Direct Measurement of Interactions Forces between Silica Surfaces in Organic Solvents and Mixtures by Atomic Force Microscopy: Agreement with DLVO Theory

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The dispersion of colloidal particles in organic solvents is important in many industrial fields. The dispersion behavior of particles in liquids is governed by the interaction forces between their surfaces; therefore, a detailed understanding of these forces is essential for evaluating dispersion in organic media. While interaction forces in aqueous solutions are generally described by DLVO theory, those in organic solvents remain less understood, and no unified theoretical framework exists due to the diversity of solvent properties. In this study, interaction forces between silica surfaces in polar organic solvents and mixed solvents were directly measured using colloidal probe atomic force microscopy (AFM), and their consistency with DLVO theory was evaluated.

Measurements in various organic solvents revealed long-range repulsion in N,N-dimethylformamide (DMF) and ethanol. In ethanol, an additional attractive force was observed at separations of several nanometers, whereas only attractive forces were observed in 1,4-dioxane. The repulsive forces measured in ethanol and DMF were well fitted by the DLVO theory, suggesting an electrostatic origin.

Furthermore, interaction forces between silica surfaces were measured in binary mixtures of water and DMF, ethanol, and 1,4-dioxane at specified ratios, with NaCl added to a concentration of 1 mM relative to the total volume. The results indicated that electrostatic repulsion acts in solvents with dielectric constants down to approximately 20, but may disappear below this threshold. In solvents with lower dielectric constants, solvation forces were found to dominate the interactions.

Keywords:
Interaction force, Organic solvents, DLVO theory, Atomic force microscopy