

Structural Investigations of Dilute Silica/Poly(Ethylene Oxide) Suspensions by Small Angle X-Ray Scattering Measurements

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Suspensions consisting of colloidal particles and grafted polymer chains have found important industrial applications. One of the model systems is the silica/PEO suspension. As the silica particle surface is covered by PEO, a core-shell structure is formed (the core and shell are the silica particle and PEO chains, respectively). In this study we investigate the structure features and adsorption properties of a series of dilute silica/PEO suspensions with different PEO concentrations (0.5, 1.0, 2.0, 4.0, 6.0, and 10.0 g/L) in 12.0 g/L silica suspensions. At low PEO concentrations, the adsorbed PEO chains lead to steric repulsions and prevent aggregation in a suspension. A higher PEO concentration, on the other hand, tends to increase the amount of suspended PEO. It will be demonstrated that complementary information about the suspension properties at various PEO concentrations can be obtained, and check on self-consistency of central implications can also be made.

Figure 1 shows the results of SAXS measurements for a series of dilute silica/PEO suspensions with various PEO concentrations. Comparisons of some of the results with the predictions of core-shell model¹ are shown in Fig. 2. It was found that a good agreement is obtained only for a PEO concentration of 2.0 g/L. It appears that only at PEO concentrations close to the indicated value will a homogeneous shell be formed. In addition, the seemingly greater deviations at lower q -range noted in Figs. 2b and 2c with increased PEO concentration might arise from the extra contribution of the non-adsorbed PEO chains to the total scattering intensity of core-shell particles.

In general, SAXS data at the high- q range can provide useful information about the surface properties of suspended core-shell particles. It was seen from Fig. 1 that high- q data ($q > 0.06 \text{ \AA}^{-1}$) show quite distinct behavior at various amounts of PEO addition. This q range corresponds to the probed length scale approximately smaller than 1.6 nm, which is close to the shell thickness but smaller than the particle diameter. Lindner and Zemb² analyzed the fractal structure of the particle surface on the basis of $I(q)$ data. It was found that $I(q)$ is proportional to $q^{-\nu}$ with $\nu = -3$ to -4 ; the surface is rough for $\nu \sim -3$, and smooth for $\nu \sim -4$. For each dispersion we calculated the slope at q greater than $0.06 \text{ \AA}^{-1}$ but smaller than a certain value around $0.15 \text{ \AA}^{-1}$ where the $I(q)$ may begin to be affected by the scattered signals of suspended PEO chains. According to Fig. 1, the slope at the high q -range varies from -2.62 to -4.40 with increased PEO concentration, suggesting a gradual increase in surface smoothness. Moreover, at PEO concentrations above 2.0 g/L, the slope remains unchanged.

Overall, a variety of material properties in dilute

silica/PEO suspensions can be characterized by SAXS measurements. The maximum adsorption of PEO onto silica particles is estimated to be near 2.0 g/L. The central implications are also consistent with what revealed by dynamic light scattering results from our lab.

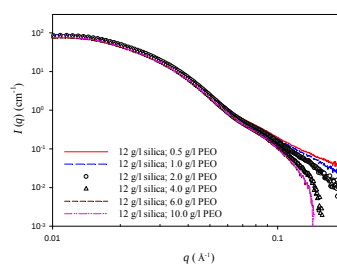


Figure 1. SAXS results for dilute silica/PEO suspensions with various PEO concentration.

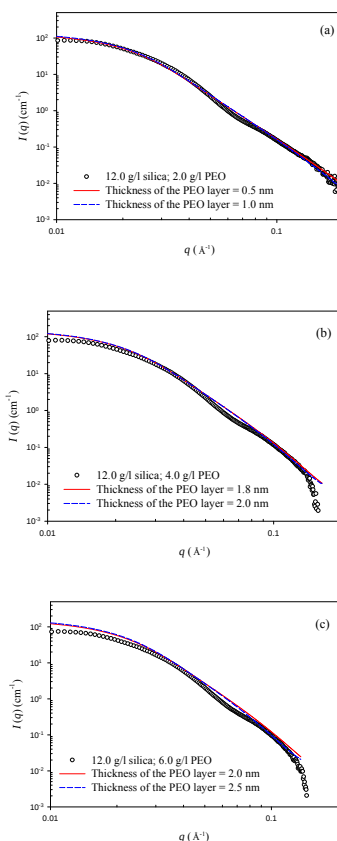


Figure 2. Comparisons of the SAXS data with the predictions of Eq. [7] for dilute silica/PEO suspensions with (a) 2.0, (b) 4.0, and (c) 6.0 g/L PEO.

References

1. Marković, I., Ottewill, R. H., Cebula, D. J., Field, I., and Marsh, J. F., *Colloid Polym. Sci.* **262**, 648 (1984).
2. Lindner, P., and Zemb, T., "Neutron, X-ray and Light Scattering: Introduction to an Investigative Tool for Colloidal and Polymeric Systems." North-Holland, 1991.