Honors and Awards: Presidential Young Investigator, National Science Foundation, 1984

Concurrent University Appointments: Affiliated Faculty, Princeton Institute for the Science and Technology of Materials

Research Interests

Our work focuses on how weak forces at the molecular level determine macroscopic properties at larger length scales. We spend equal time understanding the details of molecular-level interactions using NMR, neutron scattering, x-ray scattering, or electron microscopy and making measurements of bulk properties such as rheology, diffusion of proteins in gels, drop sizes of sprays, or pressure drop measurements in porous media. Our work is highly interdisciplinary; many of the projects involve joint advisors and collaborations with researchers at NIH, Argonne National Labs, CNRS in France, or major corporate research.

Concentrated surfactant phases. By tuning the morphology of the micelles from spheres to rods it is possible to produce tunable viscoelastic fluids that find application in oil recovery and heat transfer.

Polymer-surfactant phases. Hydrophilic polymers generally phase-separate from concentrated surfactant solutions because the polymer chain entropy opposes confinement of the chain within the small inter-lamellar spaces. By adding associating hydrophobic groups to the chain it is possible to compensate for the loss of entropy by the gain in binding free energy and thereby to make stable one-phase fluids (see figure). The structure of these systems is studied by neutron scattering. With concentrated lamellar phase systems it is possible to create shear-induced "multi-lamellar vesicles" or "onions" which are attractive as delivery vehicles for pharmaceuticals.

Vesicles and liposomes. Unilamellar vesicles, or liposomes, are also of interest in drug delivery. Hydrophobic polymers anchored on their surface protect the liposomes from fusion or create fluid gels. The attachment of several anchoring sites to a long polyethylene glycol chain produces strong attachment and protects the liposomes against recognition by the immune system. This concept of "multi-loop" anchoring has wide application to produce novel triggered delivery systems.

Polymer assembly for control of wax. We have been studying new polymers for control of the gelation of waxes in crude oil pipelines, by tuning crystallizable sequences within the polymer chain. The bulk properties of interest are gel yield stresses and surface deposition rates. The microscopic molecular interactions are studied by small angle neutron and synchrotron x-ray scattering.

Polymer-drug nanoparticle formation. We have developed a new "flash precipitation" process for making nearly monodisperse particles of hydrophobic drugs by kinetically co-crystallizing the drug with biodegradable block copolymers.

Biopolymers. Nature uses hydrogen bonding and ionic interactions to tune biopolymer self-assembly. Carrageenan polysaccharides that assemble into helical structures are the basis for porous supports for non-aqueous enzymology. Guar galactomannans form hydrogen-bonded gels with anomalously high viscosity. Using a technique developed at NIH we quantify the role of guar secondary structure on hydrogen bonding. Using confocal microscopy we have studied the diffusion of enzymes through the guar gels, which is important in processes involving degradation of guar or controlled release from gels.

Emulsions. Stabilization of emulsions, foams and thin films requires that the interfaces be kept far enough apart to prevent rupture induced by long-range, London-van der Waals attractions. We study the stabilization of thin films by hydrophobically modified polymers using a novel thin film apparatus.