Kinetics of dispersion of nanoparticles in thin polymer films at high temperature

Nafisa Begam, Sivasurender Chandran, Nupur Biswas and J K Basu*
Department of Physics, Indian Institute of Science, Bangalore-560012
*basu@physics.iisc.ernet.in

Dispersion of particles in polymer nanocomposite (PNC) thin films has been found to be the key in tapping the different novel properties like optical, thermal and magnetic. It has been reported earlier both by our group and others that thermal annealing plays a major role in tuning the dispersion state. However, how the dispersion state evolves from a non-equilibrium state to equilibrium state during annealing remains open. Here we report the in-situ X-ray scattering measurements vindicating the evolution of the dispersion of polymer grafted gold nanoparticle dispersed in homopolymer matrix in a thin film. X-ray reflectivity measurements were done on these films before annealing, during annealing and after annealing. Electron density profiles (EDP) have been extracted from X-ray reflectivity profile using Parrat formalism with three layer model- surface, bulk, interface. The resultant volume fraction of particle for these three layers with time is shown in Fig. 1. It is clear from figure that the segregated un-annealed film is becoming homogeneous during annealing. The diffusion coefficient has been calculated using an error function fit to the EDP. The average diffusion coefficient turns out to be 0.014 $\text{Å}^2$/s which is two order of magnitude slower than bulk diffusion of particles in polymer melts.

The in-plane observation we have also probed the in-plane diffusion characteristics of the particles with x-ray diffuse scattering (XDS) measurements (Fig-2). As is visual from the data, there is an evolution of the length scale with time and it varies with time as a power law with an exponent $> 1$ indicating a super-diffusive motion along the lateral direction. This slow out-of-plane and superdiffusive out-of-plane motion simultaneously helps it to make a homogeneously dispersed film.

References: