Depletion restabilization of colloidal silica

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Introduction

Colloidal interactions play a significant role in the rheological and sedimentation behavior of particulate suspensions. In the absence of depletant species, however, the initial suspension of primary colloids becomes weakly flocculated. Earlier rheological studies indicated that upon addition of the depletant, the suspension was restabilized. The goal of this study is to follow the behavior of the colloidal particles and the depletant in suspension using ultrasmall-angle x-ray scattering (USAXS) to observe possible changes in the surfaces of the colloid. Preliminary USAXS measurements have been carried out to assess the microstructure of suspension systems stabilized either electrostatically [1] or via depletion forces [2]. We have shown that either mechanism results in disperse particles in suspension.

Methods and Materials

Liquid cells specifically designed for USAXS, with 1 mm x-ray path length and polyimide windows, were used to hold the suspensions. Care was taken to insure that measurements were made while settling particles were still in suspension. Scattering measurements over a scattering vector range from Q = 0.00015 $Å^{-1}$ to 0.1 $Å^{-1}$ were taken from suspensions of 10% by volume silica ($D \approx 0.5$ µm and 1 µm) stabilized with nonadsorbing (or depletant) 10^{-3}% by volume zirconia ($D \approx 0.01$ µm) colloids under conditions close to the isoelectric point of silica. (Note: Under these pH conditions in the absence of zirconia depletants, such suspensions are unstable and consequently flocculate). For comparison to a known stable silica suspension, scattering measurements of 10% by volume silica electrostatically stabilized in deionized water were also taken.

Results

Results from one set of measurements are shown in Figure 1. Three curves are given: the smeared data as it was recorded, the data after desmearing with a Lake program, and a seven-parameter fit to the desmeared profile. The periodic oscillations at low Q are attributed to the primary colloidal silica particles. At large Q, beyond the camera length, the smeared data and the desmeared intensity follow the same profile, as expected. An additional population is seen here, as indicated by the appearance of a Guinier region and Porod scattering. The results from particles stabilized electrostatically or through depletion were similar.

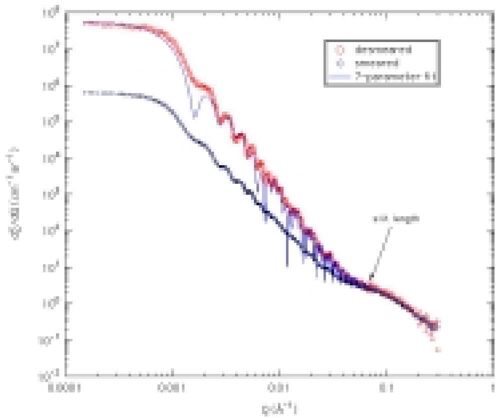

Figure 1: USAXS from a sample containing colloidal silica and depletant species. Three curves are shown: the smeared data as it was recorded, the data after desmearing using a Lake program, and a seven-parameter fit to the desmeared data.

Discussion

Silica particles in deionized water have sufficient surface charges and screening length to be stabilized electrostatically. In the absence of electrostatic or steric repulsive barriers, silica colloids close to their isoelectric point normally flocculate in unordered clusters. Earlier rheological and sedimentation studies indicated that additions of zirconia depletant completely restabilized the silica. The USAXS from both suspension systems showed little evidence of flocculating. Thus, the presence of the nonadsorbing zirconia restabilizes the silica under otherwise unfavorable stability conditions.

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