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Photovoltaic characterization of di-branched organic sensitizers for DSSCs



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ABSTRACT

In this work, the data on the effect of peripheral functionalization of a series of triphenylamine based di-branched dyes used as sensitizers in dye-sensitized solar cells are presented. The effect of different alkyl functionalities on the donor moiety upon the optical and photovoltaics parameters have been investigated in dye-sensitized solar cells (DSSCs) using a 10- μm TiO₂ active layer. The absorption spectra, output efficiency, and incident photon to conversion efficiency of the DSSCs have been collected. The data can be exploited for properly designing efficient, stable, and industrially viable dyes for third generation solar devices.

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Specifications table

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|----------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Subject area | <i>chemistry, material science, photovoltaics, renewable energies</i> |
| More specific subject area | <i>organic dyes, solar cells</i> |
| Type of data | <i>Figure, table, graph</i> |
| How data was acquired | <i>UV–Vis spectroscopy (V-570 Jasco spectrophotometer); Photovoltaic measurements (ABET Technologies Sun 2000 class ABA Solar Simulator; Keithley digital source meter; Omni 300 LOT ORIEL)</i> |
| Data format | <i>Analysed</i> |
| Experimental factors | <i>UV–Vis spectroscopy of sensitized photoanodes. Current density–voltage (J/V) scans of dye-sensitized solar cell stained with sensitizers with chenodeoxycholic acid (CDCA) as co-adsorbent agent. Incident photon-to-current conversion efficiencies (IPCE) of dye-sensitized solar cell stained with sensitizers with chenodeoxycholic acid (CDCA) as co-adsorbent agent.</i> |
| Experimental features | <i>UV–Vis spectroscopy of sensitized TiO₂ films, J/V scans and IPCE measurements of dye-sensitized solar cell</i> |
| Data source location | <i>Department of Materials Science and Milano – Bicocca Solar Energy Research Center – MIB-Solar, University of Milano – Bicocca, Via Cozzi 55, I-20125 Milano, Italy</i> |
| Data accessibility | <i>Data is with this article</i> |
| Related research article | <i>Manfredi N, Trifiletti V, Melchiorre F, Giannotta G, Biagini P, Abbotto A. Performance enhancement of a dye-sensitized solar cell by peripheral aromatic and heteroaromatic functionalization in di-branched organic sensitizers. New J Chem. 2018, 42, 9281-90. https://doi.org/10.1039/c7nj05188c [1]. - Abbotto, A., Acciarri, M., Biagini, P., Binetti, S. (2012) Organic dye for a dye sensitized solar cell. Patent No. WO 2014053626 A1 20140410. [2]</i> |

Value of the data

- The UV–Vis spectroscopy of the sensitizers can be useful to evaluate the effect of different functionalization on the donor moiety of a sensitizer in DSSCs.
- The photovoltaic performances of DSSCs sensitized with this class of di-branched dyes can be compared with those previously presented in Ref. [1].
- The IPCE plot may be useful to other researches to compare the efficiency of other donor-acceptor linear or di-branched dyes able to convert light to electricity in a specific range of wavelengths.

1. Data

The dataset presented in this article show pertinent properties about a series of di-branched dyes, depicted in Fig. 1, which have been previously included in a patent application [2]. This dataset is mainly addressed to researchers and practitioners in the field of hybrid and organic solar cells.

Fig. 2 shows the UV–Vis absorption spectra of dye-sensitized TiO₂ films. Table 1 and Fig. 3 describe the photovoltaic performances of DSSCs sensitized by the investigated dyes, in presence of chenodeoxycholic acid (CDCA) as a co-adsorbent agent. Fig. 4 shows the corresponding IPCE plots.

2. Experimental design, materials, and methods

The following materials were purchased from commercial suppliers: FTO-coated glass plates (2.2 mm thick; sheet resistance ~7 Ω per square; Solaronix); Dyesol 18NR-T transparent TiO₂ blend of active 20 nm anatase particles; N719 (Sigma-Aldrich). UV-O₃ treatment was performed using Novascan PSD Pro Series – Digital UV Ozone System. Details on materials and instruments are reported in Table 2.

The thickness of the layers was measured by means of a VEECO Dektak 8 Stylus Profiler. PV measurements of DSSCs were carried out with an antireflective layer and with black metal mask on top of the photoanode of 0.28 cm² surface area under a 500 W Xenon light source (ABET Technologies Sun 2000 class ABA Solar Simulator). The power of the simulated light was calibrated to AM 1.5 (100 mW cm⁻²) using a reference Si cell photodiode equipped with an IR-cutoff filter (KG-5, Schott) to reduce the mismatch in the region of 350–750 nm between the simulated light and the AM 1.5 spectrum. Values were recorded after 3 and 24 h, and 7 days of ageing in the dark. I–V curves were

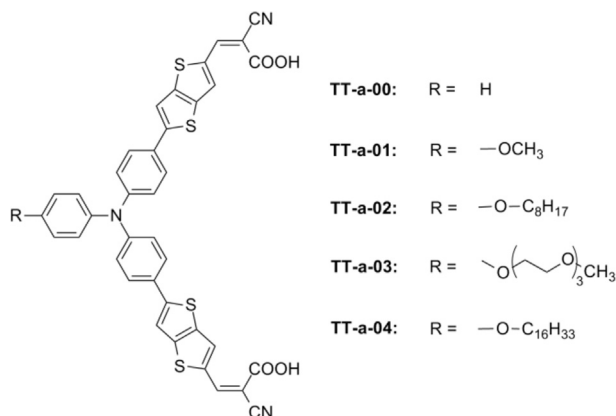


Fig. 1. TT-a dyes investigated in this work.

obtained by applying an external bias to the cell and measuring the generated photocurrent with a Keithley digital source meter. Incident photon-to-current conversion efficiencies (IPCE) were recorded as a function of excitation wavelength by using a monochromator (Omni 300 LOT ORIEL) with single grating in Czerny-Turner optical design, in AC mode with a chopping frequency of 1 Hz and a bias of blue light (0.3 sun). Absorption spectra were recorded on a V-570 Jasco spectrophotometer.

3. Preparation of DSSCs

DSSCs have been prepared to adapt a procedure reported in the literature [3]. In order to exclude metal contamination all of the containers were in glass or Teflon and were treated with EtOH and 10% HCl prior to use. Plastic spatulas and tweezers have been used throughout the procedure.

- FTO glass plates were cleaned in a detergent solution for 15 min using an ultrasonic bath, rinsed with pure water and EtOH.

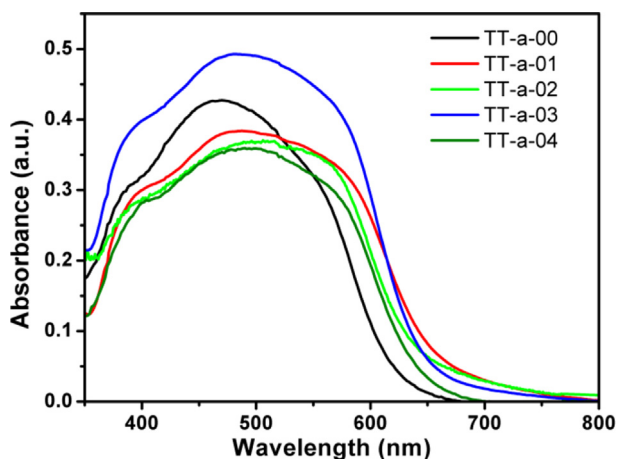


Fig. 2. UV–Vis spectra of the 10- μm thick transparent TiO_2 (Dyesol 18NR-T) photoanodes sensitized by TT-a-00 – TT-a-04 dyes with an equimolar amount of CDCA.

Table 1

Main PV parameters of DSSCs based on the di-branched sensitizers TT-a-00 – TT-a-04 in comparison with the benchmark N719.

| Dyes ^a | J_{sc} [mA cm ⁻²] | V_{oc} [mV] | FF [%] | PCE [%] |
|----------------------|---------------------------------|---------------|--------|---------|
| TT-a-00 ^b | 12.5 | 636 | 63 | 5.0 |
| TT-a-01 ^b | 14.8 | 604 | 62 | 5.6 |
| TT-a-02 ^b | 14.2 | 642 | 64 | 5.9 |
| TT-a-03 ^b | 14.9 | 643 | 62 | 5.9 |
| TT-a-04 ^b | 12.9 | 625 | 58 | 4.7 |
| N719 ^c | 14.8 | 724 | 68 | 7.3 |

^a Active layer 10- μ m TiO₂ Dyesol 18NR-AO; electrolyte: Z960 (1.0 M 1,3-dimethylimidazolium iodide, 0.03 M I₂, 0.05 M LiI, 0.10 M guanidinium thiocyanate, and 0.50 M 4-*t*-butylpyridine in acetonitrile/valeronitrile 85:15).

^b 2×10^{-4} M dye solution in EtOH with an equimolar amount of CDCA.

^c 5×10^{-4} M dye solution in EtOH with an equimolar amount of CDCA.

- After treatment in a UV-O₃ system for 18 min, the FTO plates were treated with a freshly prepared 40 mM aqueous solution of TiCl₄ for 30 min at 70 °C and then rinsed with water and EtOH.
- A transparent layer of 0.20 cm² was screen-printed using Dyesol 18NR-T TiO₂ paste described above.
- The coated films were thermally treated at 125 °C for 6 min, 325 °C for 10 min, 450 °C for 15 min, and 500 °C for 15 min. The heating ramp rate was 5–10 °C/min.
- The sintered layer was treated again with 40 mM aqueous TiCl₄ (70 °C for 30 min), rinsed with EtOH and heated at 500 °C for 30 min.
- After cooling down to 80 °C the TiO₂ coated plate was immersed into a solution of the dye for 5 h at room temperature in the dark. Counter electrodes were prepared according to the following procedure.
- 1-mm hole was made in a FTO plate, using diamond drill bits.
- The electrodes were then cleaned with a detergent solution for 15 min using an ultrasonic bath, 10% HCl, and finally acetone for 15 min using an ultrasonic bath.
- After thermal treatment at 500 °C for 30 min, a drop of 5×10^{-3} M solution of H₂PtCl₆ in EtOH was added on the cold FTO and the thermal treatment at 500 °C for 30 min repeated. Cells assembly procedure.

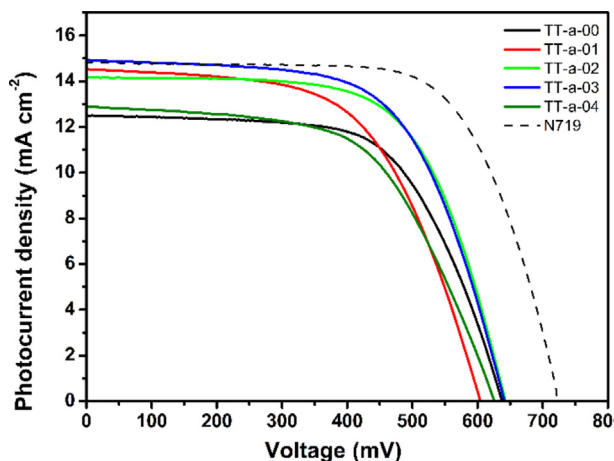


Fig. 3. Current–voltage characteristics of DSSCs sensitized by TT-a-00 – TT-a-04 in comparison with the control cell sensitized by benchmark N719.

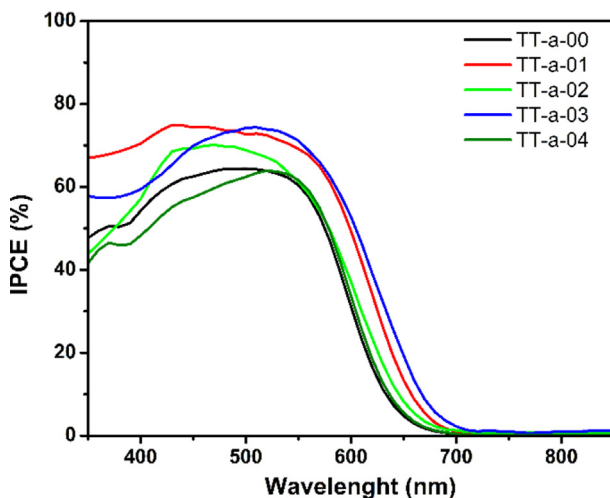


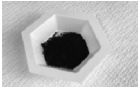
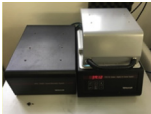


Fig. 4. IPCE of DSSCs sensitized by TT-a-00 – TT-a-04.

Table 2
Detailed description of materials and instruments.

| Materials/Instrument | Physical form | Picture | Market price | Note |
|---------------------------------------------------|------------------------------|-------------------------------------------------------------------------------------|----------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| FTO-coated glass plates | Transparent glass |  | Solaronix, TCO30-8, 10.00 CHF each | |
| Dyesol 18NR-T | Titanium dioxide paste (gel) |  | Greatcell Solar's 18NR-T, 476.78 AUD\$ 100 g | |
| N719 | Dark purple powder |  | Sigma Aldrich, 703214-1G, 437.00 € 1 g | CAS Number: 207347-46-4 |
| Novascan PSD Pro Series – Digital UV Ozone System | Instrument |  | Contact suppliers | http://www.novascan.com/products/uv_ozone_cleaners_silicon_glass_wafers.php |

- The dye adsorbed TiO₂ electrode and Pt-counter electrode were assembled into a sealed sandwich-type cell by heating with a hot-melt ionomer-class resin (Surlyn 30- μ m thickness) as a spacer between the electrodes.
- A drop of the electrolyte solution was added to the hole and introduced inside the cell by vacuum backfilling.
- Finally, the hole was sealed with a sheet of Surlyn and a cover glass. A reflective foil at the back side of the counter electrode was taped to reflect unabsorbed light back to the photoanode.

Acknowledgments

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Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.dib.2019.104167>.

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- [1] N. Manfredi, V. Trifiletti, F. Melchiorre, G. Giannotta, P. Biagini, A. Abboto, Performance enhancement of a dye-sensitized solar cell by peripheral aromatic and heteroaromatic functionalization in di-branched organic sensitizers, *New J. Chem.* 42 (2018) 9281–9290, <https://doi.org/10.1039/c7nj05188c>.
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