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TRIPLE-JUNCTION TANDEM ORGANIC SOLAR CELL PERFORMANCE MODELING FOR ANALYSIS AND IMPROVEMENT

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Abstract

The development of organic solar cells is encouraged by the fact that building cells with a tandem structure shows significant promise in increasing light usage and reaching high efficiency. In this work, we use electron beam evaporated TiOx and PEDOT:PSS to create a cutting-edge linking layer for tandem organic solar cells. A dense, crisp, and smooth TiOx/PEDOT:PSS contact can be achieved using electron beam evaporation. The charge recombination between two subcells is ensured in PBDB-TF:GS-ISO/TiO1.76 and TiO1.76/PEDOT:PSS through careful regulation of the O2 flux during evaporation. National Institute of Metrology, China certifies an efficiency of 20.0 % for a tandem cell with a TiO1.76/PEDOT:PSS interconnecting layer. This cell achieves an efficiency of 20.27 %. Our findings therefore herald the beginning of the 20 % era in organic solar cells.

Introduction

Due to its remarkable potential in large-area printing, low energy budget, and light weight, organic solar cells (OSCs) have garnered a lot of attention [1]. Boosting PCE will boost industrialisation value, making it a top priority in the optical signal processing (OSC) sector [2]. High PCE is achieved by making the most of the sun's radiation in the ultraviolet (UV), visible, and near-infrared (NIR) ranges. As the absorption spectrum of single-junction OSC broadens, more energy is lost as the vibrations relax from a more excited state to a less excited one. If you'd rather not deal with thermal exciton relaxation, a viable alternative is to use a multi-junction architecture built by arranging series of subcells with distinct bandgaps (tandem OSC) [3-10]. In addition, the electric loss brought on by excessive current passing through the current collector can be greatly mitigated by the series-connected subcells. As a result, utilizing tandem OSC becomes an option for enhancing the PCE [11-15, 6-7].

Experimental Methodology

The interconnecting layer (ICL) determines the final properties of a tandem OSC because it is made of multiple subcells connected in series. Tandem OSCs based on ICLs like MoOx/Ag/ZnO, ZnO/n-PEDOT:PSS, and m-PEDOT:PSS/ZnO can reach higher PCE than singlejunction OSC, but the described ICLs have significant difficulties. In MoOx/Ag/ZnO ICL, the interfacial doping between MoOx and the bottom subcell's BHJ hinders charge extraction from the BHJ to MoOx, however methanol's extensive free radical capture reduces this doping during solution processing of ZnO quantum dots (QDs) [16-18, 9].

ZnO/n-PEDOT:PSS ICL cannot employ the extraordinary acidic PEDOT:PSS (CLEVIOS P VP AI 4083) because ZnO and the QDs-surface-adsorbed stabilizer are acid-soluble. ICL fabrication requires neutral n-PEDOT:PSS (CLEVIOS P JET N). Shallow Fermi levels always lower Voc (EF). TiOx QDs had trouble dispersion in the orthogonal solvent of BHJ at the bottom subcell despite sharing energy levels and being unreactive to dilute acids (save hydrofluoric acid). BHJ's hydrophobic surface requires surfactant to modify PEDOT:conductivity PSS's and energy level in the bottom subcell of mPEDOT:PSS/ZnO ICL. Unbound, isolated solution-processed QDs and evaporated metal clusters degrade ICL quality. The porous ICL lets the bottom and top subcell BHJs touch, preventing charge collection. The porous ICL damages the bottom subcell during solution processing. Material screening limits interfacial charge extraction and Schottky barrier between subcells. A good ICL should limit solvent penetration and enhance charge collection area. For subcell charge extraction and low Schottky barrier in ICL, the interfacial layer's composition and structure must be carefully maintained. Electron beam evaporated TiOx/PEDOT:PSS was used to build a tandem OSC with a great ICL [18]. Electron beam evaporation homogenizes the rutile TiOx target, making it amorphous. PEDOT:PSS may produce a smooth, thick film because e-TiOx is flat, uniform, dense, and acid-resistant. Accurate oxygen replenishment changes the deposit's chemical composition, energy levels, relative dielectric constant (r), and doping density (Nd). This improves bottom subcell ICL charge recombination and BHJ charge extraction. PCE is 20.27 % using OSCs and e-TiO1.76/PEDOT:PSS ICLs. The Chinese National Institute of Metrology confirmed 20%. (NIM).

Results and Discussion

Figure 1A shows PBDB-TF:GS-ISO and BTP-eC9 molecular structures and electron beam evaporation diagrams. Figure 1A shows the adjusted BHJ absorption spectra. Figure 1B shows 25 nm e-TiOx absorption spectra for various O2 fluxes. Powder X-ray diffraction evaluates TiOx QD and target particle crystallinity. SAED patterns of HRTEM pictures show that TiOx QDs preserve crystallinity after solution or electron beam evaporation.

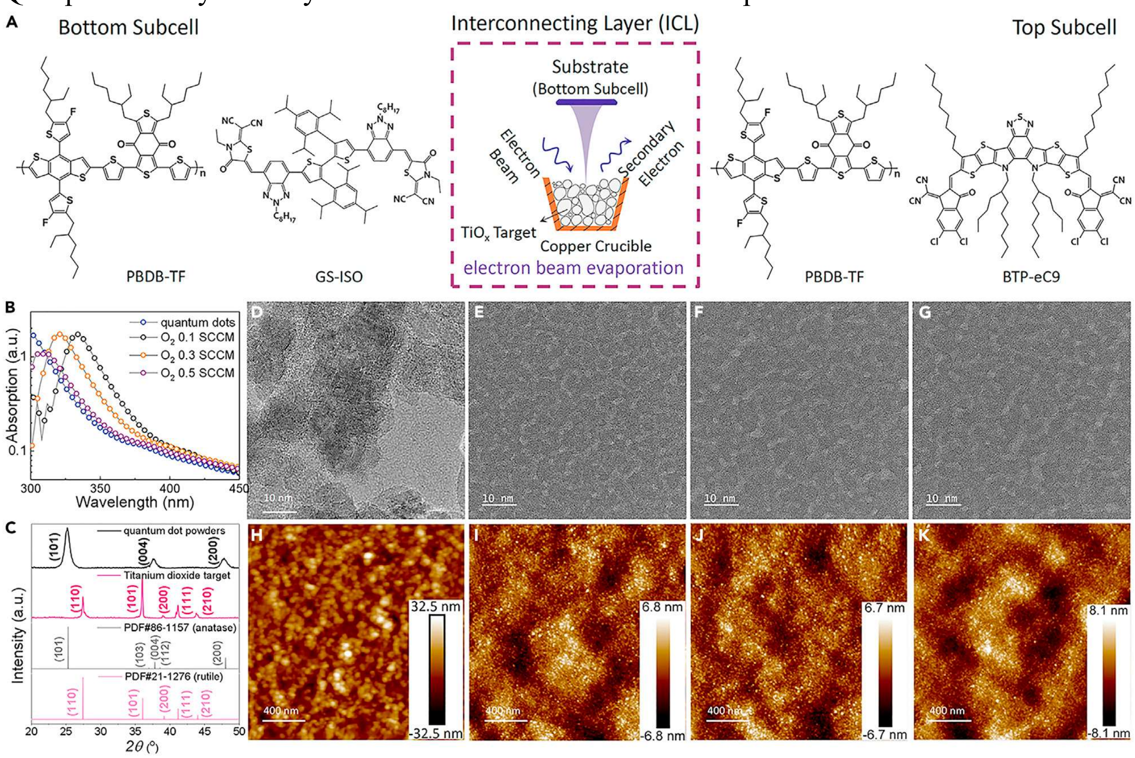

Figure 1. The essential components, electron-beam evaporation, and structural characterizations of the deposits are all described.

Controlled deposition ensures clean surfaces. e-TiOx-coated subcells match BHJs, however TiO2 QDs-coated subcells vary. Glass/ITO/PEDOT:PSS/PBDB-TF:GS-ISO/e-TiOx/BTP eC9/PDINN/silver device designs can create tandem OSCs. X-ray photoelectron spectroscopy characterizes deposited e-TiOx compositions with different O2 fluxes. An ultraviolet photoelectron spectrometer probes e-TiOx energy levels [19-25].

The Schottky barrier at the ITO/TiOx contact is nearly equal to the diode's VT. e-TiOx QDs-based diodes have lower VT than Schottky barriers due to their compactness. ESR spectra can measure TiOx's VO content and free electron density [26]. Single-junction cells using TiOx QDs in the electron transport layer perform far poorer photovoltaically than e-TiOx cells. e-ECBM TiOx's and PEDOT: differences PSS's equal the Schottky barrier height (e4B0) [27-30].

Low barriers boost tandem OSC photovoltaic efficiency. Due to its largest e4B0 and smallest D4, the e-TiO1.62/PEDOT:PSS tandem OSC has the lowest Vbi'. PBDB-TF:BTP-eC9 builds tandem cell top subcells. Lists tandem OSC photovoltaic parameters at AM1.5G 100 mW/cm2, and Figure 2 shows the J-V curves [31-36, 1-6].

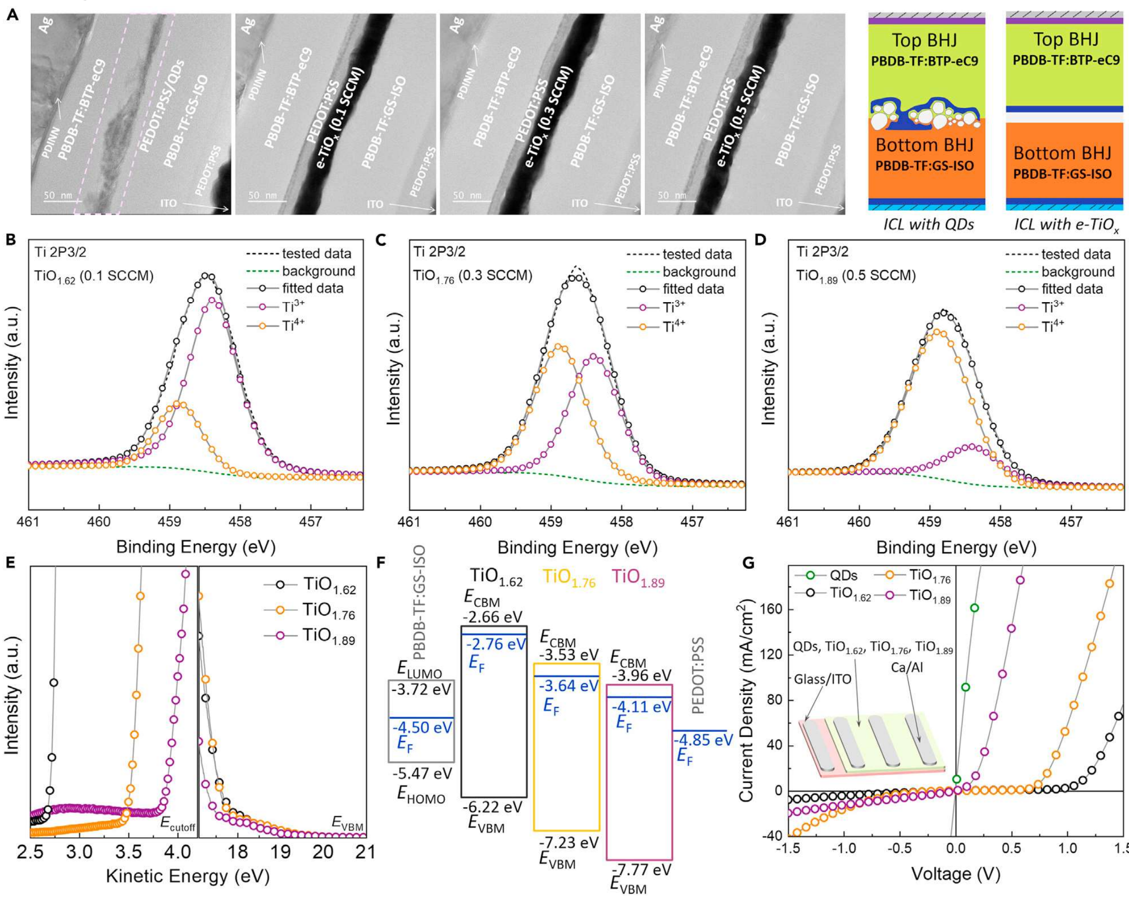

Figure 2. The study examines the compositions, structures, and morphologies of deposits in tandem OSCs. The TEM cross-sectional image and device structures are shown, along with XPS spectra and UPS spectra. Energy levels are derived from the 1st derivative of absorption and UPS data. The J-V curved of Schottky diodes is also shown.

Demonstrates that the tandem OSC with TiOx QDs/PEDOT:PSS ICL has lower Voc and PCE due to confused ICL interfaces. Figure indicates that the tandem cell produces 1.96 V, 12.90

mA/cm2, 69.45 % FF, and 17.56 % PCE. e-TiOx helps prevent "burn in" in tandem cells with various ICLs.

Conclusions

In OSC, a PCE of over 20% has now been attained for the first time. An e-TiO1.76/PEDOT:PSS ICL in a tandem OSC yields an awe-inspiring PCE. Electron beam evaporation yields exceptionally dense and flat amorphous and acid-resistant e-TiOx, which, when coated with PEDOT:PSS, guarantees crisp interfaces. Controlling the O2 fluxes at 0.1, 0.3, and 0.5 SCCM yields e-TiO1.62, e-TiO1.76, and e-TiO1.89, respectively. Due to its poor suitability as ETL in OSC, e-TiO1.89 has low bulk and interfacial conductivities. The Schottky barrier in ICL will be high because e-TiO1.62/PEDOT:PSS has the highest Schottky barrier height and the lowest Schottky barrier decline. The related tandem OSC demonstrates a PCE of up to 20.27 % thanks to the e-TiO1.76/PEDOT:PSS ICL's clean interface, high conductivity, appropriate energy levels, and low Schottky barrier. NIM has validated this %age at 20.0%. Our finding heralds the beginning of the 20 % era in organic solar cells.

Conflicts of Interest: The authors have not any potential conflicts of interest. To collect and analyses data, to write a manuscript, and to decide whether or not to publish findings.

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