Predictive design of polymeric capsules by microflow-SANS

The coupling of microfluidics with small angle neutron scattering (SANS) provides unique opportunities for phase mapping of complex fluids and elucidating molecular conformation, both in and out of equilibrium. We employ microfluidic-SANS to spatio-temporally resolve the mechanism and kinetics of polymer capsule formation employing ubiquitous (i) droplet solvent extraction and (ii) salt-induced polyelectrolyte collapse approaches. Microfluidics enables the generation of precise polymer solution droplets and facilitates the triggering and mapping of these phase transformations. Droplet solvent extraction is examined with solutions of poly(vinyl alcohol) of various polymer mass and degree of hydrolysis, investigating the role of composition (with respect to c* and c**) and viscosity in particle and capsule formation. Sodium carboxymethyl cellulose (NaCMC) is employed as a model system for salt-induced capsule formation. NaCMC is an anionic, weak, semiflexible polyelectrolyte, and one of the most widely used cellulose derivatives in industry, from food to personal care. We employ SANS, light scattering, and rheology to probe the conformation and dynamics of aqueous NaCMC solutions across a wide range of molecular weight (Mw), degree of substitution, salt (mono, di and trivalent) and polymer concentrations. We then investigate the addition of a series of multivalent salts to induce the gelation and/or precipitation of bulk NaCMC solutions, and resolve salt front propagation kinetics and accompanying conformational changes of the polymer. Equipped with this knowledge, we then predictively design and fabricate PVA and NaCMC capsules and particles with prescribed dimensions, shape, microstructure and dissolution profile.