Self-powered Nanosensors Set to Revolutionise Healthcare and Environmental Monitoring

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

The sensor is an array of nanowires, in a square one fifth of a millimetre per side, which means it could be easily incorporated into a silicon chip.

It also needs no power source, as it runs on its own solar power, said Shiyu Wei, first author of the paper reporting the research in Advanced Materials.

“As we integrate devices like this into the Internet of Things, having low power consumption is a huge benefit in terms of system size and costs,” said Shiyu Wei, a PhD scholar in the Electronic Materials Engineering (EME) Department and TMOS Centre of Excellence.

“The device could also be adapted to detect other gases, such as acetone, which could be used as a breath test for diabetes.”

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 Miss Wei’s 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 nanometres, height 3 to 4 microns) sitting on a base. An ordered array of thousands of nanowire solar cells, spaced about 600 nanometres 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 oxidiser 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 modelling by Dr Zhe Li, a postdoctoral fellow in EME, showed that the PN junction’s design and fabrication are crucial to maximising the signal.

The characteristics of nitrogen dioxide – strong adsorption, strong oxidisation – make it easy for indium phosphide to distinguish it from other gases. The sensor could also be optimised to detect other gases by functionalising the indium phosphide nanowire surface.

“The ultimate aim is to sense multiple gases on the one chip,” said Professor Lan Fu, leader of the research group.

“As well as environmental pollutants, these sensors could be deployed for healthcare, for example, for breath tests for biomarkers of disease.”

To realise these goals, the team are in close collaboration with Professor Antonio Tricoli’s group in the Research School of Chemistry and the ANU Our Health in Our Hands Grand Challenge Program.

While nanowires have the advantage of sensitivity, their fragility is a challenge that the team had to address. They did this by surrounding the array of nanowires with a polymer, which provided structural robustness. The layer of polymer did not extend all the way up the nanowire, but left the N-doped tip exposed.

Then a layer of gold was applied, by spraying it at an angle to the nanowires, coating one side of the wire, and most of the polymer surface, except a small I-region in the gold-rain shadow behind the nanowire, which formed gas molecule sensing site.

The tiny gas sensor is easily integratable and scalable, said Professor Fu.

“Our nanowire arrays promise to achieve multiplexing sensors with high performance and multiple functionalities, which will enable it to fit into smart sensing networks,” she said.

“These technologies 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 healthcare.”

Read the original article on Australian National University (ANU).