



News and opinions

Nanowire makes smallest spectrometer

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Researchers have created the world's smallest spectrometer with a single nanowire, which could make environmental and process monitoring, food and drug quality testing, and identifying counterfeit goods easier [Yang et al., *Science* **365** (2019) 1017, <https://doi.org/10.1126/science.aax8814>].

"Our approach enables miniaturization without the need for optical components to separate the different wavelengths of light, which are common in traditional spectrometers," says Tawfique Hasan of the University of Cambridge, who led the research with colleagues from King's College London, University of Shanghai for Science and Technology, Nanjing University, Zhejiang University, Shanghai Jiao Tong University, Peking University in China, and Aalto University in Finland.

Instead, the new approach relies on a single semiconductor alloy nanowire with varying composition, in this case $\text{CdS}_x\text{Se}_{1-x}$ with predominantly Cd and S at one end of the wire and Cd and Se at the other. The nanowire is sensitive to a wide spectrum of visible light and the variation in chemical composition along its length allows the creation of sub-device units.

"These individual device units work as 'photodetectors': each of which respond to an incident spectrum of light in slightly different ways," explains Hasan. "[Our spectrometer] represents a new generation of computational spectrometer that works by combining the response from the hardware (the device) with a powerful computation algorithm to reconstruct the incident spectrum."

Unlike conventional spectrometers, which require complex optics to split light into different wavelengths and detectors to monitor them, the nanowire generates an electric current that is dependent upon the wavelength of incident light and the composition at that particular spot. The computer algorithm does the rest, reconstructing the signals into a spectral image. This straightforward concept creates the simplest possible spectrometer platform, which is compact enough for portable devices and could be easily integrated into other larger systems or devices.

Any light-sensitive material with closely spaced band gaps could be used to create this type of compact spectrometer, points out Hasan. By engineering nanowires with different compositions, the spectrometer can be designed to operate right across the spectrum from the infrared to the ultraviolet (Fig. 1).

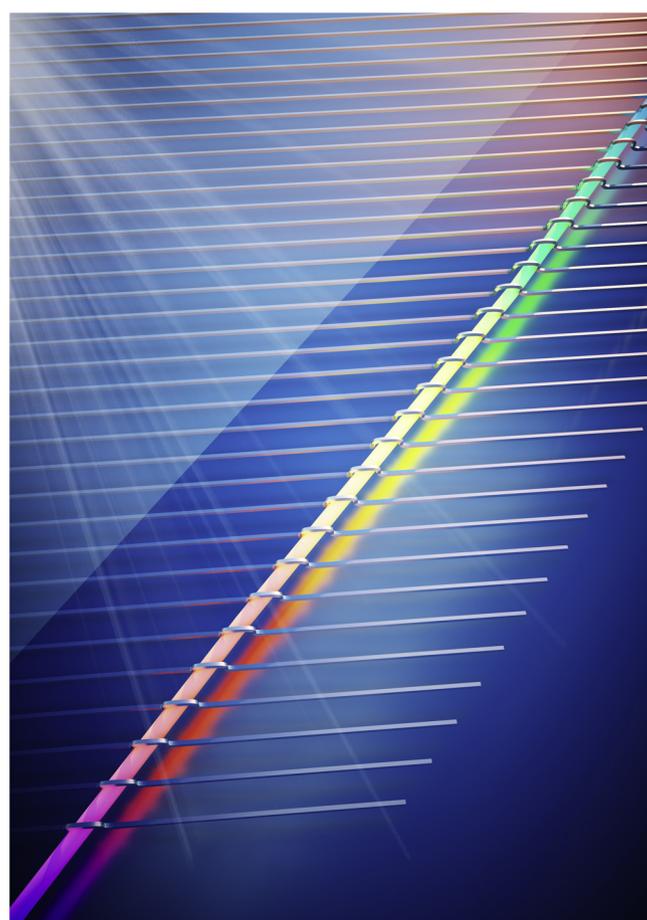


Fig. 1. Illustration of the nanowire spectrometer. [Credit: Ella Maru Studio.]

"The extreme miniaturization could allow a lot of exciting applications for industry, research and consumers," he says.

Bozhi Tian of the University of Chicago agrees that the highly miniaturized spectrometer could be useful for applications such as medical diagnostics and integrated nanosystems.

"This work represents the first demonstration of a spectrometer, which is significantly more complex than the photovoltaic devices, photodetectors, lasers, light-emitting diodes, etc. that sin-

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gle nanowires have been configured as previously,” he comments. “The use of compositionally graded nanowires is an ingenious design, which integrates multiple photodetectors into a single nanowire backbone.”

Cun-Zheng Ning, director of the International Center for Nano-Optoelectronics at Tsinghua University in China and professor of electrical engineering at Arizona State University adds:

“Compared to other miniaturized spectrometers, this design does not need an extra spectrum splitting device. The unique feature is that it combines the spectrum splitting and selective absorption in one shot.”

The spectrometers could be integrated into lab-on-a-chip systems or used to monitor industrial or agricultural manufacturing processes. The devices could be incorporated into microscopes, drones, or satellites for astronomy or environmental studies.

“I really like this work,” adds Tian, “because it shows the power of bottom-up growth – the same material cannot be made by top down lithography. It also suggests a future direction in which the complexity of chemical synthesis may serve as the new component for computation.”

Jie Bao, also of Tsinghua University, points out that the work demonstrates the potential of composition-varied nanowires for novel applications.

“The beauty lies in the idea of connecting the varying composition (thus the spectral responsivity) of nanowires to spectral discrimination, as well as the realization of it,” he says. “The unique advantage of this approach, to my mind, might be its ability to be fabricated in combination with nanowire-based light sources.”

The main challenge ahead will be scaling up the fabrication of the spectrometers, which will require the growth or placement of nanowires with predetermined properties in specific locations at large scales.

“This is not easy to achieve now,” cautions Hasan. “But our next step is to identify suitable material systems that would enable seamless integration to extend the operation wavelength region in both directions. Following this, an ultra-compact snap-shot spectrometer with different device designs, with arrays of spectrometers working together like a CCD camera could be the next significant achievement.”