

3.063
Polymer Physics Spring 2007

Problem Set 3
Due 4/10/07

3.1 Block Copolymers in Tomorrow's Plastics

Read the article (pdf) by Ruzette and Leibler concerning the high tech applications of block polymers. Based on your reading and knowledge from 3.063, choose one figure from their paper and describe a related application that you believe is noteworthy. Explain in about 200 words (a schematic may be useful) why the block copolymer application is exciting and likely to solve an important problem and provide an important advantage.

3.2 Dispersing Nanoparticles in Polymeric Matrices

(a). The interaction between a nanoparticle and the host polymer is dependent on the ligands on the surface of the nanoparticle and the relative sizes of the nanoparticles and the homopolymer chains. The ligand coating surrounding a nanoparticle has an interaction parameter with the segment of a homopolymer. Describe the relative ability to homogeneously disperse a set of nanoparticles in a homopolymer as a function of the interaction parameter, the size of the nanoparticle, the molecular weight of the ligands and the molecular weight of the homopolymer matrix. Explain the relative "dispersability" of: small nanoparticles with negative χ in a low molecular weight polymer vs. larger nanoparticles with a positive χ in a high molecular weight polymer. Hint: think Flory-Huggins theory, draw a schematic of the nanoparticle-ligand coating in the homopolymer matrix and identify important parameters that enter into the free energy.

(b). Explain using interaction parameters, symmetry, size and shape considerations, how the ligand coating and shape of a nanoparticle can influence its location in a block copolymer having a certain type of microdomain structure.

(c). Suggest reasonable choices of diblock copolymer microdomain morphologies for precisely sequestering and locating the following types of carbon nanoparticles: C₆₀ and a SWCNT in a block copolymer.

C60 = Buckminsterfullerene
SWCNT = single wall carbon nanotube

3.3 Microphase Separation in Diblocks

- Explain the “max – min” principle for understanding the thermodynamics of block copolymer microphase separation.
- Carefully draw and label the χ vs. volume fraction morphology diagram for a A/B diblock. Label the ODT and the various regions of microdomain morphology.
- Which microdomain types have an IMDS with constant mean curvature? Which microdomain types have a constant microdomain thickness? Why does the lamellar microdomain morphology exhibit the largest stability region in the morphology diagram?

3.4 Templated Self Assembly and Pattern Transfer

- One of the challenges that must be overcome if block copolymer lithography is to be successful is the elimination of unwanted defects. Describe how you would design a template (include a schematic of the actual template) that would be able to order spherical microdomains such that the template takes up a *minimum area* of the substrate and yet provides a global single crystal array of microdomains over the entire wafer.
- Pattern transfer into the substrate by the block copolymer lithographic mask requires certain properties. Describe the various parameters that need to be considered in choosing a suitable pair of blocks.

3.5 ABC Architecture

- Determine the total number of topologically distinct molecules for an ABC polymer containing loops and/or arms.
- Which of the molecular architectures that you have drawn in part (a) will have the junctions confined to surfaces and which ones will have the junctions confined to lines?
- Which molecule(s) (and compositions) from part (a) do you think would be the most interesting microdomain morphologies? Why?