CENS Sensor Research: Overview

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Introduction: New sensor technologies to improve the capabilities of wireless sensor networks

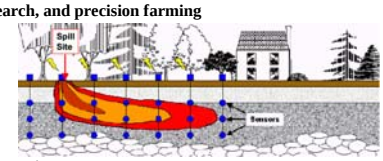
A miniature Small, low-cost, robust, reliable, and sensitive sensors are needed to enable the realization of practical and economical sensor networks. Although there are a large number measurands that are of interest for sensor-network applications (e.g., seismic, temperature, light, sound, magnetic, chemical, etc.), appropriate commercial sensors exist for many of these measurands. However, one prominent exception is the fact that appropriate chemical sensors are not available. It is for this reason that the sensor technology effort within CENS is researching the design, fabrication, and implementation of chemical sensors that have the specifications needed for sensor networks. The first targeted application is nitrate detection in ground water.

Group Organization: Multiple different approaches to develop chemical sensors for CENS

In order to detect nitrate in aqueous solutions with concentrations in the range of 1 to 100 µM, the sensor technology development team is taking multiple approaches. Two efforts are focused on developing miniaturized and selective electrochemical sensors and one effort is focused on developing a microscale liquid chromatography (LC) system. The development of the electrochemical sensors are both near-term projects but will be highly tailored for nitrate detection. The development of the LC system is a long-term project but has the potential to be a general sensing system. The projects and teams are described below.

Why Nitrate (NO_3^-) Sensor Important?

- **Nitrate is a major contaminant in ground water**
- **Nitrate-sensor applications**
  - **In-situ nitrate monitoring, environmental science/biology research, and precision farming**



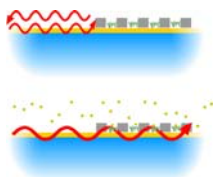
- **Sensor requirements**
  - **Inexpensive, small, remotely operable, detection range (1 µM to 1 mM)**

Proposed Solution: Leverage CENS technologies to develop a wireless neural interface

Surface Plasmon Resonance (SPR)

Arnaud Benahmed and Chih-Ming Ho (UCLA)

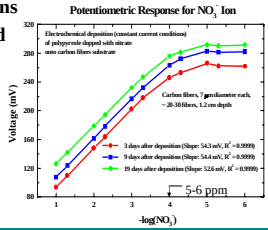
- **Surface Plasmon (SP) based sensors can detect a wide range of molecules with slight variations, making them attractive for an adaptive sensor network**
  - Within CENS, nitrate and algae detection are two examples of applications of SP sensing under development
- **We invented a new sensor, the Surface Plasmon Band Gap Sensor (SPBG) that can be miniaturizable and detect a wide range of molecules**
- **Surface plasmons (SP) are electromagnetic waves propagating on the surface of a metallic interface**
- **Their wavelength is strongly dependant of molecular binding on the surface**
- **We showed that it is possible to use nanostructures to measure SP wavelengths using the plasmonic band gap phenomenon: when molecular binding occurs, the propagation of surface plasmon through the nanostructures is forbidden**



Potentiometric Electrochemical Detection

Tatyana Bendikov and Thomas C. Harmon (UC Merced)

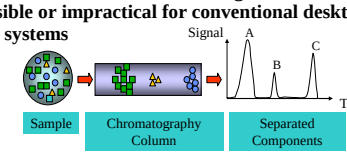
- **We are working on a novel concept, that of scaleable nitrate sensors created in a form appropriate for dense soil deployments--mimicking root fibers**
- **Our sensors will be inexpensive and environmentally benign and minimally disturb the soil moisture propagation and chemical transport regime during observations**
- **Proof-of-concept with nitrate-doped polypyrrole ion selective electrodes (Bendikov et al. 2005 Sensors and Actuators B: Chemical)**

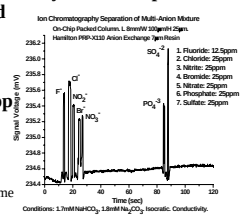


HPLC Chip-Based Chemical Sensing

Qing He, Yunan Miao*, Terry Lee*, and Yu-Chong Tai (Caltech/City-of-Hope)

- **High Performance Liquid Chromatography (HPLC) is one of the most powerful, versatile, and widely used separation techniques**
- **It allows separation, identification, purification, and/or quantification of the chemical compounds in complex mixtures**
- **By miniaturizing HPLC system onto a chip, significantly lower sample and solvent requirements, higher mass sensitivity, and lower cost can be achieved**
- **Moreover, portable HPLC chips can be used for field tests and/or networked sensing, which is impossible or impractical for conventional desktop HPLC systems**





Micromachined Amperometric Nitrate Sensor

Dohyun Kim, Ira Goldberg, and Jack W. Judy (UCLA)

- **Electrochemical Method (Amperometry and Potentiometry) are:**
  - **simple in design and operation, easily minaturized, low power, sensitive**
- **Electrochemical reduction of nitrate:** $NO_3^- + H_2O + 2e^- \rightarrow NO_2^- + 2OH^-$
- **NaOH supporting electrolyte, working electrode (Ag), reference electrode (Ag/AgCl), counter electrode (Pt)**
- **Ground water contains many ionic/non-ionic interfering species**
- **Selective measurement achieved with an anion-selective membrane**