A 3D solution to solar cell inefficiencies

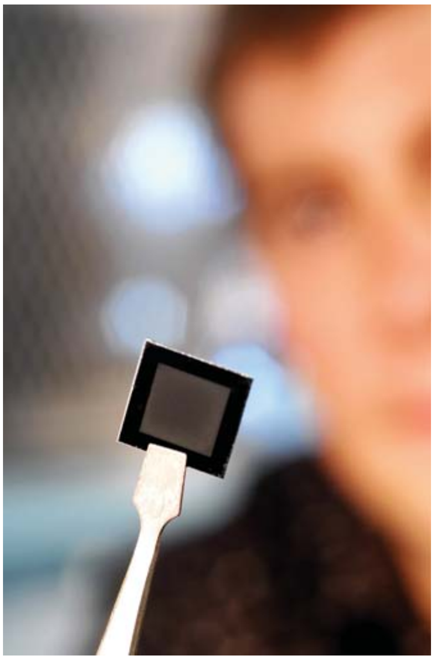
Inspired by the rising spires of the Manhattan skyline, a group of scientists from the Georgia Tech Research Institute, USA, have created a 3D solar cell that they claim can capture nearly all the light that strikes it.

Conventional flat solar cells reflect much of the light that strikes them, reducing the amount of energy they absorb. They also require thicker photovoltaic (PV) coatings that slow down conversion of the sun's photons into electrical current. The novel 3D cell traps light using an array of 'tower' carbon nanotube structures that are 100 microns tall and 10 microns apart. The structure allows more light to be absorbed from different angles, thus requiring a thinner PV coating.

'Our novel structure is unlike planar solar cells in that our efficiencies actually increase with changes in azimuthal angle [the horizontal angular distance from a reference direction],' says Jud Ready, Senior Research Engineer in the Electro-Optical Systems Laboratory at Georgia Tech. 'Planar cells perform best at "high noon". Currently, we get 3.5% at a high noon arrangement, but this doubles to seven per cent at 45º.' This could be particularly useful in regions that do not have much direct sunlight – in the UK, 50% of light is diffused.

Constructing high-rises

To produce the cells, the research team coated a silicon wafer with a thin layer of iron using a patterned photolithography process.



A sample of the 3D solar cells

The wafer was heated to 780ºC. Hydrocarbon gases that were released into the furnace separated into their constituent elements. Using chemical vapour deposition, arrays of multi-walled carbon nanotubes were grown on the iron-patterned wafers.

Once grown, the nanotube towers were coated with cadmium telluride and cadmium sulphide using molecular beam epitaxy. These served as the PV layers.

Cadmium telluride was chosen because it had already been successfully applied to silicon, and, says Ready, it is 'an extremely good match for the spectrum of our sun'. On top of this layer was added a thin coating of indium tin oxide, a clear conducting material, that acts as the cell's top electrode.

One of the biggest benefits of using carbon nanotubes to capture light is that the wafers do not require single crystal silicon, but can be made from cheaper, non-microelectronics-grade smooth silicon, says Ready. 'Many traditional planar cells compete with the semiconductor manufacturers of the world for high grade silicon, and, thus, it has become [more] scarce and costly.' Finding a method of producing solar cells with less silicon is the *modus operandi*, and Ready hopes to someday develop a flexible fabric substrate that would completely do away with its use.

Staying in the spotlight

Keith Barnham, Senior Research Investigator at Imperial College London, UK, and long-time proponent of solar energy, comments on Ready's research, 'Flat solar cells can be quite effective over a wide range, but this system has the potential to do better.' Barnham is currently developing a technology for photon recycling in solar cells (see box below, left).

He adds, 'The highest efficiency cells need light concentrating systems – they are always being moved to follow the sun and collect direct sunlight. [Georgia Tech's] system offers two benefits – it picks up more diffuse light without needing to be moved, and it uses a thinner cell with third generation materials [such as cadmium telluride], which is useful for reducing the cost.'

For now, Ready's team is focusing on improving the efficiency of the 3D cells and lowering production costs. He believes the cells are best suited for aerospace applications, 'where our tiny footprint and small weight would make a real difference'. Ready also believes the technology has a more terrestrial future, and his group is seeking commercialisation partners.

Barnham is encouraged by recent developments in solar technologies, but, ultimately, he believes researchers have a long way to go to improve cell efficiencies so that solar can become a viable energy source. 'Given the cell cost is only 25-50% of any system, even a zero cost cell is not competitive if it doesn't have an efficiency close to current technology, that is at least 10%.'

Meagan Ellis

Sunny developments

Researchers continue to strive to improve solar energy efficiency. There have been many developments in the field.

- **Keith Barnham and other members of the Experimental Solid State Physics group at Imperial College London, UK, claim to have achieved photon recycling in strain balanced quantum well solar cells under high concentration. The technology has attained 27% single junction efficiency in a concentrator cell, reducing the amount of silicon required.**
- **StarSolar, a startup company based in Cambridge, USA, have made use of photonic crystals to capture and recycle photons that slip through the thinner layers of silicon. Precisely patterned microscopic spheres of glass within a photonic crystal redirect unabsorbed photons back into the silicon, increasing the cell's efficiency by up to 37%.**
- **By using nano-filaments within light-absorbing plastics, researchers from Wake Forest University, Winston-Salem, USA, have improved the efficiency of plastic solar cells to more than six per cent. Inexpensive and lightweight, plastic is an ideal replacement for silicon. But to be viable for commercial use, these cells must convert about 10% of solar energy into electricity. The Wake Forest researchers believe this will be achieved within two years.**
- **UK-based company Microsharp has developed a low-cost solar concentrator. The engineered plastic film focuses sunlight on a base power generator, such as a silicon cell. The film replaces some of silicon's duties, so less material is used and the cell is lighter and cheaper.**
- **Scientists at the University of New South Wales, Australia, have reported a 16-fold rise in the light absorption of 1.25 micron thin film cells (which use less silicon than thicker wafers). The team has devised a way to deposit a silver film (about 10nm thick) onto a solar cell surface, where it is heated to 200ºC. The film breaks up into 100nm islands of silver, boosting the device's light-trapping ability.**