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Solar cell efficiency boosted with pine tree-like nanotube needle

'Dye-sensitised solar cells' (DSSCs) are an alternative to traditional silicon photovoltaic (PV) cells. They have a number of advantages over traditional PV solar cells, including greater flexibility and lower manufacturing cost, but they are less efficient at turning sunlight into electricity. Taking inspiration from nature, new research has doubled their efficiency using pine tree-shaped nanotubes.

Averaged over the entire planet, each square metre of the Earth's surface receives energy worth about a barrel of oil, in the form of sunlight, every year. As such, solar power is among the most promising sources of renewable energy.

The most common way of extracting energy from sunlight is through the use of silicon-based solar panels. Currently, these are around 20% efficient at converting light energy in to electrical energy. However, while the costs of making this type of solar cell are coming down, they remain expensive to produce, both in terms of material cost and energy use.

This study enhanced the design of a type of DSSC using nanotechnology so that they are more efficient at converting sunlight into electrical energy. DSSCs are semi-transparent solar cells that use dye molecules to generate electricity. Electrons are knocked off the dye molecule by light and picked up by the 'photoanode': an electrode coated in nanoparticles of an electron-absorbing material, such as titanium dioxide (TiO_2). A thin layer of liquid electrolyte between this layer and the negative electrode completes the circuit.

The main disadvantage of DSSCs is the use of liquid electrolytes. These typically contain volatile organic compounds (VOC), which are hazardous to health and the environment. Additionally, liquid electrolytes make DSSCs less durable, prone to electrode corrosion and electrolyte leakage.

Solid State DSSCs (ssDSSCs), where liquid electrolytes are replaced with more durable polymers or solid materials, were developed to overcome these disadvantages. However, they are currently only half as efficient at converting light energy into electrical energy as liquid-based DSSCs. Boosting the efficiencies of ssDSSCs has mainly focused on identifying improved dyes and electrolyte replacements. However, this research shows how efficiency can also be improved through changes to the nanoparticle-covered photoelectrode, common to many DSSCs and ssDSSCs.

The researchers found that they could capture more electrons from the dyes by boosting the surface area of nanotubes with the pine tree-like nanotubes, than when they used straight nanotubes. The pine tree-like nanotubes, around 19 micrometres long could double the efficiency of the ssDSSC from 4% to 8% compared to regular TiO_2 coatings.

DSSCs and ssDSSCs have a number of advantages, other than cost, over traditional silicon solar cells. They perform better in low light, meaning they can extract energy from the sun during the mornings and evenings, or even indoors. This leads to more consistent output. Additionally, they are relatively thin, flexible and can be produced to be semi-transparent. This means that windows could become a power source, supplementing conventional power usage with eco-friendly solar electricity.

It is an important finding that improved dyes and electrolyte substitutions can improve the efficiency of ssDSSCs to around 15%. It suggests that applying the pine tree-like nanostructured photoanodes, while unlikely to double efficiency in practice, could further boost it. This would make ssDSSCs even more cost-effective while improving their eco-friendliness compared to DSSCs.