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New four-terminal tandem organic solar cell achieves 16,94% power conversion efficiency

Researchers at ICFO have fabricated a new four-terminal organic solar cell with a tandem configuration with a 16.94% power conversion efficiency (PCE). The new device is composed by a highly transparent front cell that incorporates a transparent ultrathin silver (Ag) electrode of only 7nm, which ensures its efficient operation.

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Two-terminal tandem organic solar cells (OSCs) represent one of the most promising approaches to address the transmission and thermalization losses in single-junction solar cells. These organic solar cells consist of front and rear subcells with varying bandgaps, enabling broader absorption and use of the solar spectrum. However, achieving optimal performance in such configurations demands a sufficient current balance between the two subcells. Moreover, fabricating tandem organic solar cells of these types are challenging because they need a robust interconnection layer capable of facilitating efficient charge recombination while maintaining high transparency.

The **four-terminal** tandem configuration has emerged as a highly efficient alternative strategy in solar cell design. Unlike the two-terminal approach, this configuration features separate electrical connections for the transparent front cell and the opaque back cell. Consequently, the issue of electrical current matching is no longer a limiting factor. This setup enables greater flexibility in selecting the bandgaps of each cell of the tandem, thereby optimizing photon absorption and enhancing the overall efficiency of solar energy production.

Now, in a new study published in the Journal Solar RRL, ICFO researchers and team members of the SOREC2 European project, **Francisco Bernal-Texca**, and **Prof. Jordi Martorell** describe the fabrication of a four-terminal tandem organic solar cell that has achieved a 16.94% power conversion efficiency (PCE). Central to this achievement is the fabrication of an ultrathin transparent silver electrode, a critical component that played a pivotal role in optimizing the performance of the tandem solar cell.

To fabricate the new device, the researchers first explored the organic materials destined for the photoactive layer of both cells. They examined the effectiveness of three distinct blends for the front cell, which is designed to harvest the high-energy photons. The blend that

performed the best, named PM6:L8-BO, was finally chosen. For the back opaque cell, the researchers decided to use the PTB7-Th:O6T-4F blend, with a narrow bandgap, which makes it better suited to absorb the infrared part of the spectrum (low-energy photons).

After choosing the blends, the researchers used a numerical approach to design the four-tandem OSC's final structure. They used the matrix formalism combined with the conventional inverse problem-solving methodology to find the optimal performance and the final configuration of the solar device.

The fabrication of an ultra-thin transparent silver electrode with a thickness of only 7nm was the key ingredient in the current research. This element was placed at the back of the front cell, ensuring a good light transmission to power the back cell. Conventional top A
 electrodes utilized for transparent solar cell applications typically range in thickness from
 to 15 nm.

? Its production demanded meticulous control of laboratory conditions to ensure precision a
d consistency. The electrode was then stacked with three dielectric layers alternating tungst
n trioxide (WO3) and lithium fluoride (LiF). This photonic multilayer structure has a crucial ro
e, because it is positioned between the two cells to facilitate efficient and uniform li
ht distribution. i¿½This structure exhibits a high transmission in the 750-1000 nm rang
 and a high reflectivity in the 500-700 nm rangei¿½, researche
s wrote. i¿½The development of a transparent silver intermediate electrode is crucial for th
 efficient operation of the solar cell. It must present a delicate balance, being transparen
 enough to allow light to reach the back cell while maintaining high electrical conductivity to ensure the optimal performance of the front cell, said **Elisa Bernal**, ICFO researcher and first author of the study. i¿½Being able to fabricate an electrode of only 7nm without observi
g losses in the front transparent cells is a significant advancement in the field of transpare
t cellsi?
½. The researchers tested the photovoltaic performance of the device under 1 su
 of illumination with a solar simulator and measured its quantum efficiency. The device achi
ved **16,94% of power conversion efficiency** which, to date, would be the **highest reached for a four-terminal tandem organic cell**. The authors of the study remark that the current official record in efficiency for organic tandem devices is 14,2% and that the last reported PCE for 4-terminal organic tandems is 6.5% .

i¿½Our research holds potential applications in photoelectochemical cells (PEC), addressi
g crucial electrical requirements such as providing the necessary voltage to surpa
s established for driving water splitting or CØreduction reactions like in SOREC2 projecti¿?
, explains **Prof. Jordi Martorell**, researcher at ICFO and SOREC2 project coordinator. i¿½T
e methodology for the design and implementation of the four-terminal tandem structure cou
d be applied to design news systems where an adequate distribution of light in the elements
s crucial for the performance of a certain devicei?
½. The researchers are currently directing their focus towards refining, tuning and enhan

ing the methodology and structural design tailored for applications such as solar fuels, w ere tandem devices hold widespread applicability. By optimizing the methodology and de ign strategies, researchers aim to unlock the full potential of these devices in harnessing s lar energy for diverse and sustainable energy conversion processes, such as CO_2 conversion and valorization.

The SOREC2 project is a EU funded project seeking to develop a new technology to transform directly the sunlight, and CO_2 into added-value chemicals, enabling safe and efficient energy storage. The consortium will develop a new compact tandem photo electrochemical cell powered by sunlight and a new hybrid catalyst system to enhance the selectivity towards C2 products.

Original article

Bernal-Texca, F; Martorell, J. (2024) Four-Terminal Tandem Based on a PM6:L8-BO Transparent Solar Cell and a 7nm Ag Layer Intermediate Electrode. Solar RRL. DOI: 10.1002/solr.202300728

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Artistic illustration of the developed four-tandem organic solar cell (ICFO/Francisco Bernal-Texca)