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New energy-efficient manufacture of perovskite solar cells that rivals silicon solar cells

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'Perovskite solar cells' (PSCs) are less costly than conventional silicon solar cells, but one of their key components is energy-intensive to manufacture as high temperatures are needed. Now researchers have identified new alternative materials for this component which cut energy demands as they can be produced at low temperatures.

PSCs replace the energy intensive, expensive, conventional silicon solar cells with cheaper materials based on organic lead halide perovskites. PSCs share the advantages and applications of other thin film solar cell technologies, such as dye-sensitised solar cells, over conventional silicon cells. For instance, as they are flexible, they can be installed from rolls, or they can be used as semi-transparent coatings on buildings and windows to generate electricity.

One of the main advantages of PSCs is the lower energy and financial costs of their production compared with conventional solar cells. The perovskite and many of the other components can be produced using low-temperature methods.

In a PSC, light is absorbed by the perovskite pigment, which generates electrons and their positive counterparts, holes. To prevent electrons and holes recombining, the perovskite is sandwiched between two layers: a nano-particle layer, which quickly conducts electrons away, but not holes, and a layer which allows holes, but not electrons, to pass. This sets up an electric field that forces the electrons to flow in a single direction, through an electrical circuit, eventually recombining with holes at the positive cathode of the cell.

However, the nanoparticle electron-selective layer is typically made of titanium dioxide and has needed a high-temperature step (of around 500°C) as part of its manufacture. Researchers have now developed a low-temperature alternative to this.

The researchers identified two 'organic compounds' that could replace current hole- and electron-selective materials. PCBM ((6,6)-phenyl C61-butyric acid methyl ester) was used as an electron-selective material to replace titanium dioxide, while PolyTPD was used as a hole-selective layer. These were added to the solar cell using a process called 'meniscus coating', at room temperature, which allows layers of just 10 nanometres (nm) thick of each material to be made. The electrical properties and efficiency of the cells were then measured.

The researchers produced a PSC cell 475 nm thick, which is less than a half of a millionth of a metre. Their measurements suggested that only a few electrons and holes were recombining, which indicated that the new hole- and electron-blocking layers were effective. The efficiency of the solar cell converting light energy into electrical energy was measured at over 13%.

The most commonly used silicon solar cells, first developed in the 1940s, took around 50 years to reach their current 25% efficiency, but such high efficiency cells are expensive to manufacture. Today, due to economies of manufacturing, a typical solar cell installation is around 15% efficient.

In comparison with silicon solar cells, PSCs have grown in efficiency from 4% in 2009 to in excess of 17.9% in just five years. These remarkable increases in efficiency in such a short time make them an increasingly viable commercial prospect. This research has further improved the potential cost-effectiveness of PSCs by showing that lower energy production methods can be used in their manufacture. Additionally, the methods used in this research could be transferred to existing production techniques, such as reel-to-reel production, when a reel of the base material is unrolled and coated with a functional material, such as PCMB or PolyTPD, before being rolled up on a second reel in a single step, bringing commercial realisation of low-power technologies a little closer.