Block Copolymer Films for Microelectronics, Water Treatment and Energy

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Abstract: Block copolymers are constructed by linking two (or more) chemically-distinct polymer chains. Under certain conditions, these systems can spontaneously self-assemble into dense arrays of nanostructures. I will describe our recent work with three types of block copolymers: First, we examine self-assembly in thin films of polystyrene-b-poly(methyl methacrylate) (PS-PMMA) diblock and PMMA-PS-PMMA triblock copolymers. These systems are used for large-area surface patterning, as PMMA can be selectively removed to produce a nanoporous template. Using a combination of x-ray scattering and surface microscopy, we show that substrate interactions can induce and/or trap a variety of defects that include lattice disclinations, tilted/bent domains, and deformed domain shapes. These defects are very challenging for applications of block copolymers in microelectronics, as they broaden the size distribution of patterned features. Second, we examine structure-property-processing relations in thick films of sulfonated penta block copolymers. These materials are attractive for water purification and electrochemical devices, as the sulfonated blocks can transport water and protons, but their long-term stability is not well understood. Using a suite of complementary techniques that include X-ray scattering, impedance spectroscopy, and tensile tests, we find that cycles of swelling/deswelling in water will lead to unusual changes in transport and film mechanics: Cycling will change the nanoscale structure and increase the interactions between sulfonated domains, which is favorable for water and proton transport. However, cycling can also induce macroscale buckling, and the associated strain will reduce ductility, swelling and water uptake. The trade-off between nanoscale restructuring and film mechanics is revealed by examining properties as a function of film thicknesses: thick films are less susceptible to buckling, so interactions between sulfonated domains will enhance water uptake and transport, while thin films undergo extensive mechanical deformations that limit their ability to take up water. These studies highlight the complex relations between nanoscale structure and bulk mechanics in block copolymer membranes. Finally, we examine self-assembly and crystallization in poly(alkylthiophene)-based block copolymers with time-resolved X-ray scattering. PATs are a well-studied class of polymer semiconductors with potential applications in thin film transistors and solar cells. PATs are semicrystalline, and properties such as crystallinity, melting temperature, and crystallization temperature are controlled by alkyl chain length and monomer regio-regularity. With systematic changes to the PAT design, we show that crystallization can be confined within the block copolymer template, leading to regular arrays of functional nanostructures.

Biography

Dr. Gila Stein received her BS in Chemical Engineering from Drexel University in 2002, and obtained a PhD in Chemical Engineering from the University of California, Santa Barbara, in 2006. She then joined the National Institute of Standards and Technology, where she was a National Research Council Postdoctoral Fellow in the Center for Nanoscale Science and Technology from 2007-2008. Dr. Stein moved to the University of Houston as an Assistant Professor of Chemical and Biomolecular Engineering in 2009, received the Henley Professorship in 2012, and was promoted to Associate Professor in 2015. She joined the University of Tennessee as the Prados Associate Professor of Chemical and Biomolecular Engineering in 2016.