**Supporting Information**

# Concordantly fabricated heterojunction ZnO-$TiO_2$ nanocomposites electrodes via co-precipitation method for stable quasi-solid-state dye-sensitized solar cells

*Ahmed Esmail Shalan[1], Ahmed Mourtada[1], Mahmoud Rasly[1], Marwa M. Moharam[1], Monica Lira-Cantu[2] and Mohamed M. Rashad[1]**

[1]Electronic and Magnetic Laboratory, Advanced Materials Division, Central Metallurgical Research & Development Institute (CMRDI), P.O.Box 87 Helwan, Cairo, Egypt

[2]Centro de Investigació en Nanociència i Nanotecnologia, CIN2 (CSIC-ICN). Campus UAB, Edifici ETSE 2nd Floor, Bellaterra, Barcelona, Spain E-08193.

*Tel: 202-25010640-43, Fax: 202-25010639 E-mail: **rashad133@yahoo.com**

## Experimental

## Materials and methods

***(Preparation of pure $TiO_2$ nanoparticles)***

In a typical procedure for co-precipitation, titanium trichloride ($TiCl_3$) -Sigma Aldrich- as a source of $Ti^{+2}$ ions is dissolving with an aqueous sodium hydroxide solution (5M) (Fluka) and adjust pH at desired values 7. The resulting milky white precipitate was collected, filtered, washed with distilled water for several times to remove impurities, and then dried at 80$^{o}$C for 24 hr. The as prepared $TiO_2$ nanopowders were annealed at 600$^{o}$C for 2 h. After cooling down, the thermally treated powders were collected, packed and kept in a desiccator for further physicochemical investigations.

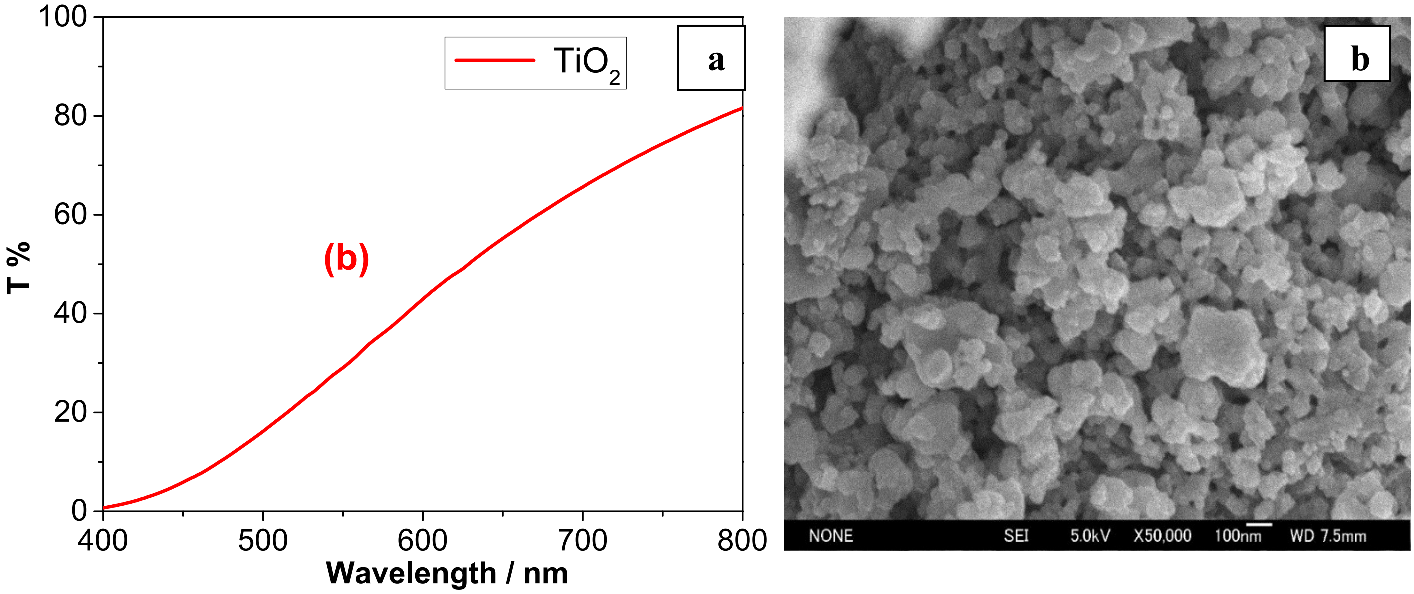


Fig. S1. FESEM patterns of the pure $TiO_2$ nanoparticles (a), and UV-vis T % of pure $TiO_2$ nanoparticles (b), respectively.

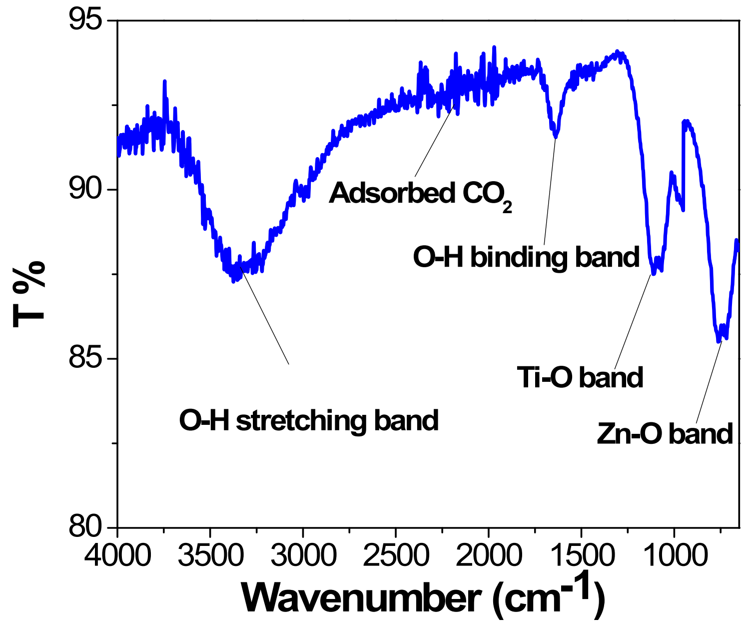


Fig. S2. FTIR T % versus wavenumber ($cm^{-1}$) of ZnO/ $TiO_2$ nanocomposite.

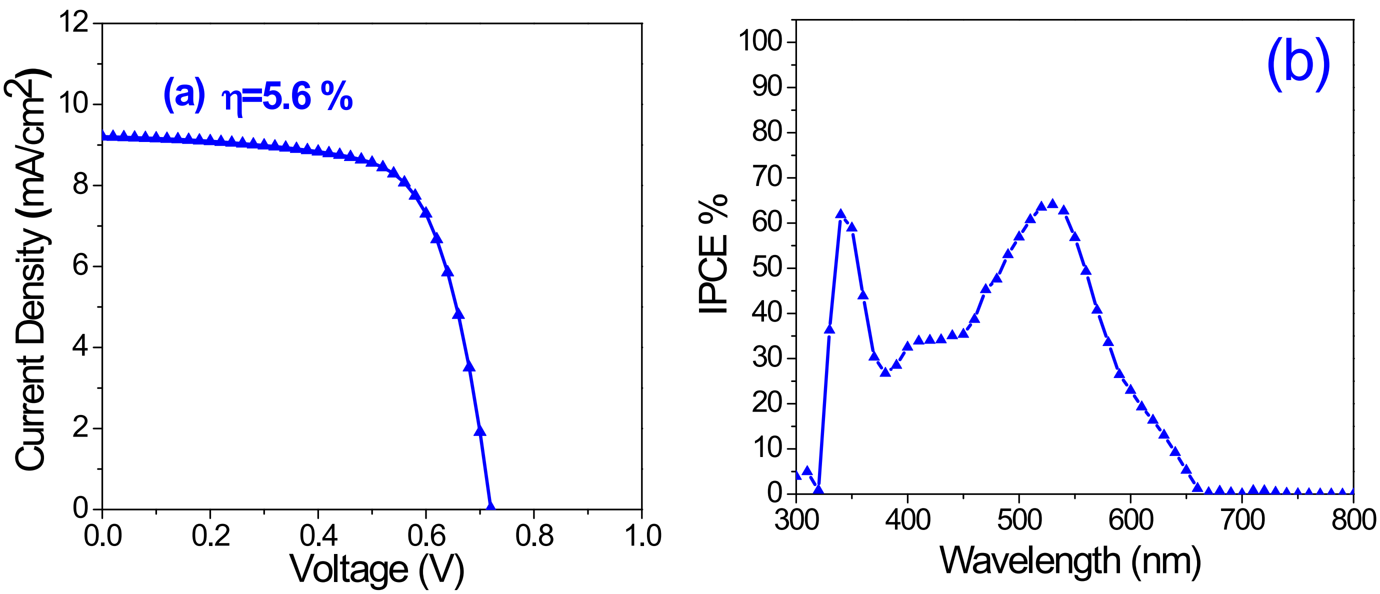


Fig. S3. I–V characteristics of DSSCs made from the pure $TiO_2$ (a), and IPCE % of pure $TiO_2$ nanoparticles (b), respectively.

**Effect of Dyes on the Photovoltaic Performance.** Dyes also have important effect on the photovoltaic performance of quasi-solid-state DSCs. The photovoltaic performance of cell with ZnO-$TiO_2$ nanoparticles is superior to that of cell with pure ZnO or pure $TiO_2$ nanoparticles. The illumination intensity has stronger influence on the performance of cell with ZnO-$TiO_2$ nanoparticles. Under the illumination intensity of 100 mW $cm^{-2}$, the η of cell with ZnO-$TiO_2$ nanoparticles is 6.5 %. While it were 3.8 % and 5.6% in case of cell with ZnO and $TiO_2$, respectively. With the ZnO-$TiO_2$ nanocomposites, the photocurrent is small, which decreases the mass-transfer-related losses in $J_{sc}$ and FF and increases the conversion efficiency. For the cell with ZnO nanoparticles, the change of η as a function of light intensity is not as obvious as that of cell with ZnO-$TiO_2$ nanoparticles because of its lower photocurrent even under the light intensity of 100 mW $cm^{-2}$.

The superior performance of cell with ZnO-$TiO_2$ nanoparticles to cell with ZnO nanoparticles can be analyzed from the properties of the dye molecular. The lowest unoccupied molecular orbital (LUMO) level of the dye plays an important role in the determination of current flow in the electron injection process.  The more negative LUMO level can supply stronger driving force for effective electron injection. This is one of the reasons why the Ru-N719-sensitized solar cell has higher $J_{sc}$.

On the other hand, for the cell with ZnO-$TiO_2$ nanoparticles, the lower back reaction rate at the ZnO-$TiO_2$/electrolyte interface between the injected electrons and $I_3^-$ also results in higher $J_{sc}$ as well as $V_{oc}$ (1, 2).

## REFERENCES AND NOTES

(1) Ardo, S.; Meyer, G. J. Chem. Soc. Rev. 2009, 38, 115–164.

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