Forces Acting on Small Particles in Water: Role of Hydrodynamics and Interfacial Structure

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Small particles (radius = nm~µm) experience the same forces as macroscopic particles, but the relative importance of the forces changes with the size of the particle. Whereas gravitational forces are important in everyday experience, the behavior of small particles is dominated by van der Waals, electrostatic, capillary, and structural forces. Control of the magnitude of these forces is an important tool in a diverse range of industries, for example, in minerals processing, paint manufacture, pharmaceutical preparation, personal product formulation, and food preparation.

In this talk, I will describe my recent contributions to the understanding of surface and interfacial forces in water. The first part will describe the use of evanescent waves in atomic force microscopy (EW-AFM) for surface forces measurement. Evanescent waves allow us to measure the separation between particles more accurately, and thus allow more accurate testing of theory. I will show how we have used evanescent waves to verify the accuracy of Reynolds lubrication theory in very thin films. Despite recent claims for altered properties of water in very thin films, and claims that the boundary condition for fluid flow alters from the no-slip boundary condition, we find that Reynolds lubrication theory accurately describes the flow for all systems that we have studied. This includes hydrophobic and hydrophobic solids and shear rates up to 250, 000 s^{-1}. I also also show how EW-AFM can be used for detecting phase separation in confined geometries.

In the second part, I will describe our recent efforts to understand the nature of the interface between hydrophobic solids and water. Recent claims that hydrophobic solids are coated in layers of "nanobubbles" are examined. We verify these claims through measurement of rotational fine structure in the infrared spectrum of the interface. This fine structure only occurs in the gas state and shows the existence of the gas state at the interface. Some of the controversy in the literature is understood by examination of the conditions under which the nanobubbles form. We and others show that the nanobubbles are not always present, but are induced by changes in the solubility for gas of the liquid that baths the solid.