

## In Situ Process Promises Mass Production of Nanowire-Based Photodetectors

A fundamental hurdle in the race to develop viable optoelectronic devices based on nanoscale structures is finding an easy way to place those structures as desired and to connect them with much larger components. Now John T.L. Thong and Jaslyn B.K. Law of National University of Singapore have constructed a photodetector based on ZnO nanowires using an in situ growth process that they suggest overcomes this hurdle and may enable the mass production of nanowire detector arrays for applications including optical communications, target acquisition, and radiation calibration and monitoring.

Law, a postgraduate student in the department of electrical and computer engineering and an A\*Star research scholar, explained that most nanowire-based photodetectors have been single-nanowire devices, constructed using a number of time-consuming steps. "The nanowires are typically synthesized on a substrate, harvested, redeposited and individually contacted for electrical characterization."

Although this approach has enabled researchers to construct operational

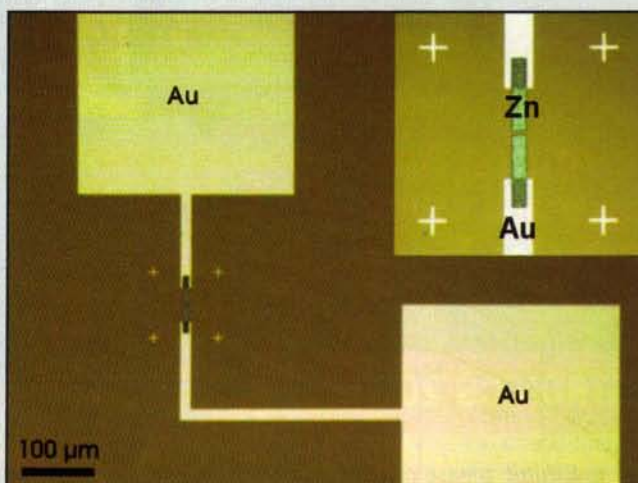
proof-of-concept devices, she said, they are not suitable for mass production. Moreover, they have tended to suffer from relatively low collection efficiencies because of the difficulties involved in stimulating an individual nanoscale detector element.

Thong and Law believe that they have a solution to both of these problems. In their approach, they combine the directed synthesis and assembly of the nanowires into one in situ fabrication step, using a self-catalytic growth process. The result is the generation of multiple inter-

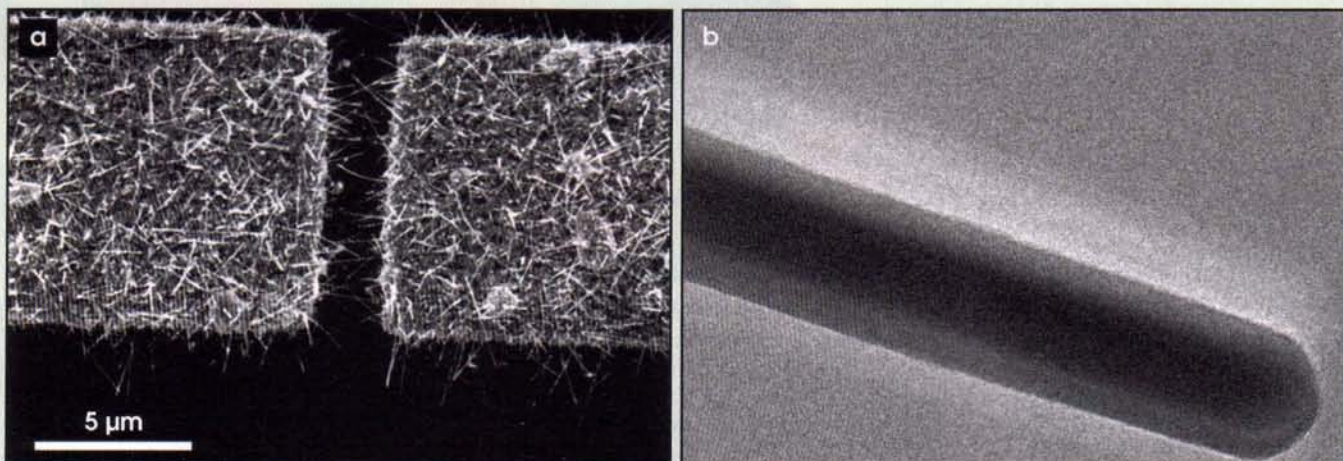
connected nanowires that extend across the gap between the prepatterned microscale electrodes.

To create their demonstration device, they deposited gold on a  $\text{Si}_3\text{N}_4$ -coated silicon substrate to form microscale bond pads and electrodes. Next, they deposited zinc on the electrodes, narrowing the gap to  $3\ \mu\text{m}$  (Figure 1). Finally, they heated this assembly for three hours at  $700\ ^\circ\text{C}$  in the presence of oxygen and argon gas at 1 atmos.

The scientists suggest that the zinc melts and forms droplets at the



**Figure 1.** An optical micrograph shows the patterned zinc electrodes extending from the gold electrodes and bond pads. The inset offers an enlarged view of the gap between the electrodes. Courtesy of Jaslyn B.K. Law.



**Figure 2.** The ZnO nanowires form between the electrodes as the zinc is heated beyond its melting point in the presence of oxygen (a). A bright-field transmission electron micrograph reveals a single-crystal ZnO nanowire (b).

apexes of the hexagonal grains of the metal as its temperature passes approximately 419 °C, which then react with the oxygen to produce ZnO. The low wettability of the ZnO with the zinc leads to the oxide migrating outward from the zinc across the gap, creating a web of 20- to 40-nm-diameter ZnO nanowires (Figure 2).

They investigated the time-dependent photoresponse of the device at room temperature and under a bias of 5 V using a 370-nm LED driven

by a 600-Hz square wave from a Thurlby Thandar Instruments Ltd. function generator to offer pulsed operation. A Tektronix oscilloscope monitored the response of the detector at a sampling interval of 0.4  $\mu$ s. At ambient conditions, the detector displayed a response time of less than 0.4 ms. Other photodetectors based on ZnO nanowires, they note, have displayed photoresponse times ranging from less than 1 s to thousands of seconds.

Law said that the team is investigating the effects on device responsiveness of using networks of interconnected nanowires. The scientists also hope to explore the potential applications of the detectors in trace gas sensing, noting the influence of the presence of water vapor on the response curve of the photodetector in the experiments. □

Daniel S. Burgess

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## Microscale Tubes Incorporate Quantum Dots

A team at Max Planck Institut für Festkörperforschung in Stuttgart, Germany, has produced InGaAs/GaAs tubes with InAs quantum dots embedded in their walls. The structures suggest the feasibility of using self-assembly techniques to produce high-quality-factor (Q) resonant cavities coupled with quantum emitters for use in basic research into quantum electrodynamics and in the development of devices — such as low-threshold ring lasers — and of technologies for quantum information processing.

In the experiments, the scientists employed solid-source molecular

beam epitaxy to grow a stack of semiconductor materials incorporating InAs quantum dots embedded in an InGaAs/GaAs strained bilayer. Using

lithography and wet chemical etching, they selectively freed the bilayer, which rolled upon itself under the strain of the lattice mismatch. The

*The starting material, grown by molecular beam epitaxy, incorporates InAs quantum dots in an InGaAs/GaAs strained bilayer (a). The AlAs acts as a sacrificial layer that can be etched away to release the bilayer from the GaAs substrate, enabling it to roll into a tube. Photoluminescence experiments were performed by illuminating the cryogenically cooled tubes and bulk material with 532-nm laser light (b). A false-color photoluminescence image reveals whispering-gallery modes at the laser excitation in the middle of a tube (c). The broad, blue spots at both ends of the tube correspond to waveguided light. Courtesy of Stefan Mendach.*

