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Microsensors for In-Situ Chemical, Physical, and Radiological Characterization of Mixed Waste

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Research Objective

A widespread need exists for portable, real-time, in-situ chemical, physical, and radiological sensors for characterization of mixed wastes, groundwater, contaminated solids, and process streams. None of the currently available technologies offer a clear path to the development of sensors that are miniature, cost-effective, selective, highly sensitive with a wide dynamic range, and have the ability to work in air or liquid while providing chemical, physical, and radiological information. The objective of this research program is to conduct the fundamental research necessary to develop microcantilever-based micromechanical sensors for in-situ characterization of groundwater, sediments, and mixed wastes. Chemical selectivity will be achieved by coupling surface modification chemistry with molecular recognition agents. Physical measurements of adsorption (absorption) induced deflection (bending) and resonance frequency variation of microcantilevers can be achieved with extreme precision resulting in ppb-ppt sensitivity.

Research Progress and Implications

Good progress has been made in the first nine months of this project. Progress has been made in three focus areas: radiation detection, detection of heavy metals in water, modification of microcantilever surfaces for chemical selectivity, and pH measurement. We have achieved some interesting and significant results in these four areas. We have developed a novel sensor concept for radiation detection based on variation in resonance transients induced by alpha particles. This concept can also be extended to the detection of other heavy charged particles. Although these experiments were conducted in air, they can be used in liquids also. Heavy metal in water (lead) was detected using electrochemical microcantilevers. In these experiments, a silicon microcantilever with one surface coated with a thin gold film was used as a working electrode in a three electrode electrochemical cell. When the potential of the cantilever was changed with respect to a reference electrode, lead was electrodeposited on the cantilever surface. Since the deposition occured only on one surface, the cantilever bent due to differential stress on the surface. Microcantilever based sensors can yield additional information that other electrochemical detection methods cannot produce. Electrochemical systems produce signals only when charged particles cross the soild-liquid interface while microcantilevers produce bending signals when the charge particles are on the surface. Thirdly, progress has also been made in modification of microcantilever surfaces for chemical speciation. For example, chloro- and alkoxysilanes bind to surface hydroxyls on metals and oxide surfaces. The degree of coverage and cross-linking through alkoxy sidechains can be controlled by reaction conditions and surface preparation. Another approach for chemical selectivity that is routinely used in mass sensors is the application of polymeric film forming materials to sensor surfaces. The chemical interactions that allow selectivity are provided by the polymer subunits. Cantilevers modified with chemically specific coatings show adsorption-induced bending. Progress has also made in the area of microcantilever pH measurement. Microcantilevers with a coating that changes surface charge density as a function of the pH of the solution undergo bending if the opposite surface is made inert. We have obtained a near Nerstian behavior for microcantilever pH sensors made out of silicon and silicon nitride.

Planned Activities

Planned activities for rest of the year include developing surface coatings for chemical speciation and new techniques for radiation detection. Surface coatings that can maintain stable operation under corrosive conditions will be pursued. Experiments using many systems will be conducted for furthering the understanding of adsorption-induced forces on real-surfaces. All the experiments will be conducted under solution. Other approaches for radiation detection using microcantilevers other than transient techniques will be tested. Second year goals include detection of ppb-levels of Hg, Pb, and Cr in water and developing chemically selective ionophores of Cs and Tc and evaluating their selectivity in presence of K, and Na.