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Singapore-Sandia Collaborative Research

Sensors and Monitoring

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

What are the needs?

- Better real-time understanding of source/distribution water quality changes and contamination events.
- Improved response time and avoidance actions for contamination events
- Enhanced monitoring methods for treatment system process control

Specific Needs (1)

Protecting Water

- {Better understanding of dose-response and risk}
- {How many sensors and where?}
- Improved-performance state-change sensors
- Near-real-time pathogen/chemical detection
- Rapid, on-site characterization (moving from lab to field)
- Integration of sensor data streams with other system variables (water flow, water demand, other potential contamination indicators)
- Decision support algorithms to reduce false positives/negatives and guide effective response
- Opportunities for prototype system field trial and evaluation

Specific Needs (2)

Water Treatment

- Improved sensors for management of membrane treatment processes
- “Smart” membranes with imbedded sensor functionality

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Technical Challenges

- Low-cost, high-performance, low-maintenance, sensors
- Pre-concentration of chemicals/pathogens
- Sorting through the matrix…
  - Baseline water quality variations/sensor noise
  - Differentiating pathogens vs non-pathogens
- Data integration for decision support tools
- Moving from lab concept & prototypes to fieldable systems

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Sandia Capabilities

- **Microanalytical foundations**
  - Microsystems development expertise
  - R&D Fab facilities
  - Full spectrum research: basic to applied
- **Leveraging opportunities**
  - Microsystems for weapons systems
  - MESA investment
  - LDRD investments
- **Interdisciplines**
  - Broad staff capabilities in applicable disciplines

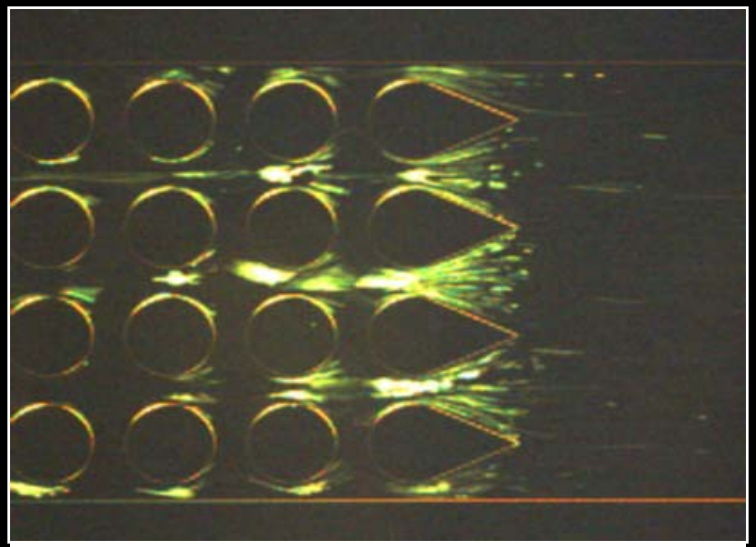
Suggested Microanalytical Sensor Research Projects

- **Pathogen Pre-concentration/Selection**
  - IDEP approaches for selective trapping
  - Combine with optical interrogation (Raman spectroscopy etc.)
- **Pathogen Detection via Chip-based Proteomics**
  - Extension of UWS system concepts
  - From biotoxins to pathogen signatures
- **Organics Detection via Micro-GC**
  - Extension of existing prototype THM system
- **Chip-based Imunochemistry**
  - Disposal systems for on-site characterization
- **Microanalytical Total Organic Carbon Sensor**
  - Current TOC size, costs and maintenance burden limit widespread distribution-side use
- **Smart Membranes with Sensor Functionality**
  - Measurement of biofilm precursors and/or early biofilm formation

Suggested Data Integration Project

- **Establish/test functional sensor-model system**
  - Distribution-side surveillance
  - Focus on using existing water quality sensors
  - Similar to EPA Sentinel in international venue
  - Incorporate and expand TEVA tool set
  - Integrate sensors and modeling in a dynamic system
  - A vital data layer for use in Decision Support Module

IDEP



Goals and Impact:

- Develop IDEP-based system for pathogen concentration and sorting
- A necessary front-end for analytical systems to detect pathogens in water

Project Description:

Develop insulative dielectrophoresis systems for concentrating and sorting target pathogenic bacterial and viral species.

Optimize these systems for 10^3 or greater concentration factors and develop for stand-alone use and for interface to microanalytical systems.

Project Tasks:

- Continue development of low-cost polymer IDEP separation modules
- Optimize and fully characterize performance characteristics in lab and field
- Explore the use of spectroscopic probes (e.g. raman) for additional characterization features
- Develop a stand-alone and interfaced field prototype

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Proteomics

Goals and Impact:

- Development of a transportable and/or on-line pathogen characterization system for treated water
- More rapid pathogen screening will improve water treatment systems

Project Description:

Further development of an existing system (UWS) for enhanced detection capabilities.

Expanded detection to include viral and bacterial pathogens using protein signatures.

Project Tasks:

- Develop cell manipulation methods at front end
- Improve separation and detection modules
- Develop statistical algorithms for protein signature detection
- Interface with IDEP-based pre-concentration system
- Develop a fieldable prototype

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Micro-GC

Goals and Impact:

- Near-real-time detection of toxic organic chemicals in water
- Faster analysis time will improve overall ability for effective system response and public health protection.

Project Description:

Expand the capabilities of the existing gas microChemLab for semi-volatile organic compounds (e.g. pesticides, chemical agents) in water.

Develop as both on-line sensor system as well as a portable system for on-site characterization.

Project Tasks:

- Optimize SAW detector for detection of semi-volatile species
- Develop and test pre-concentration approaches using solid phase micro-extraction methods
- Continue system engineering improvements for application as an on-line continuous monitor

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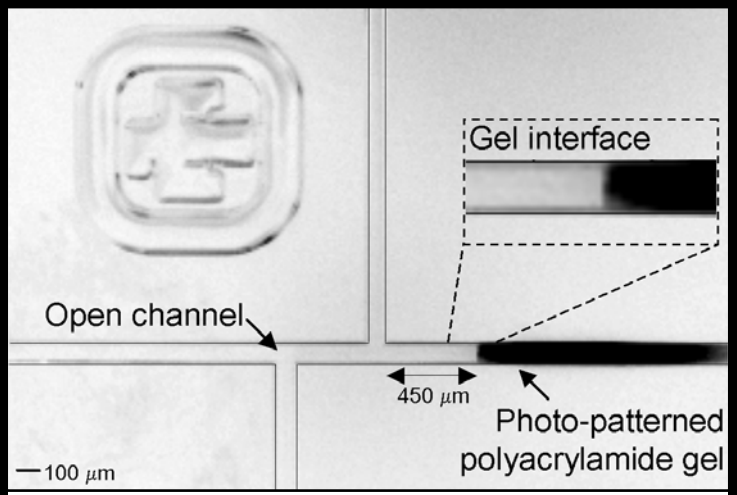
Immunochemistry



Goals and Impact:

- Explore the use of immunochemistry-based detection systems for pathogens in water
- These rapid-analysis systems could complement other molecular-based methods for pathogens

Project Description:

Chip-based immunochemistry detection of pathogens in water using low-cost disposal test kits

Multiplexed systems could provide analysis for a suite of target pathogens.

Project Tasks:

- Show feasibility for use of chip-based systems for analysis of pathogens in water
- Optimize system for maximum response and minimum cross-reactivity
- Develop and field test low-cost prototype for e. coli. bacteria.

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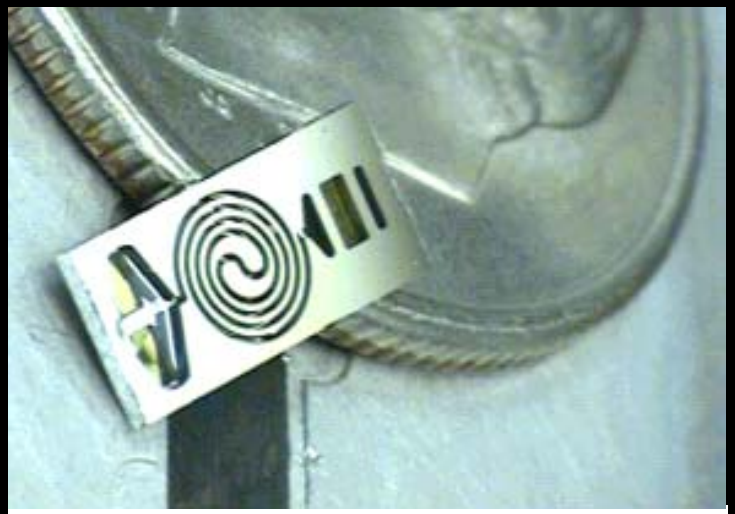
Micro-TOC



Goals and Impact:

- TOC has been shown to be one of the best indicators of system contamination
- A low-cost TOC could be widely implemented on the distribution side of a water utility

Project Description:

Early exploration of a micro-chip-based total organic carbon sensor.

Project Tasks:

- Literature search
- Basic concept development
- Preliminary design and fabarication
- Early lab prototype testing

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Smart Membrane

Goals and Impact:

- Explore the use of microanalytical sensors for membrane treatment process control

- Reduce the operational costs associated with biofilm formation on reverse osmosis membranes

Project Description:

Explore the development of integrated sensor/membrane systems that will provide better biofilm control methods as well as reduced treatment system operation and maintenance costs.

Project Tasks:

- Identify key biofilm precursor chemicals or organisms in process feedwater
- Explore electrochemical and chemical means of early biofilm formation detection
- Develop and test lab-scale prototype analysis system

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Data Integration

Goals and Impact:

- Develop a functional sensor/model system that monitors and interprets distribution-side water quality in real-time
- The first step toward a decision support system to better manage utility water quality on a routine basis

Project Description:

Incorporate existing water quality data from networked, distribution-side sensors with a calibrated water flow model of the distribution system

Incorporate change detection and contaminant plume prognostic capabilities through inclusion of software routines.

Project Tasks:

- Identify target set of water quality sensors for integration
- Develop calibrated flow model of Sinagpore distribution system
- Apply software algorithms (e.g. change detection) for better event detection
- Develop and test working prototype of integrated system

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