Georgia Tech

Research News

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HIGH-TECH GOES COUNTRY:
INEXPENSIVE OPTICAL SENSOR
PROMISES TO LOWER FARMING COSTS

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To save energy and lower the cost of fertilizing cropland, Georgia scientists are developing low-cost optical sensors that will monitor chemical changes in the soil.

Once completed, the device could also prove useful as an inexpensive way to detect environmental pollutants, monitor industrial processes, or even measure substances in human blood.

When soil loses nitrogen, the key component of many fertilizers, it frequently emits ammonia. That's why scientists at the Georgia Institute of Technology and the University of Georgia are designing sensors to measure fluctuating ammonia levels. The device promises to cut fertilizer costs while saving energy.

"In agriculture, the production of nitrogen-based fertilizers accounts for major energy costs," explained James L. Walsh, a senior research engineer in Georgia Tech's Environmental Sciences and Technology Division. "You could use a sensor to manage the application of fertilizer in real-time, and you might be able to save half your fertilizer."

Developed by researchers Nile Hartman and Dan Campbell at Georgia Tech, the device uses beams of light that act like 'feelers' to sense chemical changes.

Existing technology makes it difficult, if not impossible, for farmers to accurately measure the effectiveness of fertilizer, Walsh said. "The only thing you can do right now is get a student with a pup tent to sit in the field and run wet chemistry tests every two hours," he added. "That's not real-time."

Hartman believes the optical sensor promises a low-cost solution because it can be fabricated using standard techniques, and components cost less than $100.

As light passes through different substances such as glass and air, it "refracts" or bends. Georgia Tech researchers make use of this phenomenon by monitoring changes in guided light beams subjected to various substances.

Here's how it works: First, scientists equip a small, rectangular piece of glass with optical pathways or waveguides in the form of a thin film that guides the light beams.

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Next, the glass is coated with a special material known to react with certain chemicals. When a tiny laser is guided into the chip, it enters the waveguide and splits into two or more optical pathways, behaving as separate light beams. The "higher order" beams extend through the surface material, sending 'feelers' of light into the surrounding environment. Meanwhile, a "lower order" light beam remains confined within the waveguide and serves as a reference point. If the surface coating encounters a particular substance in the environment, a chemical reaction occurs, and this alters the refraction angle of light beams guided through the chip. Thus, with the help of an ordinary light detector, scientists can sense the presence of various chemicals by observing the interference pattern within the beams. The device senses even the most minute changes, Hartman said -- as small as 10^{-6}.

Hartman has already demonstrated feasibility for the optical sensor, but an ideal coating material has not yet been identified. Campbell, a chemist, is analyzing various substances to determine which materials would be most responsive to changing ammonia levels.

"Since ammonia has a weak base, I'm looking for a weak acid to interact with it," Campbell said. "Right now, I'm experimenting with things like phenols and ammonium salts, both weak acids."

Once the device is completed, Walsh and agricultural engineer Chuck Ross will measure its effectiveness in a Georgia Tech laboratory. After these tests, they will work with University of Georgia scientists Drs. Fred Boswell and Bill Hargrove to conduct field tests on an actual cropping system at the Georgia Experiment Station in Griffin.

"The sensor, if it works, could lead to a whole series of experiments to measure the loss of nitrogen under a wide range of conditions and with a large number of crops," Boswell said. "We would like to use the prescription approach (in applying fertilizer), like a pharmacist does."

Ross believes the optical sensor could benefit various industries. For example, he said, it might be possible to detect byproducts generated during biological processes such as alcohol fermentation and waste treatment. The sensor might also be used to monitor industrial processes, pollutants in the environment, or toxic fumes in the workplace, Campbell said.

And it's not difficult to imagine biomedical applications for the sensors, he added. Perhaps a modified version of the device could someday monitor chemical changes in the bloodstream, such as changing levels of antibodies.

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