X-ray microprobe investigations of mineral-metal-microbe interfaces

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Bacteria have a key role in determining a contaminant's speciation and thus its mobility in the environment. The metabolism and surface properties of bacteria can change greatly when the cells are planktonic (free floating) versus in a biofilm (surface adhered), and the microenvironment in and near actively metabolizing cells can differ significantly from the bulk environment. To understand the microscopic physical, geological, chemical, and biological interfaces that determine a contaminant's macroscopic fate, the spatial distribution and chemical speciation of contaminants and elements that are key to biological processes must be characterized at micron and submicron lengths. We have used x-ray fluorescence microscopy (100-nm spatial resolution) and microspectroscopy to investigate the spatial distribution of 3*d* elements in both planktonic and surface-adhered *Pseudomonas fluorescens* cells, as well as the chemical speciation and distribution of Cr introduced to the cells as Cr(VI). We used similar approaches to investigate the distribution and chemical speciation of iron in internal iron-rich precipitates in *Shewanella oneidensis* CN32. The objectives were to (1) determine the spatial distribution, concentration, and chemical speciation of metals at, in, and near bacteria and bacteria-geosurface interfaces; (2) identify the metabolic processes occurring within the microbes; and (3) identify the interactions among metals, mineral surfaces, and bacteria near these interfaces. Results will be presented.

Fishing at the nanoscale

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We give a broad description of AFM in the study of biological systems at nanoscale and focus specifically on the chemistry of tethering biomolecules to AFM tips. The motivation behind this work is that, once fully developed, this approach has great potential for detecting and localizing receptor-ligand interactions in the natural environment of the biomolecules found in the Martian meteorites. The interaction of an unmodified AFM tip with biomolecules has been used extensively in pull-off experiments with biomolecules such as collagen and titin to probe their mechanical and physical properties. We have used such an approach to determine the integrity and functionality of collagen molecules dating back to the Cretaceous period. However, the interaction of the unmodified tip with the biomolecules is a detriment in the study of specific receptor-ligand interactions. Hence, we used oligo(ethylene-glycol) and poly(ethylene-glycol) to prevent the nonspecific binding of proteins to the tip surface by adopting a *flowers-in-the-meadow* approach. This approach employs a mixed monolayer consisting of *short* "*meadow*" tethers interspersed with *longer*, antibody-terminated "*flower*" tethers. We examine several methods for passivating the AFM tip surface with novel *bidentic* tethers, which provide a stronger connection to the surface because the removal of each tether molecule from the surface requires *simultaneously* breaking the two bonds. Furthermore, we find that the *p*H value of the buffer used for these studies has considerable influence on the nonspecific binding between the antibody attached to the tip surface and the Cytochrome *c* protein chosen for these studies. By manipulating the tip modification and the *p*H of the buffer we are able to minimize the contribution of nonspecific binding to the AFM force curves and isolate the specific antibody-antigen interaction events.