Influence of shear-flow on carbon-nanotube filled interface of immiscible polymer blends

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The combined Rheology-SAXS setup at the DORIS beamline BW1 was utilized to study the effect of shear flow on the morphology of immiscible blends decorated with carbon-nanotubes (CNT). The incorporation of phase-selective or interfacially confined carbon-based conductive loads, into phase separated polymer blends has long been regarded as an effective method for the development of conductive composites with very low filler concentrations.

Recently, Baudouin et al.¹,² have demonstrated the confinement of a large proportion of unpurified and unfunctionalized CNTs at the interface of immiscible blends of polyamide and ethylene-acrylate copolymer (Fig. 1). A significant fraction of the CNT is observed to accumulate at the PA12/EA interface by using a special extrusion technique¹⁴. There is a high interest to investigate the shear-induced morphology changes by CNTs along the interface of polymer blends.

![Figure 1. Images of PA12/EA with 1.8wt% CNT, obtained by premixing CNT with EA next blending with PA12: a) from SEM (the PA12 droplet is embedded in the EA matrix), b) from TEM (the dispersed PA12 phase appears darker).](image)

The droplets were found to resist strong flow fields in the compounder and did not seem to break under shear flow³. That means, the flow conditions necessary for modifying the droplet structure are not reached.

The molten material was sheared in a 40 mm plate-plate disc geometry using a ThermoHaake MARS rheometer with different shear stresses while simultaneously 2-D scattering patterns were recorded by SAXS perpendicular to flow direction. Figure 2 shows the first combined Rheo-SAXS results for the PA12/EA blend with 1.8wt% CNT before shear and in comparison to when different shear stresses of 1 kPa or 3 kPa are applied.
In the scattering data a peak is observed at around $q = 1.5$ nm$^{-1}$ indicating a structure of about 4.2 nm in size. This presumably stems from the wall thickness of the multiwalled CNT which are depicted in the inset of Fig. 2. The width of the peak between $q = 1.3$ - 1.9 nm$^{-1}$ is not affected by the shear flow. Furthermore, the intensity dependence on the scattering angle is approaching $I \sim q^{-3}$ towards the low $q$-range while towards higher scattering angles the dependence is $I \sim q^{-1}$. The slope of the intensity curve $I(q)$ has possibly changed after applying the shear flow at the high $q$-range above the peak. These results show the effect of shear flow on the CNT at the interface of immiscible polymer blends, and a more detailed analysis with quantitative evaluation using recent scattering models is currently in progress.

Further work is planned to study by in-situ Rheo-SAXS scattering with high spatial and temporal resolution the shear-flow influence and time-dependence during start-up of flow and subsequent relaxation on the CNT orientation, as well as conditions for breaking the droplet structure. Thus, it is possible to get some insights into the dynamics of the filler and dispersed phase due to shear flow.

Related own publications on this subject are listed below in references 1-4. Financial support by the 7th Framework Program research project “HARCANA” and Marie-Curie IEF fellowship as well as technical support with the beamline BW-1 by Dr. Bernd Struth (DESY) are gratefully acknowledged.

References