Boise State University

Ion Mobility Spectrometer (IMS) Sensor Project

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Overview of the IMS Sensor Project

The goal of this project is the development of a miniature, high resolution IMS sensor system for detecting gaseous volatile organic compounds in the vadose zone.

This sensor system will allow for in-situ measurement, unattended operation, and wireless or satellite transmission of data to the user via the Internet.

Can be used individually for characterization or in arrays for long-term monitoring of contaminated sites.
Block Diagram of the BSU IMS Sensor System

Down Hole

- Power Manager
- IMS
- Gas Controller
- Sampling Module
- Ancillary Sensors
- Working Gas
- Sample

Up Hole

- Solar Panel & Battery
- Communication
- User Interface

Key

- Low Voltage
- High Voltage
- Digital Signals
- Analog Signal
- Gas Sample
- Working Gas
- Probe Housing
Probe Deployment
The IMS Sensor

Down Hole

- Power Manager
- IMS
- Gas Controller
- Sampling Module
- Data Acquisition and Control
- Ancillary Sensors
- Sample

Up Hole

- Working Gas
- Solar Panel & Battery
- Communication
- User Interface
IMS is Used for Rapid Analysis of

- Chemical warfare agents
- Narcotics
- Explosives
- Amino acids, peptides, etc.
- Pesticides
How an IMS works:

- A gaseous sample is introduced to the IMS reaction region, where it is ionized.
- The ion gate is activated to allow the ionized species into the drift tube.
- In the presence of an electric field and a counter-flowing drift gas, the ionized species travel through the drift tube toward the detector.
- The various ionized species separate due to charge and size differences, arriving at the detector at different times.
As each ion discharges on the detector, a small current is generated. The measurement of this current over time yields a spectrum which is then used to identify and quantify the analytes in the sample.
Parallel Paths of IMS Sensor Development

- Low Temperature Co-fired Ceramic (LTCC)
- Macor (Machinable Ceramic Material)
What is LTCC?

- **Low Temperature Co-Fired Ceramics**
- Layered Structure of glass and alumina
- Sinters at **Low Temperature** (< 900°C)
- Substrate and embedded elements are **Co-Fired** in one step.
Why LTCC for this application?

- Closely-packed electrodes
  - ~ 50 electrodes/cm with circuitry printed on each layer
  - Provides very uniform electric field at ~500 V/cm
  - Reduces radial diffusion → higher resolution than typical IMS designs
- Integrated circuitry
- Robust and hermetically sealed
LTCC-IMS Test Article

Device Specifications:
• 156 layers
• 31.75 mm tall
• Full conductivity through all layers
• 5 embedded metal ion gates

156 layers is the tallest known LTCC device
Macor IMS Path

- Electrode density ~ 1/10 that of LTCC IMS $\Rightarrow$ *resolving power is reduced compared to LTCC device*
- Electrical components are discrete as opposed to integrated $\Rightarrow$ *less compact than LTCC*, but…
- Complete Macor IMS sensor has been successfully fabricated
- Macor IMS has allowed us to verify other subsystems while LTCC design work continues

*Experimental results shown here are for the Macor IMS*
Macor IMS Sensor System Lab Test
Prototype Testing Methodology

Test Various Components
- Macor IMS and Sampling Module
- Our High Voltage Power Supply vs. Lab Supply
- Our Preamplifier vs. Lab Preamplifier

Test System
- Macor IMS + Sampling Module + Data Acquisition System vs. Lab Data Acquisition System
Macor IMS Test Setup

- Ion Gate Control
- Faraday plate output (detector)
- High Voltage
- In
- Drift gas in
Macor IMS + Sampling Module Testing

Carrier Gas In  Sampling Module  Macor IMS

Sample
Macor IMS Sensor Testing
Macor IMS + Sampling Module

Test Results

RIP

PCE

TCE

Drift Time [ms]
High Voltage Power Supply Test Setup
Macor IMS + Power Supply Comparison

Drift Time [msec]

Ion Current [nAmps]

Our System Power Supply
Lab Power Supply

RIP
Macor IMS + Preamplifier Comparison

Our system preamplifier
Lab preamplifier

PCE and TCE
End-to-End Macor IMS Test Setup
End-to-End Macor Test Results

Our system components
Lab components

PCE and TCE

Ion Current [nAmp]

Drift Time [ms]
Summary of IMS Accomplishments

Component Design and Test
- ✓ Macor IMS
- ✓ Sampling Module
- ✓ High Voltage Power Supply
- ✓ Preamplifier

System
- ✓ End-to-End (sample to spectra)
Next Steps…

The IMS sensor system has been proven and will provide a capable platform for work in the following areas:

- Improving quality of IMS output
- Field-scale design of components for probe integration
- Field-testing of probe system (invitation to demo at Savannah River in January 2006)
Thank you for your attention.

Any questions?