Project ID: **60197**

Project Title: **Microsensors for In-situ Chemical, Physical, and Radiological Characterization of Mixed Waste**

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RESEARCH OBJECTIVE

A wide spread need exists for a portable, real-time, in-situ chemical, physical, and radiological sensors in characterization of mixed waste, ground water, contaminated soils 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 with the ability to work in air or liquid while providing chemical , physical, and radiological information.

The goal of this project is to develop a single-sensor platform approach that is based on the recently discovered extreme sensitivity of microcantilever sensing using adsorption-induced forces. The objective of this research is to gain better understanding of the basic mechanism of adsorption-induced differential surface stress variation and to use this concept for developing sophisticated microsensors for chemical and radiological sensing in liquids.

RESEARCH PROGRESS AND IMPLICATIONS

Within the past one and half years, we have demonstrated a number of sensors:

Cantilever sensor operation under liquid
Detection of lead in water
Cantilever surface modification
Radiation detection
Electrostatic method
Cantilever resonance frequency method
Detection Cs ions in presence of high concentration of Na and K ions
Experiments in simulated tank waste

<u>Cs ion detection</u>

To make the microcantilevers selective for Cs, the cantilevers were coated with cesium-selective ionophores (which have selectivities for cesium over sodium in the range of 20,000 to 50,000). We have used chemically modified 1,3-alternate 25,27-dialkoxy –26,28-calix[4]-benzo-crown-6 ionophores, for attachment to the microcantilever. The ionophores were synthetically modified with long-chain alkanethiols for attachment to a gold-coated microcantilever for the detection of cesium ions. The octyl chains were derivatized with terminal thiols for adsorption onto gold.

Initially, the chemically modified cantilever response was recorded for a flow of distilled, de-ionized water. As the Cs solution was introduced, the cantilever was found to bend to an equilibrium value depending on the concentration of the Cs ions in the solution. It was found that the cantilever responded to Cs concentrations ranging from 10^{-2} to 10^{-11}M. From the response curves it is clear that Cs concentrations as low as 10^{-12} M could be detected using this unique approach.

We have also performed similar experiments with monovalent ions such as Na and K. The Na ions produced no detectable bending of the cantilevers. The cantilever bending response to K ions were three times less than that of Cs ions for similar concentrations. Cantilever response for mixtures of Na, K, and Cs were also recorded. In the case of mixtures, the response closely followed a superimposition of individual responses.

Experiments are presently underway to detect Cs ion in tank waste simulant. Initial results are very encouraging. We are also investigating surface modification chemistry that will ensure stable operation of microcantilevers under corrosive environments.

Radiation detection

A radiation sensor concept based on electrostatic interaction between a cantilever and radiation induced surface charge on a surface is presently under development. Initial results were obtained for alpha radiation. A second approach of radiation detection using radiation-induced damage of surface coating is being tested at this time.

PLANNED ACTIVITIES

- Validate the microcantilever technology in an aqueous environment and develop methods for detection of ppb-leveles of Hg in simulated waste.
- Explore coatings and electrodeposition for Pb, Hg, and Cr^{6+}
- Test the microcantilever sensors in ground water for simultaneous detection of heavy metals.
- Develop advanced radiation detectors based on microcantilevers.
- Calibrate intrinsic cantilever response to soft radiation. Explore radiation effects on coated cantilevers.
- Develop and implement algorithms to decouple interferences, including chemical, temperature, pressure, viscosity, vibration, and others, using reference cantilevers.
- Test microcantilever sensors in low level mixed waste for radiation detection and selected chemicals.
- Develop designs for multi-element/multi-target array sensors.

Publications

T. Thundat, E. Finot, Hai-Feng Ji, R. Dabestani, P. F. Britt, P. V. Bonnesen, G.M. Brown, and R. J. Warmack, "Highly selective microcantilever sensor for cesium ion detection" (submitted).

Hai-Feng Ji, R. Dabestani, E. Finot, P. F. Britt, G.M. Brown, and T. Thundat, "Microcantilever ion sensors with high sensitivity and selectivity based on ionic-recognition of self-assembled monolayer" (submitted).

Patents

"Electromagnetic and nuclear radiation detector using micromechanical sensors", T. Thundat, E.A. Wachter, and R.J. Warmack, ESID-1604-X-1 (patent pending).

"Microcantilever radiation detector", A. Stephan, M. Smith, and T. Thundat (in preparation)