Title
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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 (NO₃⁻) Sensor Important?
- Nitrate is a major contaminant in ground water
- Nitrate-sensor applications
  - In-situ nitrate monitoring, environmental science/biology research, and precision farming

Electrochemical Methods
- Sensor requirements
  - Inexpensive, small, remotely operable, detection range (1 µM to 1 mM)
  - Electrochemical techniques meet the requirements
    - Amperometry and Potentiometry
    - Simple design and operation
    - Easily miniaturized
    - Low power & voltage
    - Sensitive

Working Principle: Electroanalytical Chemistry and Anion Permeable Membrane

Removal of Oxygen Interference
- Oxygen in electrolyte (≤ 0.26 mM) interferes with detection
- Nitrate reduction current = (nitrate + oxygen reduction current) – (oxygen reduction current)

Sensor Design, Fabrication, Experimental Results, and Summary

Sensor System Integration
- Pt counter electrode (7.7x10⁻⁵ cm²)
- Ag working electrode (0.7x10⁻³ cm²)
- Silver oxide reference electrode (0.038x10⁻³ cm²)
- polyimide insulation layer

SEM of electrodes & microfluidic channel

SEM of polyurethane-coated Ag/AgCl reference electrode and its potential drift (a) in comparison to silver oxide electrode (b). The minimal potential drift observed (3 mV for 27 hours)

Experiment: Calibration Curves and Sensor Selectivity

- Calibration curves
  - 1 to 1000 µM detection range
  - r²=0.99 linearity
- Detection limit: ~1 µM
- Sensor selectivity to interfering ions
  - Sensor output to a mixture of 100-µM nitrate and interfering ions (100 µM each of PO₄³⁻, SO₄²⁻, F⁻, Cl⁻) is only 13.9% higher than the average response for the sample consisting of nitrate

Summary and Future Work
- Electrochemical study proves that amperometric nitrate sensors are feasible with Ag working electrode and NaOH supporting electrolyte
- Integrated micromachined nitrate sensor units have been fabricated
  - Micromachined electrodes and fluidic channels
  - Anion-permeable membrane
  - Achieved a detection limit of ~1 µM and linear calibration curves
- Future work
  - Integration of PL-coated Ag/AgCl reference electrode
  - Long-term qualification test
  - Integrate into wireless sensor motes and network
  - Explore chip-scale and board-scale potentiostats for miniaturization
  - Field test