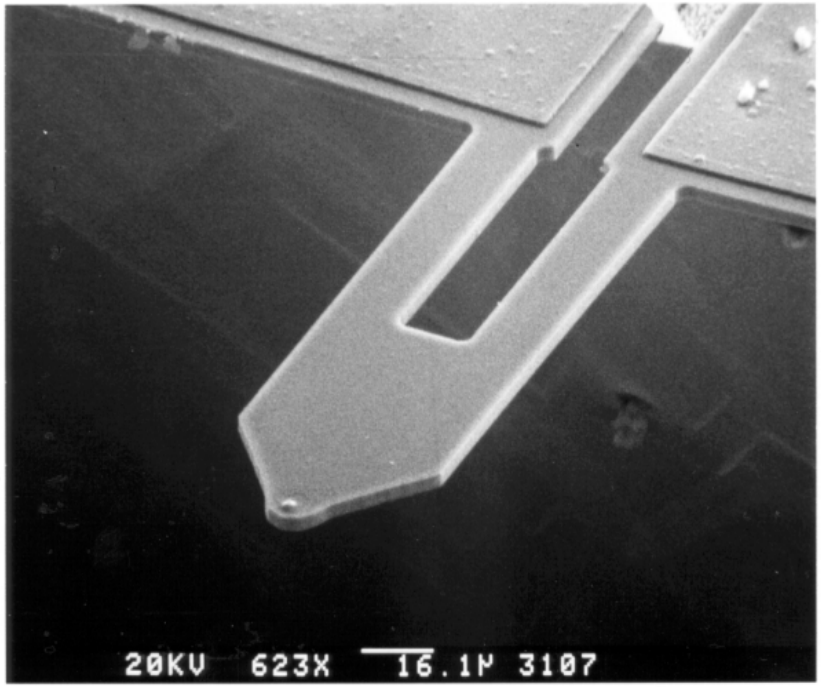
Objective

- **An urgent need exists for portable, real-time, chemical, physical, and radiological characterization of :**
  - **Groundwater,**
  - **Sediments, and**
  - **Mixed wastes.**
- **The objective of this research is to conduct the fundamental research that will lead to the development of microcantilever-based micromechanical sensors for in-situ characterization of ground water and mixed wastes.**

Microcantilever Sensors

- **Microcantilever sensors can be micromachined and mass produced (silicon, silicon nitride, etc.).**
- **Microcantilever resonance response (frequency and bending) varies reproducibly with molecular adsorption.**
- **Parts-per-billion to parts-per-trillion sensitivity has been demonstrated.**
- **Chemical selectivity can be achieved by using chemically specific coatings.**
- **Microcantilevers also can be used as physical and radiation sensors.**

Microcantilever Sensors



Advantages of Microcantilevers

- **Microcantilever sensors are:**

  * **Sensitive, small, simple, rugged, and inexpensive**
  * **Can be made chemically selective**
  * **Can be made into arrays for multi-analyte detection**

- **Microcantilever Sensors can provide**

  * **Four signals in a single measurement**
  (bending, frequency, Q-factor, and amplitude).

- **Microcantilever Sensors can be used for**

  * **Physical,**
  * **Chemical, and**
  * **Radiological sensing**

- **Microcantilevers can work in air or under solution**

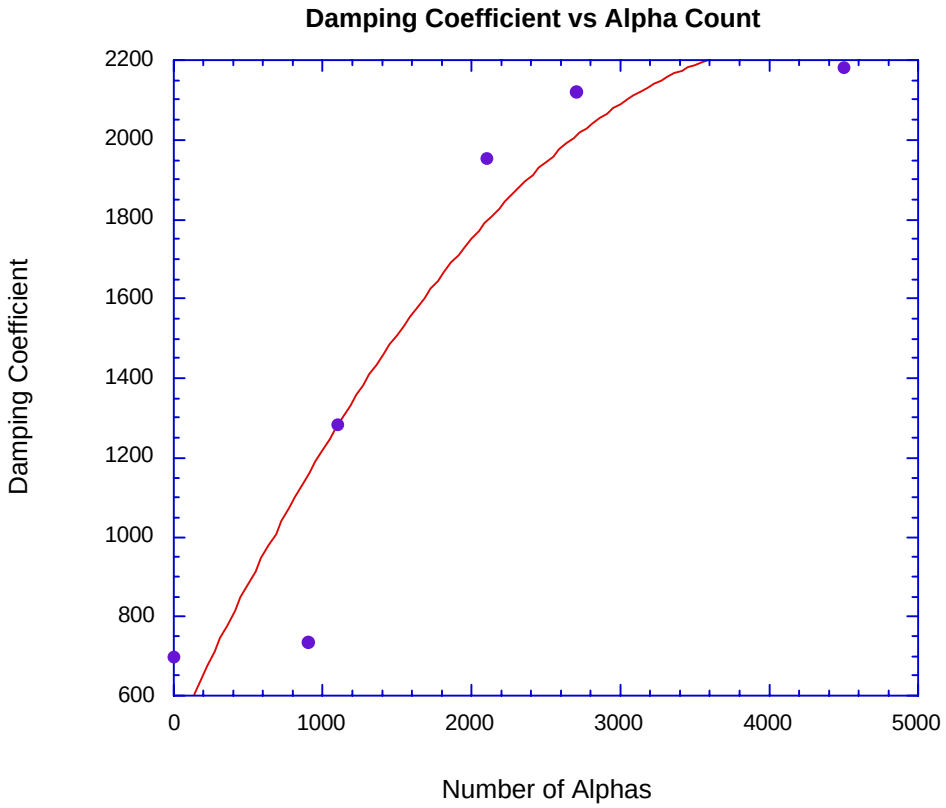
Radiation Sensing

- **Radiation can be detected utilizing:**
  - *** radiation-induced damage or**
  - *** radiation-induced charge generation**

- **Radiation-induced damage in either in the coating or in the substrate changes the elastic properties of the cantilever. Resonance response variation is proportional to the radiation damage. Can be used for dosimetric applications.**

- **Radiation-induced charge on the cantilever or an adjacent surface can be used for sensitive detection of radiation. Completely reversible.**

Detection of alpha particles using microcantilevers



Measurement of pH

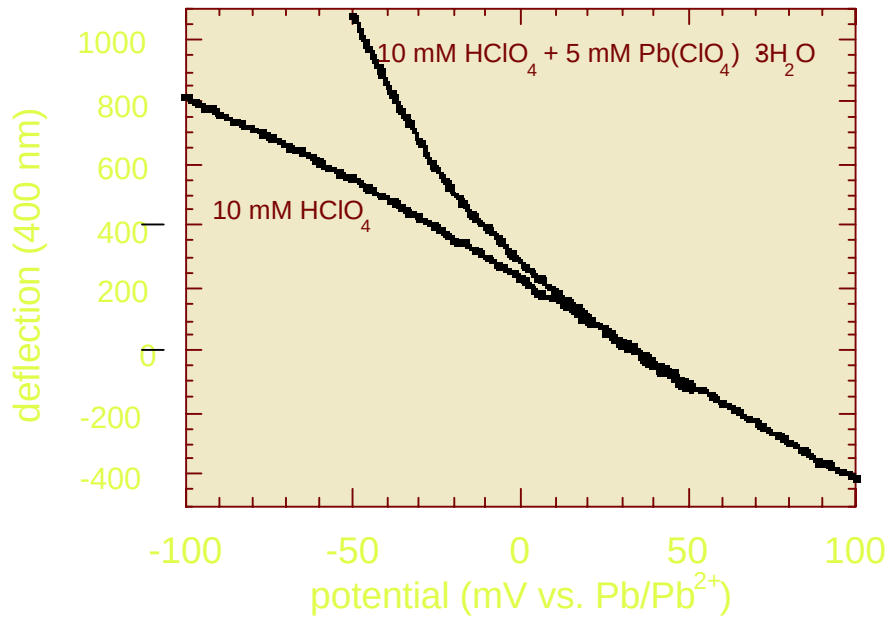
- **Microcantilevers can be used as miniature pH sensors**
- **When immersed in solution properly treated cantilevers can accumulate surface charge depends on the pH of the solution. If the charge generation is confined to a single surface, microcantilevers bends due to differential stress caused by the variation in surface charge.**
- **Almost Nerstian behavior can be obtained by coating the cantilever with Al_2O_3 or Ta_2O_5**

Electrochemical Microcantilevers

- **Electrochemical detection provide signal only when there is a charge transfer at the interface.**

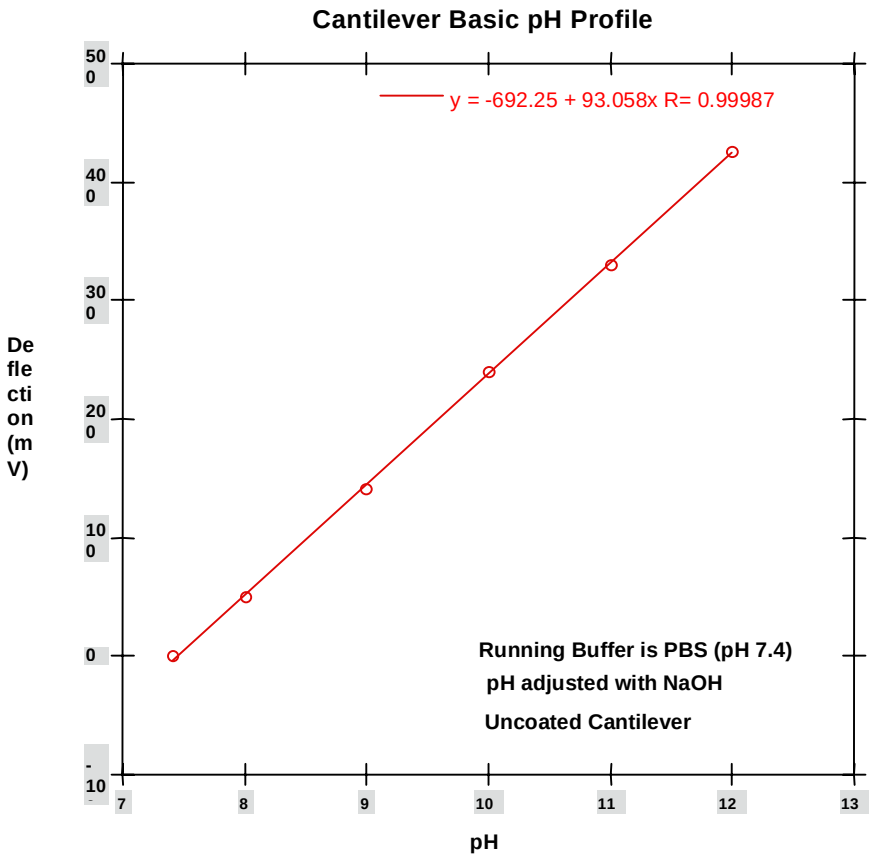
- **In addition to electrochemical information, microcantilevers can provide information on presence of charge on or near the surface.**

Electrochemical Microcantilevers



P.I. Oden, T. Thundat, and R.J. Warmack, Scanning Microscopy (in press).

Measurement of pH



A. Subramanium et al. (ORNL, to be published)

Preparation of alkylthiols for the detection of metal ions in ground water

The following alkyl thiols (shown in **Scheme I**) have been synthesized for use in the detection of metal ions such as Hg, Pb, and Cr (in the form of $CrO_4^{=}$) in ground water.

$HSCH_2CH_2CH_2CH_2CH_2CH_2\ CH_2CH_2CH_2\ CH_2CH_2CH_2N^+(CH_2CH_3)_3Br^-$ **1**

$HSCH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2OH$ **2**

$HSCH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2OH$ **3**

$HSCH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$ **4**

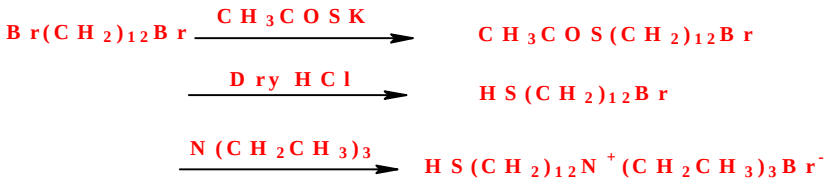
$HSCH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_3$ **5**

$HSCH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2COOH$ **6**

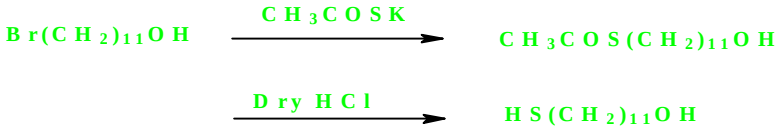
Scheme I

Synthetic Route for the preparation of alkyl thiols shown in **Scheme I:**

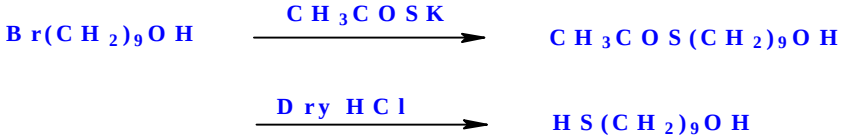
1. 1-Thio-12-dodecyltriethyl-ammonium Bromide. $HS(CH_2)_{12}N^+(CH_2CH_3)_3Br^-$



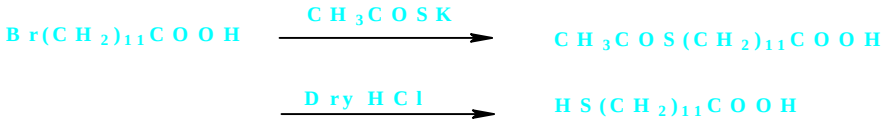
2. 11-Hydroxy-1-undecanethiol. $HO(CH_2)_{11}SH$



3. 9-Hydroxy-1-nonanethiol, $HO(CH_2)_9SH$



6. 11-Thio-1-undecanoic acid, $HS(CH_2)_{11}COOH$



4 and **5** were purchased from Aldrich without further purification

Planned Activities

- **Developing chemically selective coatings that can maintain stable operation under corrosive conditions.**
- **Understanding and optimizing adsorption-induced forces.**
- **Detection of ppb levels of Hg, Pb, and Cr in water.**
- **Developing chemically selective ionophores of Cs and Tc and evaluating their selectivity in presence of Na and K.**
- **Developing microcantilever based radiation sensors.**

Conclusions

Microcantilevers offer a simple, miniature, selective, and extremely sensitive sensor for physical, chemical, and radiological characterization of mixed wastes, groundwater, and sediments.

Acknowledgments

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