Properties of Polymers **Exam #2** **11 May 2010**

Total of 100 points. Each question is worth of 5 points, unless otherwise noted.

1. For a polyethylene chain of the molecular weight of 14000 with the characteristic ratio of 6.8, the bond angle of 112°, and the C-C bond length of 1.53 Å:
   (a) How many conformations are available to this chain?
   (b) Calculate the unperturbed root-mean-square end-to-end distance.
   (c) Calculate the length of Kuhn chain. Take the extended chain with the bond angle maintained as the contour length.
   (d) Suppose that this chain is freely rotating with a bond angle of 90°, what is the root-mean-square end-to-end distance?
   (e) How much larger is the chain of (d) than if it were freely jointed?

2. (a) Explain in your own words why you expect the dimension of a polymer chain in amorphous bulk state is the same to that in a theta condition.
   (b) Explain in your own words why you expect the dimension of a polymer chain in semicrystalline state is the same to that in a theta condition.

3. [Fill the blanks. No need to explain. Each right answer counts 3 points, plus 1 point when you get all eight correct.]
   By slowly lowering the temperature of a polyethylene solution, plate-like single crystal, called (a)_____, is formed. The typical unit cell crystallographic structure of this crystal is (b)_____, in which the c-axis (chain axis) is perpendicular to the a-b plane. The crystal grows by crystallization of the chains on (c)_____ plane (write down the Miller index). By the discovery of this polyethylene single crystal, the idea of folded-chain model, in contrast to the earlier (d)_____ model, of polymer semicrystalline state was developed.
   By lowering the temperature of a polyethylene melt, ball-like crystal, called (e)_____, is formed. In this type of crystal, chain axis is (f) radial *or* tangential (choose one) to the ball surface. The crystallization proceeds by (g)_____ -and- _____ mechanism, in which the two processes have different temperature dependences. As a result, size of the ball is smaller when the crystallization occurs at a temperature closer to (h)_____ temperature of the polymer.

4. (a) How is physical aging distinguished from annealing?
   (b) How is nematic mesophase distinguished from smectic mesophase?
   (c) Arrange the followings in the order of increasing permeability, and explain. (A) N_2 through natural rubber, (B) O_2 through natural rubber, (C) N_2 through PVC, (D) O_2 through PVC, all at room temperature.
   (d) How would you determine the equilibrium melting temperature of a polymer? [Explain Hoffman-Weeks plot. Explain in words, not by drawings only.]
   (e) Why is the dielectric constant of a polymer related to its solubility parameter?

5. A thin sheet of polyethylene (E = 1.0 GPa, $\nu = 0.4$) is subjected to a tensile load (force) of 2.0 kN in the x-direction. The dimension of the sheet is 150 mm long (x), 100 mm wide (y), and 1.0 mm thick (z).
   (a) Calculate σ_x.
   (b) Since it is a thin sheet, the specimen does not contract in y-direction, i.e., $\varepsilon_y = 0$. Since it is on a free surface, there is no stress in z-direction, i.e., $\sigma_z = 0$. Find out σ_y.
   (c) Estimate the final thickness of the specimen.