New Fabrication Method Improves the Efficiency and Economics of Solar Cells

Synthetic fabrication strategy optimizes the illumination geometry and transport properties of dye-sensitized solar cells.

Using oriented titanium oxide (TiO_2) nanotube (NT) arrays has shown promise for dye-sensitized solar cells (DSSCs). High solar conversion efficiency requires that the incident light enters the cell from the photoelectrode side. However, for NT-based DSSCs, the light normally enters the cell through the counter electrode because a nontransparent titanium foil is typically used as the substrate for forming the aligned NTs and for making electrical contact with them.

It has been synthetically challenging to prepare transparent TiO_2 NT electrodes by directly anodizing Ti metal films on transparent conducting oxide (TCO) substrates because it is difficult to control the synthetic conditions. National Renewable Energy Laboratory (NREL) researchers have developed a general synthetic strategy for fabricating transparent TiO_2 NT films on TCO substrates. With the aid of a conducting Nb-doped TiO_2 (NTO) layer between the Ti film and TCO substrate, the Ti film can be anodized completely without degrading the TCO. The NTO layer protects the TCO from degradation through a self-terminating mechanism by arresting the electric field-assisted dissolution process at the NT-NTO interface.

NREL researchers found that the illumination direction and wavelength of the light incident on the DSSCs strongly influenced the incident photon-to-current conversion efficiency, light-harvesting, and charge-collection properties, which, in turn, affect the photocurrent density, photovoltage, and solar energy conversion efficiency. Researchers also examined the effects of NT film thickness on the properties and performance of DSSCs and found that illuminating the cell from the photoelectrode side substantially increased the conversion efficiency compared with illuminating it from the counter-electrode side.

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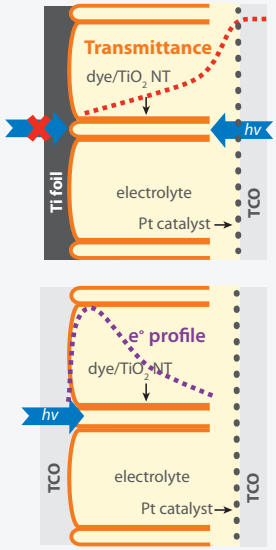
Reference: Kim, J.Y.; Noh, J.H.; Zhu, K.; Halverson, A.F.; Neale, N.R.; Park, S.; Hong, K.S.; Frank, A.J. (2011). "General Strategy for Fabricating Transparent TiO2 Nanotube Arrays for Dye-Sensitized Photoelectrodes: Illumination Geometry and Transport Properties." *ACS Nano* 5, 2647.



Illuminating the NT-based DSSC from the photoelectrode side substantially increased the conversion efficiency compared with illuminating it from the counter-electrode side. Back-side illumination (top image) shows light loss by the counter electrode and electrolyte. Front-side illumination (bottom image) shows higher electron density near the current collector.

Key Research Results

Achievement

NREL developed a new strategy for synthetically fabricating transparent TiO_2 NT films on TCO substrates that uses a conducting Nb-doped TiO_2 (NTO) layer, enabling the Ti film to be anodized completely without degrading the substrate TCO layer.

Key Result

This method solves a key challenge in fabricating NT-based DSSCs and determines an optimal illumination direction to use in these cells.

Potential Impact

The synthetic fabrication strategy will improve the economics and conversion efficiency of DSSCs.

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