Tiny 'gas-flow' sensor has industrial, environmental applications

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Researchers at Purdue University have shown how to create a new class of tiny sensors for applications ranging from environmental protection to pharmaceutical preservation.

Although similar "gas-flow sensors" are currently being used for a variety of industries, the new sensor is the first that works on the scale of micrometers and nanometers, or millionths and billionths of a meter, respectively, said Steven Wereley, an associate professor of mechanical engineering.

Gas-flow sensors currently used, including those in residential gas meters to determine how much to charge customers, operate on a principle known for at least 100 years. According to that principle, as gas flows over a surface, such as the wall of a pipe or an object flying through the air, molecules of gas nearest the surface remain stationary. The molecules farther away from the surface move progressively faster.

"That model works really well in many situations, including aerodynamics and applications where the scale of the flow is large compared to the size of the molecules," Wereley said.

This principle, however, does not apply to gas flowing through channels on the scale of micrometers or nanometers, meaning ordinary designs will not work for sensors needed for applications on those scales. In such applications, gas molecules immediately adjacent to the wall of a tube do flow and are said to "slip."

"This exception to the model carries important design implications," Wereley said.

Findings will be detailed in a research paper to be published in the February issue of the Journal of Micromechanics and Microengineering. The paper was written by Wereley and Jaesung Jang, a postdoctoral research associate in Purdue's School of Electrical and Computer Engineering.

The paper describes how the sensor is designed.

As gas flows through a tiny channel, some of it is diverted into a reservoir, where it pushes against a silicon diaphragm coated with metal. As the diaphragm balloons outward from the pressure of the gas, it comes close to an electronic device called a capacitor, which stores an electric charge. The closer it comes to the capacitor, the more it affects the capacitance in the device. The changing capacitance is related to a difference in pressure, and a mathematical model is then used to precisely measure how much gas is flowing through the sensor based on the changing pressure.

Because of the channel's diameter, which is 128 microns, barely wider than a human hair, it is extremely sensitive to small gas flows, Wereley said.

Gas-flow sensors that operate on the scale of micrometers and nanometers could have applications in environmental protection, particularly to measure the leakage of hydrocarbon fumes from fuel tanks in new cars on the manufacturing line. Federal environmental guidelines specify how much leakage is allowable.

Automakers currently test empty fuel tanks by pressurizing them with a gas, such as helium, and then measuring whether the pressure drops, indicating leakage. The test is limited because, while it can determine whether a tank is leaking, it cannot reveal how severe the leak is. Using a sensor capable of measuring gas flow on small scales would make it possible to yield more accurate data.

An accurate test also could be applied to the pharmaceutical industry, which preserves drugs in packages filled with a gas free of the molds and impurities of ambient air. Pharmaceuticals are shipped and stored in the packaging, and the industry tests packages for leakage, but gas-flow sensors could be used to test them more accurately.

The Purdue researchers worked with industry to develop the sensors, which currently are too costly to be manufactured profitably. The research is associated with the Microfluidics Laboratory at the Birck Nanotechnology Center in Purdue's Discovery Park.

Source: Purdue University

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