Center for Embedded Networked Sensing

New Wireless Miniature Sensor Technologies for CENS

Beth Stauffer[1], Astrid Schnetzer[1], Leyla Sabet[2], Robert Lam[2], Alexander Rat'ko[3], Buddy Aswin, Christopher A. Butler[3], Dohyun Kim[4], Michael J. Glickman[4], Ira B. Goldberg[4], Mike Liu[5], Siyang Zheng[5]

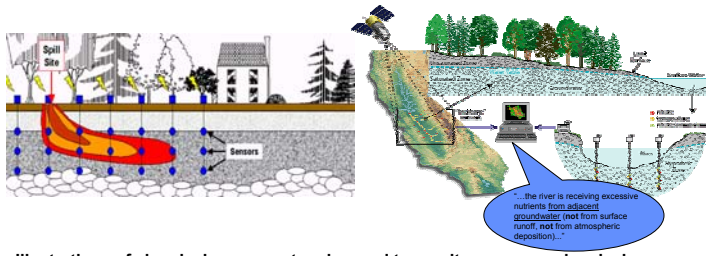
David A. Caron[1], Chih-Ming Ho[2], Thomas Harmon[3], Jack W. Judy[4], and Yu-Chong Tai[5]

1. Biological Sciences, USC, 2. Mechanical & Aerospace Engineering, UCLA, 3. School of Engineering, UC Merced, 4. Electrical Engineering, UCLA, 5. Electrical Engineering, Caltech

Overview: Design, Fabrication, and Implementation of Miniature Bio/Chemical Sensors

Motivation and Strategy

- Small, low-cost, robust, reliable, and sensitive sensors for practical and economical sensor networks
- High sensitivity, low power, small sample volume, and autonomous operation and wireless communication capability are important for field deployable sensors
- Enables spatially and temporally dense environmental and ecological monitoring
- Expedite research in marine biology using chip-based technology – lower sample volume, higher throughput
- Develop detection system to significantly improve toxin detection limit

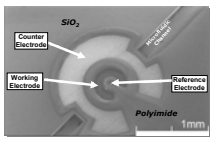


Illustrations of chemical sensor networks used to monitor aqueous chemical contaminants in the soil and ground water.

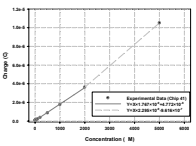
Nitrate Sensors/Soil Contamination Monitoring

1. Micromachined Nitrate Sensors - Professor Jack W. Judy

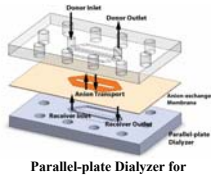
- Micromachined Amperometric Nitrate Sensor: simple electronics, easy fabrication, small form factor, low detection limit (~4 uM) and large dynamic range (3-4 orders of magnitude)
- Sample Preparation System: anion-exchange-membrane-based ionic separation, high filtration efficiency (~90%), throughput (1 sample/hr), small volume (< 10 ml)
- Multiplexible Fiber-optic Spectrochemical Nitrate Sensor: Absorption-based micromachined nitrate sensor using liquid-core capillary waveguide (LCCW), sensitive optical sensing, superior long-term reliability, multiplexible (fiber optics, multiplexer), multivariate analysis.



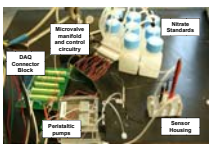
Microfabricated electrodes and microfluidic channels in a silicon substrate



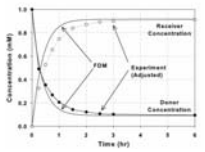
Calibration for chip-based amperometric microsensor



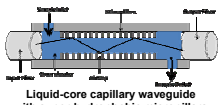
Parallel-plate Dialyzer for sample pretreatment



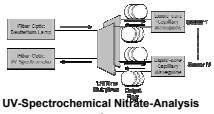
Experimental Setup for Automatic Nitrate Sensing System



Dialysis experiment



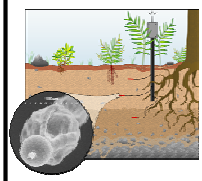
Liquid-core capillary waveguide with super-hydrophobic micropillars



UV-Spectrochemical Nitrate-Analysis system

2. Potentiometric Electrochemical Sensor –Prof. Thomas Harmon

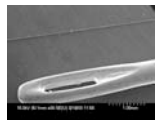
- Scalable nitrate micro- and mini-sensors suitable for dense, spatially distributed deployment in soils
- In addition to precise and accurate, these sensors must be inexpensive and have low impact on the observations (e.g, avoid flow disturbances)
- Low cost, broad range (0.01-100 mM), low detection limit (2-5 µM), selective
- Environmentally packaged microsensors for real soil test beds – extensively field-tested (dairy soil, irrigation, river applications)



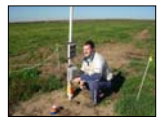
Ecological systems

Agricultural systems

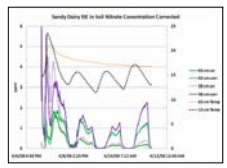
System w/circuit boards designed to make mini-sensors compatible with commercial data logger



7-mm-diam. Carbon fiber-based nitrate microsensor



Field deployment

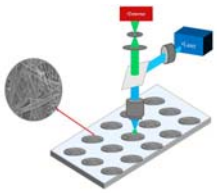


Nitrate concentrations and temperatures in manure-irrigated cropland

Aquatic Applications

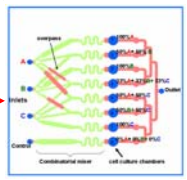
3. Lab-on-Chip Aquatic Microorganism Analysis System – Professor Yu-Chong Tai

- Chip-based algae culture system to screen for factors inducing toxin production by algae, Pseudo-nitzschia (Caltech)
  - Culture chamber: contain and culture algae
  - Combinatorial mixer: expose algae to various condition at once
  - Single cell or group of cells
  - Integration with downstream Ultra Sensitive Sensor system for Domoic Acid detection (UCLA)



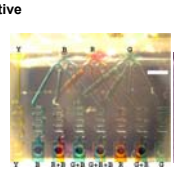
Chip-based algae culture combined with ultrasensitive toxin detection

Replace several culture experiments with a single chip

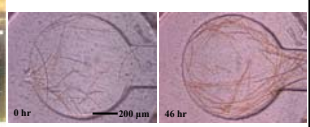


Chip to expose cells to eight different conditions at once

Chip on glass substrate



Combinatorial mixer operated at 10 µL/min. The scale bar represents 1 mm



Growing Pseudo-Nitzschia inside the chambers

4. Field Operational Electrochemical Sensor for Marine Environmental Monitoring - Professor Chih-Ming Ho

- Increase the detection sensitivity of Domoic Acid (DA), a toxin produced by *pseudo-nitzschia.*
  - A limited number of algae is trapped on a chip (Caltech)
  - The current state-of-the-art detection technology- needs sample size of at least 100 cells/mL The new sensor will push the sensitivity to 10 cells/mL or to even single molecules of Domoic Acid.
- We have developed a very sensitive electrochemical sensor for detecting both protein and RNA/DNA
  - Advantages of electrochemical sensor: 1) simple micro electrodes, 2) No need for the expensive optical components or microscope, 3) small sample volume 4) easy current read-out, 5)small foot print and field deployable.