'Quantum coaxial cable': Device proves solar cell potential of high bandgap inorganic nanowire arrays

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A report, published in the March 14 edition of the *Journal of Materials Chemistry*, announced the successful fabrication and testing of a new type solar cell using an inorganic core/shell nanowire structure.

Arrays of core/shell nanowires (described has "quantum coaxial cables") had previously been theorized as a potential structure that, while composed of chemically more stable large bandgap inorganic materials, should also be capable of absorbing the broad range of the wavelengths present in sunlight. High bandgap semiconductors are generally considered not effective at absorbing most of the available wavelengths in solar radiation by themselves. For instance, high bandgap zinc oxide (ZnO) is transparent in the visible but absorptive in the ultraviolet range, and thus is widely used in sunscreens but was not considered useful in solar cells.

In the report, a team of researchers from Xiamen University in China and the University of North Carolina at Charlotte describe successfully creating zinc oxide (ZnO) nanowires with a zinc selenide (ZnSe) coating to form a material structure known as a type-II heterojunction that has a significantly lower bandgap than either of the original materials. The team reported that arrays of the structured nanowires were subsequently able to absorb light from the visible and near-infrared wavelengths, and show the potential use of wide bandgap materials for a new kind of affordable and durable solar cell.

"High bandgap materials tend to be chemically more stable than the lower bandgap semiconductors that we currently have," noted team member Yong Zhang, a Bissell Distinguished Professor in the Department of Electrical and Computer Engineering and in the Energy Production and Infrastructure Center (EPIC) at the University of North Carolina at Charlotte.

"And these nanowire structures can be made using a very low cost technology, using a chemical vapor deposition (CVD) technique to grow the array," he added. "In comparison, solar cells using silicon and gallium arsenide require more expensive production techniques."

Based on a concept published in Nano Letters in 2007 by Zhang and collaborators Lin-Wang Wang (Lawrence Berkeley National Laboratory) and Angelo Mascarenhas (National Renewable Energy Laboratory), the array was fabricated by Zhang's current collaborators Zhiming Wu, Jinjian Zheng, Xiangan Lin, Xiaohang Chen, Binwang Huang, Huiqiong Wang, Kai Huang, Shuping Li and Junyong Kang at the Fujian Key Laboratory of Semiconductor Materials and Applications in the Department of Physics at Xiamen University, China.

Past attempts to use high band gap materials did not actually use the semiconductors to absorb light but instead involved coating them with organic molecules (dyes) that accomplished the photo absorption and simply transmitted electrons to the semiconductor material. In contrast, the team's heterojunction nanowires absorb the light directly and efficiently conduct a current through nano-sized "coaxial" wires, which separate charges by putting the excited electrons in the wires' zinc oxide cores and the "holes" in the zinc selenide shells.

"By making a special heterojunction architecture at the nanoscale, we are also making coaxial nanowires which are good for conductivity," said Zhang. "Even if you have good light absorption and you are creating electron-hole pairs, you need to be able to take them out to the circuit to get current, so we need to have good conductivity. These coaxial nanowires are similar to the coaxial cable in electrical engineering. So basically we have two conducting channels – the electron going one way in the core and the hole going the other way in the shell."

The nanowires were created by first growing an array of six-sided zinc oxide crystal "wires" from a thin film of the same material using vapor deposition. The technique created a forest of smooth-sided needle-like zinc oxide crystals with uniform diameters (40 to 80 nanometers) along their length (approximately 1.4 micrometers). A somewhat rougher zinc selenide shell was then deposited to coat all the wires. Finally, an indium tin oxide (ITO) film was bonded to the zinc selenide coating, and an indium probe was connected to the zinc oxide film, creating contacts for any current generated by the cell.

"We measured the device and showed the photoresponse threshold to be 1.6 eV," Zhang said, noting that the cell was thus effective at absorbing light wave wavelengths from the ultraviolet to the near infrared, a range that covers most of the solar radiation reaching earth's surface.

Though the use of the nanowires for absorbing light energy is an important innovation, perhaps even more important is the researchers' success in using stable high bandgap inorganic semiconductor materials for an inexpensive but effective solar energy device.

"This is a new mechanism, since these materials were previously not considered directly useful for solar cells," Zhang said. He stressed that the applications for the concept do not end there but open the door to considering a larger number of high bandgap semiconductor materials with very desirable material properties for various solar energy related applications, such as hydrogen generation by photoelectrochemical water splitting.

"The expanded use of type II nanoscale heterostructures also extends their use for other applications as well, such as photodetectors -- IR detector in particular," he noted.

More information: The report is available in the *Journal of Materials Chemistry*, issue 16, 2011. pubs.rsc.org/en/Content/Articl … g/2011/JM/c0jm03971c

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