Research Objective:

A widespread need exists for portable, real-time, in-situ chemical, physical, and radiological sensors for the characterization and monitoring of mixed waste, ground water, contaminated soil and process streams ranging from plume containment and remediation to determination of location, chemical composition, and level of DNAPLs. The objective of this research phase is to gain a better understanding of the molecular-level mechanism of adsorption-induced stress on the microcantilever. The ability to manipulate and control these stresses will lead to the development of highly selective and extremely sensitive sensors for EM specific applications in liquid environment in presence of interferents. For example, it is possible to separate chemisorption and physisorption by simultaneous measurement of resonance parameters. Based on this fact, we will develop and demonstrate corrosion resistant cantilevers with parts-per-trillion sensitivity for metal ions in solution such as Hg, CrO_4^{2-}, Sr^{2+}, and TcO_4^-. Selectivity will be achieved by orthogonal arraying of modified cantilevers.

Research Progress and Implications:

As of June 01, we have accomplished three main objectives in the first year of this three-year project. The three achievements include:

Development of a Cr ion sensor:

We have modified microcantilevers with a self-assembled monolayer (SAM) of triethyl-12-mercaptododecylammonium bromide for detection of CrO_4^{2-} ions. The self-assembled monolayer was prepared on silicon microcantilevers coated with thin layers of gold on one side. The microcantilever undergoes bending due to sorption of CrO_4^{2-} ions on the monolayer-modified side. It was found that a concentration of 10^{-9} M CrO_4^{2-} can be detected using this technology in a flow cell. Other anions, such as Cl^-, Br^-, CO_3^{2-} (or HCO_3^-), and SO_4^{2-}, have minimal effect on the deflection of this cantilever.

Development of Hg ion sensor:

For Hg^{2+} ion detection we have modified microcantilevers with a self-assembled monolayer of 1,6-dihexanedithiol. The self-assembled monolayer was prepared on a silicon microcantilever coated with a thin layer of gold on one side. The microcantilever undergoes bending due to sorption of Hg^{2+} ions on the monolayer-modified side. It was found that a concentration of 10^{-11} M Hg^{2+} can be detected using this technology in a flow cell. Other cations, such as Li^+, K^+, Na^+, Pb^{2+}, Zn^{2+}, Cd^{2+}, Ca^{2+} and Cu^{2+}, have no effect on the deflection of this cantilever.

Development of 8 cantilever array:

We have designed and developed an array of microcantilevers involving 8 cantilever elements. Each of these cantilevers can be interrogated using 8 lasers (from a single chip). The cantilevers are designed in such way to minimize the cross talk between the cantilevers.

The Q factor of a cantilever is approximately 30. Efforts are presently underway to develop techniques by which individual elements of the array can be chemically modified using selective layers for orthogonal sensing.

Planned Activities:

Remaining three months will be devoted for developing selective coatings for Sr ions in presence of Na and K ions. Tasks for next year include developing techniques for applying selective coatings on the orthogonal cantilever arrays. In addition we will also develop and implement algorithms to decouple interference, including chemical, temperature, pressure, viscosity, vibration, and other inteference, using reference cantilevers.

Publications:

"Manipulation and controlled amplification of brownian motion of microcantilever sensors" A. Mehta, S. Cherian, D. Hedden, and T. Thundat, Appl. Phys. Letts. 78, 1637 – 1640 (2001).

"Ultrasensitive Detection of CrO42- Using Microcantilever Sensor" H-F. Ji. T. Thundat, R. Dabestani, G.M. Brown, P.F. Britt, and P.V. Bonnesen, Anal. Chem. 73, 1572-1577 (2001).

"Detection of pH variation Using Modified Microcantilever Sensors" H.F. Ji, K.M. Hansen, Z. Hu, and T. Thundat, Sensors and Actuators B72, 233-238 (2001).

"Analysis of Amplifications of Thermal Vibrations of a Microcantilever" G. Muralidharan, A. Mehta, S. Cherian, and T. Thundat, J. Appl. Phys. 89, 4587-91 (2001).

"Chemical Sensing in Fourier Space", T. Thundat, E. Finot, Z. Hu, R.H. Ritchie, G. Wu, and A. Majumdar, Appl. Phys. Lett. 77, 4061 (2000).

"A Novel Self-Assembled Monolayer (SAM) Coated Microcantilever For Low Level Cs ion Detection" Chem. Commun.**6** 457-458 (2000).

"Highly Selective Microcantilever Sensor For Cs ion Deetction", T. Thundat, E. Finot, Hai-Feng Ji, R. Dabestani, P.F. Britt, P.V. Bonnesen, G.M. Brown, and R.J. Warmack, Chemical Sensors IV, ECS Proceedings 99-23, M. Butler, N. Yamazoe, P. Vanysek, and M. Aizawa, editors, 314-319, 2000.

"Metal Coated Microcantilever Hydrogen and Mercury Sensors", Z. Hu, T. Thundat, and R.J. Warmack, Chemical Sensors IV, ECS Proceedings 99-23, M. Butler, N. Yamazoe, P. Vanysek, and M. Aizawa, editors, 347-354, 2000.