Researchers develop tiny sensor for measuring subtle pressure changes inside the body

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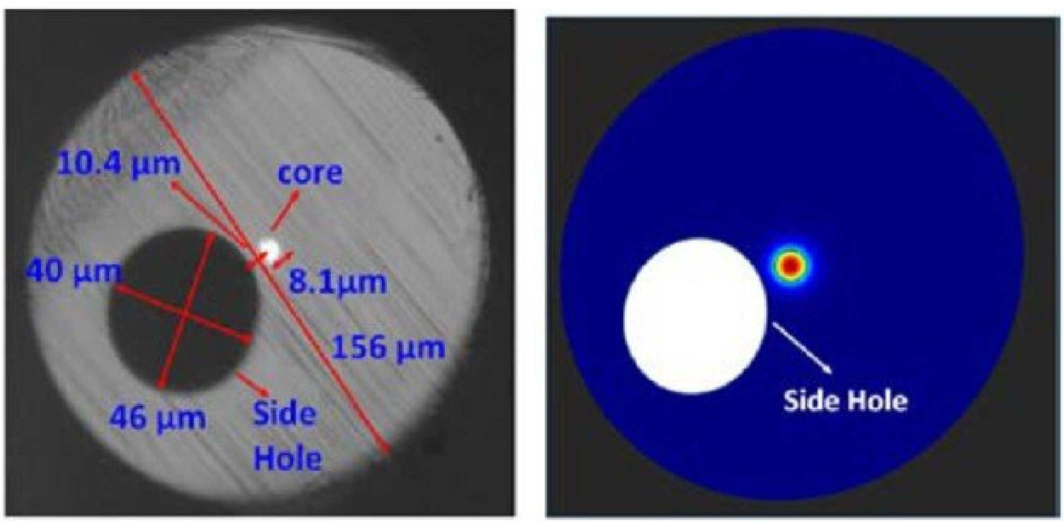


Researchers developed an extremely sensitive miniaturized optical fiber sensor that can measure small pressure changes. Adding a side hole that runs parallel to the fiber core enhanced the pressure measurement and accuracy. Credit: Xin Cheng, The Hong Kong Polytechnic University

Researchers have developed an extremely sensitive miniaturized optical fiber sensor that could one day be used to measure small pressure changes in the body.

"Our new pressure sensor was designed for medical applications and overcomes many of the issues of using silica-based fibers," said research team leader Hwa-Yaw Tam from The Hong Kong Polytechnic University. "It is sensitive enough to measure pressure inside lungs while breathing, which changes by just a few kilopascals."

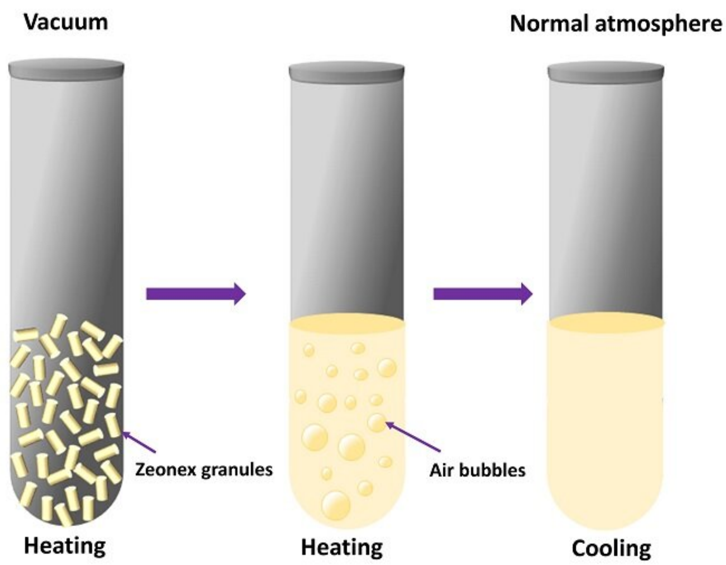
The researchers describe their new optical fiber sensor in The Optical Society (OSA) journal *Optics Letters*. The sensor, which is based on a fiber Bragg grating (FBG) inscribed into a fiber made from a new polymer called Zeonex, was able to detect pressure changes of just 2 kilopascals.

"Our FBG sensor could be used in various medical applications because, in addition to its biocompatibility, the fiber is chemically inert and also not sensitive to moisture," said Tam. "Our ultimate objective is to use these types of sensors to monitor various parameters—including pressure, temperature and strain—inside animals and people."

Making a polymer sensor

Many fiber optic sensors are based on FBGs, tiny periodic microstructures that can be inscribed onto a fiber. When pressure rises the fiber stretches slightly, increasing the grating period in a way that changes its refractive index and shifts the light output toward the red end of the spectrum. Similarly, a decrease in pressure produces a blue shift.

Making an FBG sensor from a traditional silica optical fiber is not ideal for medical applications, especially those involving long-term use in the body, because these fibers exhibit a relatively high stiffness and can be brittle. FBGs embedded in silica fibers also have limited sensitivity to small pressure changes because the material does not stretch and contract very easily. Although polymer optical fibers have been developed, they tend to absorb water—which can affect measurements—and are not very easy to inscribe with an FBG.



The optical fiber used to make the new sensor is made completely of the advanced polymer Zeonex. The diagram shows how the researchers made the preform that was then heated and pulled to make the fiber. Credit: Xin Cheng, The Hong Kong Polytechnic University

To overcome these hurdles, the researchers turned to the advanced polymer Zeonex. This new material is not only chemically inert and works well in the aqueous environments like those found in the body, but also exhibits a higher light shift in response to a pressure change compared to silica fibers. Although substances called dopants are often used to make materials with different refractive indexes for the inner core and outside cladding of fibers, the researchers simplified the fabrication process by using different grades of Zeonex to make a singlematerial fiber.

"Eliminating the use of dopants allows the optical fibers to be fabricated with good reproducibility," said Tam. "We were able to use an excimer laser to easily inscribe the FBG and to add a side hole that runs parallel to the core. The side hole enhanced the pressure measurement sensitivity and significantly reduced lag, therefore providing better measurement accuracy."

High-resolution, reproducible readings

To demonstrate the new sensor, the researchers compared its performance with a traditional polymer-based sensor of a similar design. The sensors were placed inside a chamber, where the pressure was manually increased and decreased step by step above and below the atmospheric pressure. The corresponding light shift was monitored in real time for both sensors.

They found that the Zeonex-based sensors with the side-hole design produced a response that was linear, repeatable and had negligible lag or errors. The tests showed that the sensor can be used for low pressure measurement up to 50 kilopascals above or below atmospheric pressure with a resolution of 2.0 kilopascals. The sensitivity of the pressure measurement is increased by 80% compared to a traditional polymer-based sensor.

"The pressure sensor is most useful in conditions where the change in pressure is in the order of few kilopascals above and below the atmospheric pressure," said Tam. "It could be useful for low pressure sensing in medical and high-altitude environments as well as for detecting pressure changes in gaseous containers."

The researchers are now working to further reduce the sensor's response time, which is currently few tens of seconds. They also want to expand the sensor to measure other physical and chemical parameters such as pH and to functionalize the probe so that it can detect the pressure of a particular gas.

More information: Jitendra Narayan Dash et al, Low gas pressure sensor based on a polymer optical fiber grating, *Optics Letters* (2021). DOI: 10.1364/OL.418096

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