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Article

High Performance Planar Structure Perovskite Solar Cells Using a Solvent Dripping Treatment on Hole Transporting Layer

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Experimental Section

PEDOT:PSS aqueous solution (Clevios P VP Al 4083) was purchased from Heraeus. Other chemicals, including PbI_2, $PbCl_2$, DMSO, DMF, and GBL, were supplied by Sigma-Aldrich. All materials were used as received. PEDOT:PSS films were prepared by spin coating its aqueous solution on pre-cleaned glass substrates. They were subsequently dried at 120 °C on a hot plate for 20 min. The treatment was performed by dropping 500 μL of a solvent onto each PEDOT:PSS film during the spin coating. After the PEDOT:PSS films were dried, they were then dried again at 120 °C.

2.2. Characterizations of Materials

The conductivities of the PEDOT:PSS films were measured by the four-probe technique with a Keithley 2400 source/meter. The electrical contacts were made by pressing indium on the four corners of each PEDOT:PSS film on glass substrate. X-ray photoelectron spectra (XPS) were collected with an Axis Ultra DLD X-ray photoelectron spectrometer equipped with an Al Kα X-ray source (1486.6 eV). The atomic force microscopic (AFM) images were acquired with a Veeco NanoScope IV Multi-Mode AFM in tapping mode. The thicknesses of the PEDOT:PSS films were measured using an Alpha-Step IQ surface profiler. Photoluminescence spectra and time-resolved photoluminescence (TR-PL) spectra were measured using the Pico Quant Fluotime 300 by using a 510 nm picosecond pulsed laser.

2.3. Fabrication and Characterization of PSCs

ITO glass substrates were cleaned sequentially in detergent, deionized (DI) water, acetone, and isopropanol by sonication for 20 min. After drying under N_2 stream, the substrates were further treated with UV-ozone for 15 min. A PEDOT:PSS layer with a thickness of ~60 nm was prepared by spin coating Clevios P VP Al 4083 on ITO substrates at 2000 rpm for 1 min and subsequently annealed at 120 °C for 15 min in air. The substrates coated with PEDOT:PSS were then transferred into a glove box filled with highly pure N_2. The moisture and oxygen levels in the glove box were less than 1 ppm. The perovskite layer was deposited by spin coating a solution consisting of 1.246 M PbI_2, 0.154 M $PbCl_2$, and 1.3 M MAI in cosolvent of DMSO:GBL (volume ratio = 3:7) at 1000 rpm for 20 s, and then at 3500 rpm for 60 s. After 50 s of the start of the spin coating, 1000 μL anhydrous toluene was dripped onto each spinning film. Then, the as-cast films were annealed at 100 °C for 20 min. The thickness of the perovskite thin films was around 320 nm. The phenyl-C61-butyric acid methyl ester

(PCBM) layer with a thickness of about 55 nm was deposited by spin coating a chlorobenzene solution of 20 mg/mL PCBM at 2000 rpm for 40 s. A sub-nanometer thick BCP layer was subsequently spin coated from its 0.05 wt.% isopropanol solution. The devices were completed by thermally depositing 100 nm-thick Ag in a vacuum of $<1 \times 10^{-6}$ mbar. Each device had an area of 0.09 cm^2 and a shadow mask (0.075 cm^2) was applied during the device measurement. The photovoltaic performance of the PSCs was tested in air with a computer-programmed Keithley 2400 source/meter and a Newport's Oriel class A solar simulator, which simulated the AM1.5 sunlight with energy density of 100 mW cm^{-2} and was certified to the JIS C 8912 standard.