Atomic force microscopy (AFM) is often employed to understand the physical properties, such as adhesion forces and elastic moduli of various organic and inorganic materials. The major focus of this dissertation is dedicated towards understanding the applications of AFM based F-D spectroscopy to study the elastic properties and inter/intra-molecular forces of interaction of organic and inorganic materials.

In the first half part of the thesis, F-D spectroscopy technique is employed in the low force regime (<1 nanonewton) to understand the intermolecular interactions between cerium oxide nanoparticles (CNPs) and the protein molecules for biomedical applications. The excellent antioxidant nature and biocompatibility of CNPs have made them useful as potential drug carriers that can transport and release drugs to the malignant sites inside human body. Here, single molecule F-D spectroscopy (SMFS) is employed to understand the interaction forces acting between CNPs and transferrin (Tf), a ligand protein that can bind to the overexpressed transferrin receptor proteins (TfR) on cancer cells. By treating with acidic and basic pH buffers, it was found that, the zeta potentials of CNPs can be tuned between high positive (+36.4 mV) to high negative (-35.1 mV) charges. The SMFS studies conducted on these nanoparticles demonstrated an increased Tf-CNP adhesion with an increase in the positive zeta potential of CNPs. In the case of CNPs with high positive ZP, the magnitude of TF-CNP rupture forces were found to be in the range of 150-225 pN, whereas in the case of CNPs with high negative ZP, the interactions forces measured were almost negligible. Density functional theory (DFT) simulation was used to understand the nature of the physicochemical bonding between the organic molecules and the inorganic nanoparticle. Cellular uptake studies employed to understand the mechanism of uptake pathways, displayed an enhanced ligand-receptor mediated internalization of Tf-CNPs by human lung cancer cells. As a continuation of this study, the dynamic ion exchange reactions occurring on the surface of colloidal CNPs, leading to their natural time dependent surface charge reversal and its influence in determining the CNP's adhesion properties with organic (protein) and inorganic (silica) surfaces are also investigated in detail.

The second half part of the thesis discuss about the potentials of F-D spectroscopy in the high force regime (<1 micronewton) to understand the solid-solid intramolecular interactions between silicon dioxide nanoparticles (nanosilica) in their thin film form. Here, sol-gel derived porous nanosilica optical films with varying surface morphology, particle size and porosity were prepared through acid and base catalyzed process. AFM nanoindentation experiments were conducted on these films using the F-D spectroscopy mode and the elastic properties of these films were calculated. The films displayed a range of elastic modulus from 2.4-13.4 GPa depending on the nature and concentration of the catalyst used for their synthesis. The elastic moduli reported are obtained after incorporating the surface roughness correction.

In summary, the thesis demonstrates the significance of using F-D spectroscopy to understand the basic atomic forces acting between various materials, determining their unique properties and applications.
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The public is welcome to attend.