Investigating the static and dynamic structure factor of nanoparticles in polymer solutions: resolving polymer dynamics from inter-particle effects

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Abstract

One type of polymer composite materials is formed by incorporating inorganic particles into an organic polymer phase. One significant challenge in the formation of such a composites system is stabilizing the particles. In the absence of an inter-particle repulsion, depletion forces drive the demixing of the two phases into polymer-rich and particle-rich phases. Particle stabilization can be realized using charge or grafting miscible polymers on the particle surface for entropic stabilization. Both stabilization methods result in the observed particle motion differing from the predicted motion of single isolated nanoparticles. For charge stabilized nanoparticles, their motion is both coupled topologically to the polymer and to other particles via depletion and electrostatic interactions. Herein we investigate the structure and dynamics of charge-stabilized silica nanoparticles with the aim of elucidating the dynamics of entangled star polymers from the nanoparticle motion. Silica particles with a radius of 7.5 nm in high molecular weight linear (1,125,000 g/mol, $R_{g,0} = 38$ nm) and star (2,300,000 g/mol, $R_{g,0} = 43$ nm) polystyrene in a good solvent, methyl ethyl ketone, at various polymer and particle volume fractions were utilized. Preliminary measurements of the dynamic structure factor using TPS 25A show that after initial shearing and loading samples, the dynamics slow over a number of hours and exhibit complex multi-modal relaxations. The static structure factor $S(q)$ displays a similar slow evolution reflecting the inorrelated particle positions becoming correlated due to attractive depletion forces. At lower particle and polymer volume fractions the particles display liquid like $S(q)$ with a broad maximum while increasing either the particle or polymer volume fraction increases the depletion interaction and drives the particles into more crystalline ordering with sharper features in $S(q)$. Further recent results will be presented describing the complex interactions present in the polymer composites and what information about the polymer dynamics can be extracted from the particle motion.

Keywords – XPCS, composite material, Polystyrene, nanoparticle