Electronic Supplementary Information

Enhancing photovoltaic performance of DSSCs sensitized with Ru-II complexes by D-π-A configured carbazole based co-sensitizers

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1. Device fabrication and photovoltaics studies

1.1 Photoelectrochemical Measurements

Photocurrent-voltage characteristics of DSCs were measured using a Keithley 2400 source meter under illumination of AM 1.5 G solar light from solar simulator (SOL3A, Oriel) equipped with a 450 W xenon lamp (91160, Oriel). The incident light intensity was calibrated using a reference Si solar cell (Newport Oriel, 91150V) to set 1 Sun (100 mW/cm^2). The measurement was fully controlled under Oriel IV Test Station software.

IPCE (incident monochromatic photon to current conversion efficiency) experiments were carried out using a system (QEX10, PV Measurements, USA) equipped with a 75 W short arc xenon lamp (UXL-75XE, USHIO, Japan) as a light source connected to a monochromater. Calibration of incident light was performed before measurements using a silicone photodiode (IF035, PV Measurements). All the measurements were carried out without the use of anti-reflecting film.

1.2 TiO_2 Electrode Preparation and Device Fabrication

Fluorine-doped tin oxide (FTO) coated glasses (2.2 mm thickness, sheet resistance of 8 Ω/cm^2, TEC, Pilkington) were washed with detergent, water, acetone and ethanol, sequentially. After this

FTO glass plates were immersed into a 40 mM aqueous $TiCl_4$ solution at 70 °C for 30 min and washed with water and ethanol. Thin layer (8-12 μm thick) of TiO_2 (Solaronix, Ti-Nanoxide D/SP) was deposited (active area, 0.18 cm^2) on transparent conducting glass by squeegee printing followed by drying at 350 °C for 10 min and curing at 500 °C for 30 min. Next, after drying the electrodes, scattering layer (5 μm thick) TiO_2 particles (Solaronix, Ti-Nanoxide R/SP) were printed onto the already deposited TiO_2 layer. The TiO_2 electrodes were heated under an air flow at 350 °C for 10 min, followed by heating at 500 °C for 30 min. After cooling to room temperature, the TiO_2 electrodes were treated with 40 mM aqueous solution of $TiCl_4$ at 70 °C for 30 min and then washed with water and ethanol. The electrodes were heated again at 500 °C for 30 min and left to cool to 80 °C before dipping them into the dye solution. The dye solutions (0.3 mM) were prepared in 10 mL 1:1:1 acetonitrile, *tert*-butanol and dimethyl sulfoxide. Chenodeoxycholic acid (CDCA) was added at a concentration of 20 mM. The electrodes were immersed in the dye solutions and then kept at 25 °C for 20 hours to adsorb the dye onto the TiO_2 surface.

For preparing the counter electrode, pre-cut TCO glasses were washed with water followed by 0.1M HCl in EtOH, and sonication in acetone bath for 10 min. These washed TCO were then dried at 400 °C for 15 min. Thin layer of Pt-paste (Solaronix, Platisol T/SP) on TCO was printed and the printed electrodes were then cured at 450 °C for 10 min. The dye sensitized TiO_2 electrodes were sandwiched with Pt counter electrodes and the electrolyte (Solaronix, Iodolyte HI-30) was then injected into the cell, while the two electrodes were held together with the clips.

3.3 TiO_2 Electrode Preparation and Device Fabrication for Co-sensitized devices

Fluorine-doped tin oxide (FTO) coated glasses (2.2 mm thickness, sheet resistance of 8 Ω/cm^2, TEC, Pilkington) were washed with detergent, water, acetone and ethanol, sequentially. After this FTO glass plates were immersed into a 40 mM aqueous $TiCl_4$ solution at 70 °C for 30 min and

washed with water and ethanol. Thin layer (8-12 μm thick) of TiO_2 (Solaronix, Ti-Nanoxide D/SP) was deposited (active area, 0.18 cm^2) on transparent conducting glass by squeegee printing followed by drying at 350 °C for 10 min and curing at 500 °C for 30 min. Next, after drying the electrodes, scattering layer (5 μm thick) TiO_2 particles (Solaronix, Ti-Nanoxide R/SP) were printed onto the already deposited TiO_2 layer. The TiO_2 electrodes were heated under an air flow at 350 °C for 10 min, followed by heating at 500 °C for 30 min. After cooling to room temperature, the TiO_2 electrodes were treated with 40 mM aqueous solution of $TiCl_4$ at 70 °C for 30 min and then washed with water and ethanol. The electrodes were heated again at 500 °C for 30 min and left to cool to 80 °C before dipping them into the dye solution. The dye solutions were prepared in 10 mL 1:1:1 acetonitrile, *tert*-butanol and dimethyl sulfoxide, and **NCSU-10/N3** and $\mathbf{P_{1\text{-}4}}$ were then dissolved based on the required concentration. Chenodeoxycholic acid (CDCA) was added at a concentration of 10 mM. The electrodes were immersed in the dye solutions and then kept at 25 °C for 20 hours to adsorb the dye onto the TiO_2 surface.

For preparing the counter electrode, pre-cut TCO glasses were washed with water followed by 0.1M HCl in EtOH, and sonication in acetone bath for 10 min. These washed TCO were then dried at 400 °C for 15 min. Thin layer of Pt-paste (Solaronix, Platisol T/SP) on TCO was printed and the printed electrodes were then cured at 450 °C for 10 min. The dye sensitized TiO_2 electrodes were sandwiched with Pt counter electrodes and the electrolyte (Solaronix, Iodolyte HI-30) was then injected into the cell, while the two electrodes were held together with the clips.

2. Photos of the devices:

Fig S_1: Solar Simulator (Oriel Sol3A Class AAA) for photovoltaic measurements

Fig S_2: CEP-2000 system (Bunkoh-Keiki Co. Ltd.) for IPCE measurements

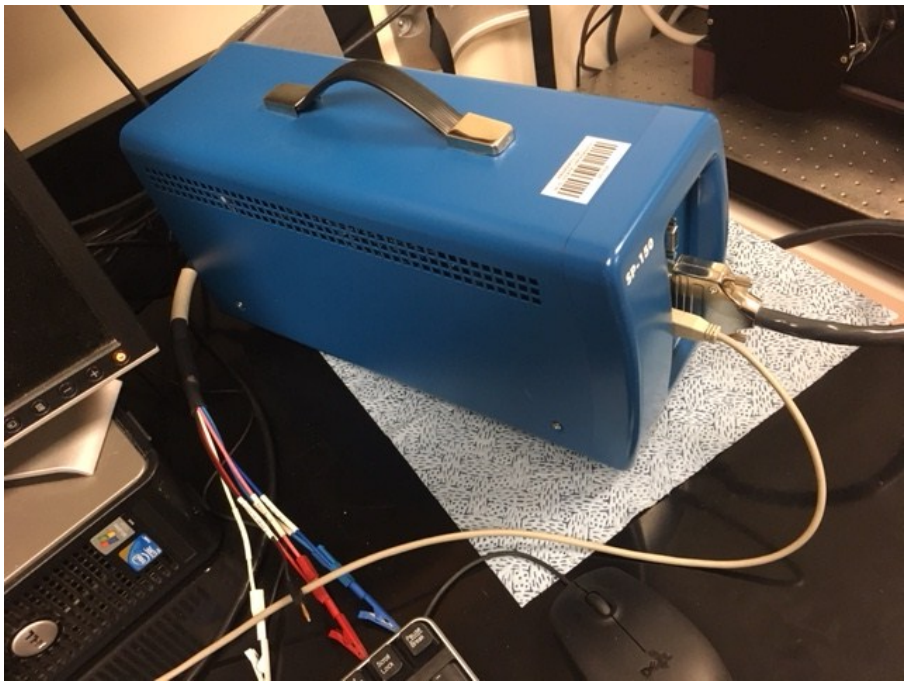

Fig S_3: Impedance analyzer potentiostat (Bio-Logic SP-150)