Abstract

During the past decade nanoparticles attracted a great deal of attention and found many applications in various fields ranging from pigments and antibacterial agents to highly effective catalysts. In this context, the handling and processing of nanoparticle powders play an important role. In contrast to macroscopic particles, nanoparticle flow properties are manly governed by the particle-particle interactions. The forces determining these interactions strongly vary not only with the material properties but also with surface chemical composition as well as the environmental conditions. Hence, a fundamental understanding of the processes and forces involved plays a key role for the prediction of nanoparticle powder behavior.

In the presented study two main questions are in focus:

1. What is the role of water adsorbate layers in nanoparticle ensembles and how does the complex water structure impact the inter-particle forces as a function of humidity?
2. What influence does the surface chemistry of nanoparticles have on the inter-particle forces and can these interactions be altered via chemical modification?

In this work, the water adsorption and capillary bridge formation within defined layers of SiO_2 and TiO_2 nanoparticles were studied by means of a novel in-situ analytical setup allowing for combined quartz crystal microbalance measurements with dissipation analysis (QCM-D) and Fourier transform infrared reflection absorption spectroscopy (FT-IRRAS). On the one hand, the QCM-D gave insights on both mass change (Δf) and changes in the contact mechanics, indicated by dissipation changes ($\Delta\Gamma$), whereas on the other hand FT-IRRAS allowed for the characterization of the adsorbed water structure. Employing peak deconvolution to the OH-signal, “ice-like” and “liquid-like” water structures could be clearly identified. Moreover, the presence of different water species was successfully attributed to changes in the particle layer mechanics.

In addition to the combined QCM-D / FT-IRRAS experiments, a new experimental setup has been established to perform AFM based force spectroscopy under controlled atmospheric conditions. Mentioned method was employed for a detailed in-situ study of the complex interplay between UV-light, humidity and surface adsorbate species towards the surface chemistry and contact forces of TiO_2 nanoparticles.