A Colloidal Model to describe the Effects of Mixing Time on Filler Dispersion in Industrial Nanocomposites

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Abstract

- Properties of industrially relevant nanocomposites depend on the degree of filler dispersion under high-shear mixing.
- Conventionally, dispersion is quantified through an index based on the reduction in micro-scale agglomerate size observed in micrographs and bulk electrical conductivity measurements.
- An alternate nano-scale dispersion technique based on x-ray scattering has been proposed.\textsuperscript{1}
- The impact of mixing time on dispersion is investigated taking advantage of the van der Waals equation to describe excluded volume and interaction energy in the dispersion.\textsuperscript{2}
- An analogy is made between the thermally driven true colloidal dispersions and kinetically accumulated strain in nanocomposites.

Results

Ultra-small angle X-ray scattering

- Structural parameters under dilute filler conditions are computed from the Unified fit.\textsuperscript{3,4}
  \[ \phi_{\text{ph}} = \frac{2}{3} \phi_{\text{un}} \]

- Under semi-dilute filler conditions, structural features are screened, and the extent of screening is approximated by RPA.\textsuperscript{5,6}

Kinetic van der Waals model

- The interaction energy is strongly dependent on viscosity and polymer chemistry.

Conclusion

- The wetting time for nano-scale incorporation of elastomer into filler can be predicted.

 Methods

- Commercial PBD (Mooney Viscosity ~ 38, 45, 54 M.U.) and SBR (Mooney Viscosity ~ 50, 62, 80 M.U.) milled with 6PPD (antioxidant) and varying amount of carbon black reinforcing filler (Vulcan S and Vulcan 3) for 6, 8, 12, 18 and 24 mins at 130°C, 60 rpm.
- Scattering from ~1.2 mm (thick) flat samples measured at Advanced Photon Source, Argonne National Laboratory using the ultra-small-angle X-ray scattering (USAXS) facility located at the 9-ID beamline, station C.
- Micrographs obtained through TEM in STEM mode from ~80 nm thin sections cryo-cooled below \( T_g \) of the nanocomposites

References


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