Title

A High-performance Micromachined Amperometric Nitrate Sensor for Environmental Monitoring

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A High-Performance Micromachined Amperometric Nitrate Sensor for Environmental Monitoring

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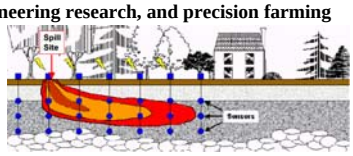
Introduction: Why a Micromachined Amperometric Nitrate Sensor?

Why Nitrate (NO_3^-) Sensor Important?

- Nitrate is a major contaminant in ground water: cause human health risks (e.g. *methemoglobinemia*)
- Nitrate-sensor applications: *In situ* nitrate monitoring, environmental science/engineering research, and precision farming

Infants *methemoglobinemia*



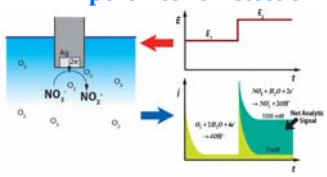
Distributed sensors for contaminant-source assessment

Electrochemical Methods

- Nitrate-sensor requirements
  - Inexpensive, small, remotely operable, and large detection range (0.1 µM to 1 mM)
- Electrochemical techniques meet the requirements
  - High sensitivity (0.1 ~ 1 µM) and good dynamic range (1-10 mM)
  - Relatively simple operation
  - Easy miniaturization
  - Low power consumption

Working Principle: Amperometric Detection of Nitrate

Amperometric Detection



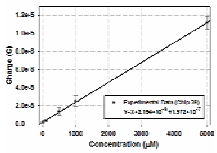
Double-potential-step chronocoulometry

- Electrochemical reaction on the sensing electrode and measured current is dependent to nitrate concentration

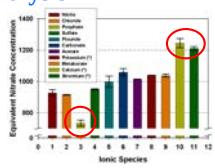
$$NO_3^- + H_2O + 2e^- \rightarrow NO_2^- + 2OH^-$$

- Proposed electrochemical system: NaOH electrolyte, Ag working , Ag/AgCl reference, and Pt counter electrode.
- Double-step chronocoulometry: less noise and minimize O_2 interference

Nitrate Analysis



Calibration curve

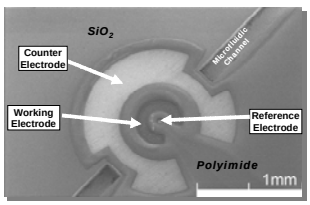


Measured nitrate concentration when 1000 µM of interfering ionic species are added to 1000 µM nitrate

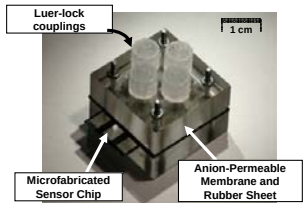
- High sensitivity: 2.47 $A \cdot s^{1/2} / (V^{1/2} \cdot M \cdot cm^2)$ – better than other electrochemical system
- Low detection limit: ~4 µM
- Wide dynamic range : ~4 to 10000 µM
- Interference : PO_4^{3-}, Ca^{2+}, and Sr^{2+} shows significant interference (20% signal distortion

Micromachined Nitrate Sensor: Design, Fabrication, Experimental Results, and Summary

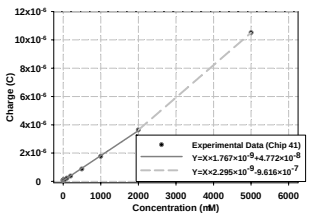
Micromachined Nitrate Sensor



SEM of electrodes & microfluidic channel



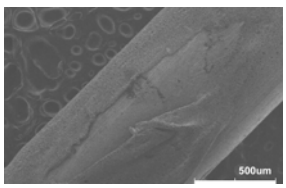
Assembled sensor unit



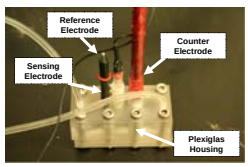
- Sensor performance
  - Linear up to 500~2000 µM
  - Detection limit: 4~75 µM
  - r^2=0.99 linearity

Calibration Curves of a Micromachined Sensing Chip for Nitrate Standards (0 ~ 5000 µM)

Improvement in Sensor Reliability



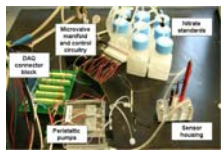
SEM of *polyurethane*-coated Ag/AgCl reference electrode



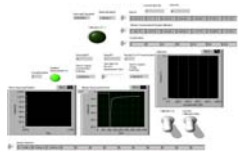
Sensor housing with commercial electrodes

- PU-coated electrode is more stable (3 mV drift/day)
- Macro-sized Ag sensing electrode and Ag/AgCl reference electrode: virtually infinite life-time

Toward Field-deployable Stand-alone Nitrate Sensor

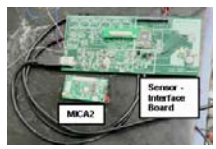


Experimental setup for automatic nitrate sensing system

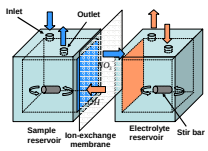


LABVIEW control panel for auto-calibration and sensing

- LABVIEW-based automatic nitrate sensing and calibration
  - LABVIEW control valves manifold, potentiostat and peristaltic pumps
  - Automatic sensor calibration from 0 to 1000 µM
  - Uninterrupted continuous sensing (adjustable time interval)



Sensor-interface board and MICA2 daughter board



Sample processor

- Palm-sized sensor-interface board with microprocessor, wireless capability, and built-in potentiostat is being developed
  - 8 bit µcontroller, SOS operating system, valve and pump control circuitry
  - Can replace bulky, expensive, power-hungry potentiostat
  - MICA 2 daughter board for wireless telemetry
- Donnan-dialysis-based sample processor (filtration unit)
  - Nitrate-specific anion-exchange membrane would improve selectivity to groundwater that contains many ionic species
  - Numerical simulation and experimental analysis making progress

Future Work

- Groundwater testing and comparison with conventional bench-top analysis techniques
- Field test (Palmdale site, Merced river etc.)