Curly nanowires catch more light to power nanoscale electronic circuits

September 11 2015

In the question of curly versus straight, new evidence suggests curly wins – at least in the world of nanowires. Researchers from Bilkent University, Ankara, Turkey, have shown that twisting straight nanowires into springs can increase the amount of light the wires absorb by up to 23 percent. Absorbing more light is important because one application of nanowires is turning light into electricity, for example to power tiny devices.

The results of this research are published in the journal *Applied Optics*, from The Optical Society (OSA).

Nanowires are a relatively new technology and their full potential is still being explored. When the tiny wires are made from a semiconductor like silicon, light striking the wire will dislodge electrons from the crystal lattice, leaving positively charged "holes" behind. Both the electrons and the holes move through the material to generate electricity. The more light the wire absorbs; the more electricity it generates. A device that converts light into electricity can function as either a solar cell or a photosensor.

In 2007, U.S. researchers introduced a single nanowire photosensor that produced enough electricity from sunlight (up to 200 picowatts) to power nanoscale electronic circuits. More recently, a European researcher team built a nanowire solar cell with almost 14 percent efficiency from the compounds of indium and phosphorus. The efficiency is not enough to beat the best crystalline silicon solar cells on the market, but because nanowires can cover more area with less material, the nanowire solar cells could ultimately be cheaper.

"There is huge potential in the area of nanoscale photosensors," said Mehmet Bayindir, Director, National Nanotechnology Research Center, Bilkent University, Ankara, Turkey. "More efficient outputs might induce the emergence of a new generation of photosensor technology and eventual commercialization of these products."

Bayindir and his colleague Tural Khudiyev, now a postdoctoral associate at The Massachusetts Institute of Technology, have found that adjusting the geometry of the typical nanowire may be one way to realize the desired efficiency enhancement. Nanowires are usually long, thin and straight. Their tiny dimensions mean they interact with light differently than ordinary materials. Certain wavelengths of light will match up in just the right way with the dimensions of the nanowire, causing the light to "resonate" or bounce around inside the wire.

So called Mie resonances are especially advantageous to the nanoscale, Khudiyev said. The resonances are named after the early-20th-century German physicist Gustav Mie, who developed equations to describe why tiny metal particles make stained glass windows glow so brightly.

Mie resonances will occur with straight nanowires, but by twisting the nanowire into a helical shape Bayindir and Khudiyev found they could take double advantage of the phenomena.

"When the nanospring period matches with the Mie resonance points, a 'double resonance' condition occurs which boosts light harvesting efficiency," Khudiyev said.

Additionally, twisting the wire upwards shortened its length, saving up to 50 percent of the original area.

The enhanced light harvesting efficiency of nanosprings opens new opportunities to build nanoscale devices that power themselves – for example sensors to detect environmental toxins or to monitor the structural integrity of a bridge.

"Our nanospring shape induces more power output both in the broad spectrum range and at some desired single point (which can be engineered easily), and these make powering of more advanced nanosystems possible with a single nanospring-based photovoltaics system," Khudiyev said.

The efficiency enhancements the researchers report were calculated using an advanced computational tool. "Experimental observation of a nanospring-based photosensor design and its integration into a large-scale fiber embedded system would be interesting as the next steps," Bayindir said.

The group has already developed an easy way to produce nanosprings by first making long nanowire arrays, then heating them to a temperature at which the arrays can be twisted into the nanospring shape. The technique can be varied to control the diameter of the spring and the tightness of the curl.

More information: "Nanosprings harvest light more efficiently." *Applied Optics* Vol. 54, Issue 26, pp. 8018-8023 (2015) DOI: 10.1364/AO.54.008018

Provided by Optical Society of America

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