Research Brief #4

Developing a Sensor to Find and Monitor Contaminants *In Situ*

Sensor Technology

Researchers at Georgia Tech are designing and developing a sensor capable of continuously measuring gases from soil, sediment, or tanks, as well as liquid-phase contaminants in groundwater. The proposed sensor is based on a patented integrated-optic (IO) interferometer chemical sensor developed at Georgia Tech and licensed for manufacturing by Photonic Sensor Systems, Inc.

The interferometer under development is an instrument that splits light into two (or more) beams, one (or more) of which is exposed to the surrounding environment as it passes over a waveguide while the other is shielded. At the end of the waveguide, the beams are optically recombined. In this particular interferometer, the surface of the waveguide is treated with one or more chemicals designed to react with certain contaminants. If no contaminants are present, the two beams match when they are recombined. If contaminants are present, the recombined beams are different. This different is called an interferance pattern—hence, the name "interferometer." The term "integrated optic" refers to the fact that all the optics (including the beam splitter, channels, beam recombiner, and surface coatings) are combined on the sensor.

The IO technology offers significant performance and economic advantages over other technologies either in existence or under development. A sensor using this technology has the potential to monitor several different chemicals on a single multichannel waveguide in a package no larger than a quarter. In addition, its performance is not hurt by moisture changes, temperature variations, or interfer-

Summary of the project

Benzene, toluene, ethyl benzene, and xylene (BTEX) chemicals are found in many Superfund sites. Techniques that exist for measuring these chemicals are often prohibitively expensive, time consuming, and sometimes difficult to use in the field. Researchers have made some advances in using microsensors to detect these chemicals. However, the use of microsensors is limited by problems with manufacturing repeatability, operation longevity, shelf life, and by the device's inability to differentiate more than one chemical at a time.

Georgia Tech researchers are developing a sensor that shows potential for detecting BTEX contaminants. The sensor incorporates a specially fabricated glass with a specific refractive index. Two or more planar waveguides are etched onto the surface of the glass, forming channels or paths for light to follow. One waveguide is not coated and acts as a reference path; the rest of the sensor is coated with a chemical(s) that will react with a particular contaminant(s). When laser light passes through one end of the sensor, its beam changes as the chemical coating reacts with the contaminant if the contaminant is present. The magnitude of the change depends on the concentration of the contaminant.

This sensor will make it possible to characterize a BTEX-contaminated site and to determine the size, shape, and amount of contamination. This information will allow remediators to determine where remediation is necessary and if the contamination is heading towards groundwater.

depicting the concentrations of contaminants and their flow. These models will help researchers determine strategies for remediating the sites.

Progress

Most of the work to date has focused on determining the waveguide-coating materials' sensitivity to benzene, toluene, ethyl benzene, and xylene (BTEX) chemicals. In the ideal case, the coating will not be sensitive to water or to other potential interferants. The objective is to develop a matrix of coatings and chemicals and to calibrate the response of each coating to the BTEX chemicals and to water vapor. Researchers can use the matrix to determine which coatings to use for the actual sensor designs.

In screening candidate sensor coatings, the researchers have concentrated on polymer materials and have identified several as potentially suitable candidates. The criteria for selecting a candidate coating included the coating's:

- sensitivity to the chemicals of interest,
- insensitivity to water or water vapor,
- tendency to respond to the presence of chemicals,
- stability and ability to withstand its environment and not evaporate, dissolve, or deteriorate.

In the screening process, the researchers first coated the waveguide surface with a candidate material and then observed the sensor's response when exposed to contaminants at a known concentration. They were looking for fast responses that quickly returned to the zero point. Once a coating was selected, researchers calibrated the coated sensor by measuring the response at different concentration levels. The calibration data and field measurements will be used to characterize contaminant concentration levels.

Researchers successfully detected benzene at low concentration levels and demonstrated the sensor's ability to measure the concentration of a pollutant. Most important, the reactive chemical used with the IO sensor showed no sensitivity to water vapor; thus, the sensor is able to monitor vapors from sediments or high-moisture-content soil.

Waveguide Protection

The sensors will be used in riverbed and lake-bottom sediments that could potentially damage the waveguide surface. Therefore, the researchers are studying two approaches to protecting the surface. One method is to provide the waveguide with a surface that fine sediment particles do not stick to. The second method is to use a permeable membrane, provided by W.L. Gore & Associates, that will keep the soil out and the vapor in. Researchers tested the protective membrane, which fits like a sock over the sensor, by placing devices in various sewers for three-week periods. When they retrieved the samples, they found the exteriors were coated with a thick layer of "crud," but the interiors were clean. Since the environment in which the sensors will be used will be much more benign than the sewers, the protective membranes should work well.

Future Activities

Researchers plan to finish screening the coating substances and select coatings for the sensors. The coatings will then be integrated onto the waveguide surfaces, forming a multichannel sensor that will be used for the BTEX tests and to develop calibration curves for each of the BTEX chemicals. Subsequently, the researchers will test the sensor in a sediment several inches thick containing known amounts of contaminants.

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