Miniature sensors may advance climate studies

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Sandia ear-plug-sized samplers, with silvery microvalves and solder connectors, seemingly hang poised to sample gases relevant to climate and weather. The prototype devices actually rest on a mirror, reflecting the day's Albuquerque weather. Credit: Photo by Randy Montoya, Sandia National Laboratories

(Phys.org) -- An air sampler the size of an ear plug is expected to cheaply and easily collect atmospheric samples to improve computer climate models.

"We now have an inexpensive tool for collecting pristine vapor samples in the field," said Sandia National Laboratories researcher Ron Manginell, lead author of the cover story for the Review of Scientific Instruments, the often-cited journal of the American Institute of Physics.

The novel design employs a commonly used alloy to house an inexpensive microvalve situated above the sample chamber.

When heated, the alloy — a kind of solder — melts and flows, blocking the inlet hole. When cooled, the alloy resolidifies into an impermeable block that seals the gas sample inside the inert chamber below. Low cost should make widespread distribution of these sensors possible, while the noncontaminating nature of the design helps meet stringent technical requirements.

Better data collection is important because uncertainties in fact-gathering is one reason climate models reach a variety of conclusions. Winds may blow gases toward or away from a sampling site, gas contents at any location may vary by the hour and by the season, and samples collected by containers in the field may evaporate or become corrupted before analysis in a distant laboratory. Compounding the problem are difficulties in widely distributing sensors, which can be heavy, fragile and require expensive tending by humans.

The Sandia phase-change micro-valve sensor is light, cheap, tough, inexpensive to fabricate and simple to operate. It takes in gas in seconds through a tiny hole about the diameter of three human hairs. The hole closes when a tiny, low-energy hotplate on the canister's surface melts shut the alloy through which the hole passes, sealing it.

Because the little container doesn't outgas internally, the trapped sample remains uncorrupted until analyzed in the laboratory. The miniature sensor's simplicity means it could travel in unmanned aerial vehicles (UAVs) or as unmonitored cargo in atmospheric balloons. The poorest countries could afford to play a role in global climate data collection.

It has so many good features that one is tempted to ask, Do you want to drive it off the lot now or accept delivery at home?

Sandia researcher Mark Ivey is interested now. He oversees the operation of sounding balloons that carry sensors skyward for the Department of Energy in Oliktok Point and Barrow, Alaska. The miniature blimps, able to sample particles around which cloud droplets form, are tethered to winches that reel the soaring balloons back in. Getting sensors to Barrow — a place no highway visits — then into the air and back to a laboratory in the lower 48 makes weight and size a factor.

"Smaller, lighter is a big deal for us," Ivey said.

Manginell's team plans to submit an atmospheric sampling proposal this spring to NASA for something called "ground-truth measurement." NASA, he said, "has a ton of satellite data, more than they know what to do with," but the agency needs to use data from ground-based or airborne sensors that physically sniff the gases reported by satellites to calibrate remote instruments.

NASA and the National Oceanic and Atmospheric Administration (NOAA), who need ground-truth data, have built systems with flask containers using conventional valves that at open flasks and then close them at specific altitudes. However, the flasks are big — perhaps half a liter in size — and heavy, and the valves they require may outgas, ruining the measurements, Manginell said.

Outgassing occurs when the material used for the container releases a gas of its own, contaminating the atmospheric gas trapped in the flask.

The Sandia system "would have 100 of these devices in a package that has a macrovalve on top," said Manginell. An altimeter sends an electrical pulse that opens the macrovalve to fill the package with air. A small pump builds up pressure, filling the tiny cylinders. "You'd use personal-computer (PC) processors that you can put on a circuit board to operate the miniature system," he said.

The balloons would have global positioning locators on them. The low weight would make them suitable for balloon and UAV applications. The tiny containers are built of alumina tubing, cheap and more inert than glass.

Data collected by the tiny cylinders also could be used to confirm satellite images of airborne industrial effluents, essential for monitoring cap-and-trade deals.

But not all potential uses are in the upper atmosphere. Geoscientists drill boreholes for oil and to understand how the Earth formed. "It's hard to build a mass spectrometer to go down a 2-inch diameter borehole," Manginell said. "We've proposed instead to use our miniature samplers outfitted with microvalves to take samples that can be transported pristinely back to the surface and then examined in a lab."

In medicine, volatile compounds that people and animals emit are indicative of disease states and stress. "Point-of-care medicine, instead of taking a blood sample, could sample a person's breath," Manginell said. "Alcohol gives a gross signal but infections have a high volatile content as well." The bacteria that give cows tuberculosis produce a characteristic signature, for example.

"It would take a miniature pump the size of the last joint of your thumb to collect a sample," Manginell said. "One can perform on-the-spot detection, but also capture a sample in the miniature chamber to send back to the lab for gold-standard tests." E coli and anthrax also have volatile signatures, he said.

The detector also could be used by the military to collect and analyze gases on the battlefield.

"We've spent a lot of time over the past 15 years doing field analysis for customers: microchemlab work for the military and General Electric, and developing handheld gas detectors. This is just another tool in the toolbox," Manginell said. "But we were pretty happy that this work proved to be broadly cost-effective."

The work, featured in the paper, "A Materials Investigation of a Phase-Change Micro-Valve for Greenhouse Gas Collection and Other Potential Applications," is a cross-department effort.

"This is a little different from what we've done in the past," Manginell said. "The widespread collection of greenhouse gases has to be extremely cheap. So we collected people who have done soldering, brazing and thick-film metallization on ceramics that's scalable to high-volume production. Some did analytical chemistry to figure out if we were contaminating the sample. Others found the perfect solder mix."

Sandia researcher Curt Mowry said, "I made sure the solder didn't contribute any CO_2 to the sample that was collected, because then you have a stinky measurement."

More certainty in data collection is good because of the uncertainties in climate predictions, Manginell said.

"The overwhelming majority of the data seems to point to the fact that there's warming, but how do you attribute that: Is it natural variation or manmade influence?" he said. "Distributions of our capsules would greatly improve the accuracy of field measurements. You'd have a platform that would be ubiquitous, on planes, UAVs, balloons in countries that can't ordinarily afford to do these things. In India, it's hard to make those measurements when you're concerned with putting food on the table. But for legislation or policy decisions on, say, cap and trade, it's important to make those measurements accurately."

Funding came from Sandia's Laboratory Directed Research and Development (LDRD) program, Manginell said.

"We thought we could do a more ubiquitous job of sensing than anything currently available," he said.

Despite successful testing of the device, Manginell's work, like science, is never finished.

"What we need to build next is a normally closed version of the valve that opens when we want it to," he said. A presealed container would eliminate another possible source of contamination in transit.

More information: rsi.aip.org/resource/1/rsinak/v83/i3/p031301_s1

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