis comparing DSC and DTA. Measurement of the heat of fusion, melting point (Tm) and testing for reorganizational/annealing effects. The thermodynamics of melting; melting points of homopolymers and copolymers.
5) Rate of crystallization (Avrami); nucleation, growth, and 'secondary crystallization'. The influence of various parameters on rate including temperature, molecular weight, molecular structure and orientation.
6) Glass transition temperature (Tg) and the concept of 'Free Volume'. The influence of parameters including plasticizers, copolymerization and molecular structure.
7) Importance of orientation in semicrystalline polymers; defining, measuring and describing orientation with a variety of methods.
8) Temperature Rising Elution Fractionation(TREF) measuring composition and/or short chain branching distribution in semi-crystalline polymers. Barrier properties of polymers, packaging and diffusion though thin films. Recycle and the solid state disposal of polymers.

Class Schedule: 3 credit course offered annually meeting 3 times per week for 50 minutes

Course Outcomes: Upon completion of the course, the student shall be able to:
1) Describe the major transitions in polymers and the influence of thermal history on such transitions.
2) Describe how a particular morphology was produced and any relationships to temperature, shape and melting.
3) The student should be able to describe several methods of measuring percentage and rate crystallinity in a sample and possible limitations of the methods, and the dependence of crystallinity and melting on a variety of structural and instrumental factors.
4) The basic concept of 'free volume' should be used to explain Tg. The influence of various molecular and process parameters on measurements of Tg should also be described. The student should be able to predict an anticipated Tg for various copolymers, blends and semi-crystalline polymers given appropriate information.
5) Students should be able to qualitatively describe the effects of molecular orientation on mechanical properties and be able to describe methods to measure such orientation in semi-crystalline and amorphous polymers. Students should be able to define/draw the 'pole figure' from a simple description of a set of planes or poles.
6) Depending on the amount of material covered students should typically be able to :
   a) Qualitatively describe TREF and the molecular origin of the separation method.
   b) Have a qualitative feel for the relative values of permeability and diffusion constant in common barrier films. Be able to describe on a molecular level the permeation process in films and the effects of various molecular and structural parameters on permeability.
   c) Be able to qualitatively describe the various classifications of ‘recycle methods’.

Assessment Tools:
1) Computer based quizzes (CBQ) *primarily for diagnosis*.
2) In-class closed book exams; *primary grading tool*.
3) Homework and extended projects based on VIs for diagnosis and grading (student collaboration and team-work encouraged).

Professional Component: Course topics address the scientific and engineering principles regarding interrelationships between structure, properties and performance of materials (with special emphasis on semi-crystalline polymers.) A emphasis is placed on integrating the student’s background in chemistry, physics, thermodynamics, kinetics and elastic/mechanical properties to the design of and with materials in thermostructural applications.

Prepared by: Ian R. Harrison, February 2002

MAP TO DEPARTMENTAL OUTCOMES (For further detail, see coursebook)											
a	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**	**l**
1	1	1	2	2	2	2	1	2	1	1	2

MAP TO DEPARTMENTAL OBJECTIVES (For further detail, see coursebook)						
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
1,2,3,4,5,6	1,2,3,4,5,6	1,2,3,4,5		2	2,6	6