New nanowire sensors are the next step in the Internet of Things

January 6 2023

Credit: CC0 Public Domain

A new miniscule nitrogen dioxide sensor could help protect the environment from vehicle pollutants that cause lung disease and acid rain.

Researchers from TMOS, the Australian Research Council Center of Excellence for Transformative Meta-Optical Systems have developed a sensor made from an array of nanowires, in a square one fifth of a millimeter per side, which means it could be easily incorporated into a silicon chip.

In research published in the latest issue of *Advanced Materials*, Ph.D. scholar at the Center's Australian National University team and lead author Shiyu Wei describes the sensor as requiring no power source, as it runs on its own solar powered generator.

Wei says, "As we integrate devices like this into the sensor network for the Internet of Things technology, having low power consumption is a huge benefit in terms of system size and costs. The sensor could be installed in your car with an alarm sounding and alerts sent to your phone if it detects dangerous levels of nitrogen dioxide emitted from the exhaust."

Co-lead author Dr. Zhe Li says "This device is just the beginning. It could also be adapted to detect other gases, such as acetone, which could be used as a non-invasive breath test of ketosis including diabetic ketosis, which could save countless lives.

Existing gas detectors are bulky and slow, and require a trained operator. In contrast, the new device can quickly and easily measure less than 1 part per billion, and the TMOS prototype used a USB interface to connect to a computer.

Nitrogen dioxide is one of the NOx category of pollutants. As well as contributing to acid rain, it is dangerous to humans even in small concentrations. It is a common pollutant from cars, and also is created indoors by gas stoves.

The key to the device is a PN junction—the engine of a solar cell—in the shape of a nanowire (a small hexagonal pillar with diameter about 100 nanometers, height 3 to 4 microns) sitting on a base. An ordered array of thousands of nanowire solar cells, spaced about 600 nanometers apart formed the sensor.

The whole device was made from indium phosphide, with the base doped with zinc to form the P part, and the N section at the tip of the nanowires, doped with silicon. The middle part of each nanowire was undoped (the intrinsic section, I) separating the P and N sections.

Light falling on the device causes a small current to flow between the N and P sections. However, if the intrinsic middle section of the PN junction is touched by any nitrogen dioxide, which is a strong oxidizer that sucks away electrons, this will cause a dip in the current.

The size of the dip allows the concentration of the nitrogen dioxide in the air to be calculated. Numerical modeling by Dr. Zhe Li, a postdoctoral fellow in EME, showed that the PN junction's design and fabrication are crucial to maximizing the signal.

The characteristics of nitrogen dioxide—strong adsorption, strong oxidization—make it easy for indium phosphide to distinguish it from other gases. The sensor could also be optimized to detect other gases by functionalizing the indium phosphide nanowire surface.

TMOS Chief Investigator Professor Lan Fu, leader of the research group says "The ultimate aim is to sense multiple gases on the one small chip. As well as environmental pollutants, these sensors could be deployed for healthcare, for example, for breath tests for biomarkers of disease.

"The tiny gas sensor is easily integratable and scalable. This, combined with meta-optics, promises to achieve multiplexing sensors with high performance and multiple functionalities, which will enable them to fit into smart sensing networks. TMOS is a network of research groups across Australia dedicated to progressing this field.

"The technologies we develop will transform our life and society in the coming years, with large-scale implementation of Internet of Things technology for real-time data collection and autonomous response in applications such as air pollution monitoring, industrial chemical hazard detection, smart cities, and personal health care."

More information: Shiyu Wei et al, A Self-Powered Portable Nanowire Array Gas Sensor for Dynamic NO 2 Monitoring at Room Temperature, *Advanced Materials* (2022). DOI: 10.1002/adma.202207199

Provided by ARC Centre of Excellence for Transformative Meta-Optical Systems