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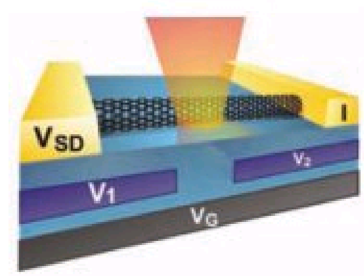
NEWS

Sep 10, 2009

# Nanotubes set to shine for solar energy



Illuminating the photodiode

Carbon nanotubes could be used to produce solar cells that generate more electrical current per photon than existing photovoltaic technologies, according to scientists in the US. The team has shown that photodiodes made from carbon nanotubes create multiple electron-hole pairs in response to a single photon – unlike other photodiodes, which produce just one pair per photon

"If this could be exploited in large-scale solar cells, it would extend the power conversion efficiency above standard limits," said Nathan Gabor of Cornell University, who was involved in the research.

Electrical current is produced in a photovoltaic cell when energy from a photon is transferred to an electron in the cell material, exciting the electron into the conduction band to leave behind a positively charged hole. Today's photovoltaics are based on materials that create just one pair per photon, which limits their efficiency.

## Junction photodiodes

Now, a team at Cornell, led by Paul McEuen, has found a way to boost the number of pairs by making photovoltaics from carbon nanotubes – tubes with walls just one carbon atom thick. The devices were made from individual single-walled nanotubes 3–4 µm long with diameters ranging from 1.5 to 3.6 nm. A nanotube is placed on an insulating substrate that contains three buried electrodes. When the appropriate voltages are applied to the electrodes, the nanotube behaves like a p–n junction photodiode.

The team then studied the photodiodes by illuminating them with lasers and monitoring the changes in the current they produced when an additional bias voltage was applied along the nanotubes. The scientists saw multiple carrier generation at temperatures of 90K or below, when voltage was applied to the diodes in the opposite direction to that in which current would flow freely. As they increased this voltage, they found that the current produced in response to light increased in steps. Then, by raising the energy of the photons coming from the laser, they increased the size of the steps.

Usually a photon would excite one electron and boost it one sub-band energy level. McEuen and Gabor believe that multiple pair generation is kick-started by photons that increase an electron's energy by more than this. Electrons in the nanotube's second sub-band and above can then move through the diode and excite other electrons themselves. The researchers say that the step-changes in current produced occur each time these second sub-band carriers gain enough energy to excite additional electrons.

## Near-perfect conversion in sight

"The second sub-band threshold means that the process uses almost all of the excess energy provided by the photon and combines this energy with the electric field to convert a single electron into extra electrons," Gabor told *physicsworld.com*. “This is very important because the ultimate goal of a highly efficient solar cell would be near-perfect conversion of light energy into electron-hole pairs.”

While this is the first observation of multiple pairs being created in carbon nanotubes, other researchers have claimed to see similar phenomena in semiconductor nanocrystals. The claims have been dogged by controversy, however, following difficulties in replicating the results and disagreements over their interpretation. Gabor points out that the Cornell work goes some way towards vindicating the original findings, and provides tools and methods to observe these processes. "This has generated excitement in the nanocrystal field," he said.

Vasili Perebeinos, a researcher at IBM's TJ Watson Research Center in New York, agrees that the Cornell team has clearly demonstrated a carrier multiplication effect that could be used in photovoltaics. "Their paper makes a solid benchmark in understanding the excited states in carbon nanotubes," said Perebeinos, who had previously predicted that this multiple carrier generation effect would be forbidden until the third sub-band. "This can help exploration of other applications like single photon light sources," he added. Perebeinos emphasizes

Their paper makes a solid benchmark in understanding the excited states in carbon nanotubes

Vasili Perebeinos, IBM

that researchers must gain an understanding of the effect's temperature dependence before it can be applied.

The work is reported in *Science*.

About the author
Andy Extance is a freelance science journalist based in the UK