Supporting Information

Low temperature growth of hybrid ZnO/TiO2 nano-sculptured foxtail-structures for dye-sensitized solar cells

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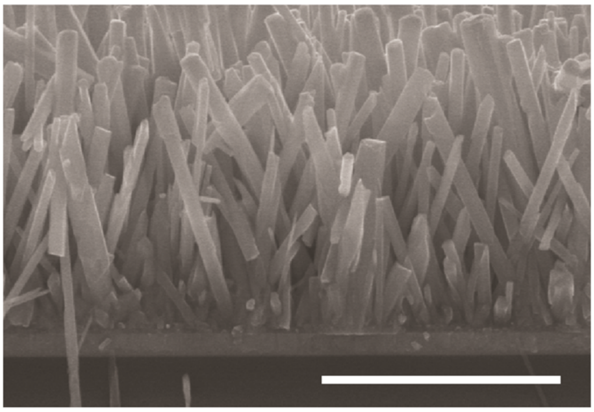


Figure S-1. Cross-sectional SEM image of the bare-ZnO NRs obtained after 4hrs growth (Z0). Scale bar is 3μm.

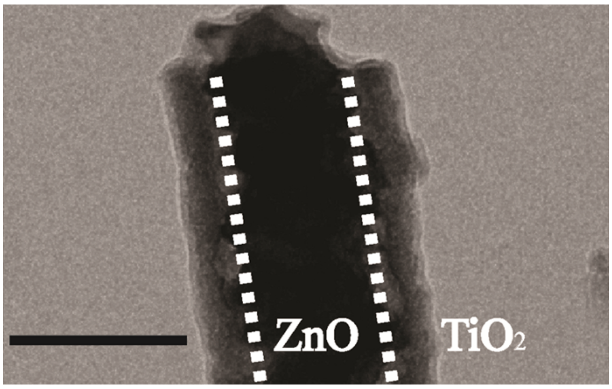


Figure S-2. TEM image of a single ZnO core-TiO2 shell hybrid structure with the modification time of 120mins (TZ4). Scale bar is 200nm. The thickness of the shell is around 55nm

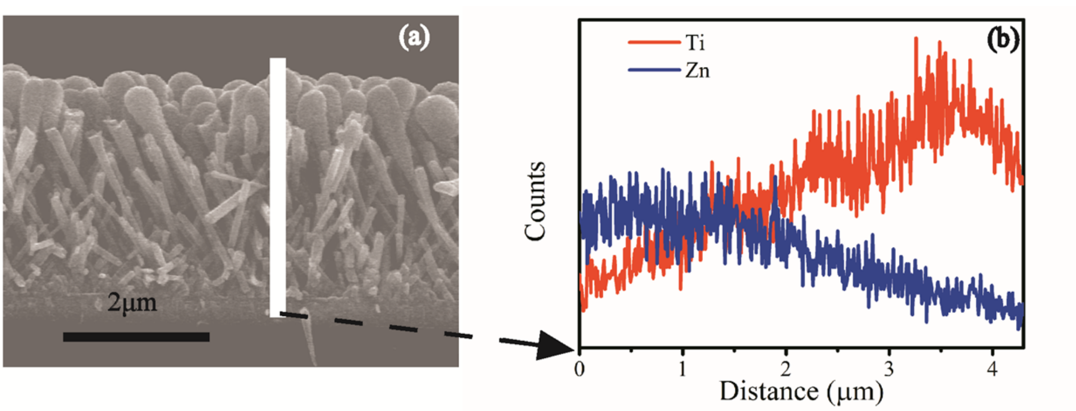


Figure S-3. (a)Cross section of the TZ4 and (b) the corresponding EDS line scan

Impedance spectra

Equivalent circuit used to fit EIS results are followed by previous studies [1,2,3]. The fitting was achieved by zview software (Scribner Associates, Inc.) using non-linear least squares regression. Constant phase elements(CPEs) are used to replace all capacitances to improve quality of fits. However, the EIS results do not show a clear transmission-line feature in this experiment, which is commonly attributed to a good electron transport in the semiconductor oxide (i.e. ZnO) [4,5]. For this reason, it is not possible to extract reliable values from the equivalent circuit-fitting and we limited our study to analyse the recombination behavior of the NRs and hybrid nanostructures.

The details of the circuit are:

R_s: series resistance, including the sheet resistance of TCO glass and contact resistance of the cell

R_{co}: resistance at ITO/seed layer/nanostructure contact

C_{CO}: the capacitance at ITO/seed layer/nanostructure contact

R_{Ct}& C_{Ct}: the charge-transfer resistance and the corresponding double-layer capacitance at exposed ITO/electrolyte interface

r_t: the transport resistance of electrons in ZnO/TiO_2 nanostructure

r_{ct}: charge-transfer resistance of the charge recombination process

C_μ: the capacitance of the nanostructure/electrolyte interface

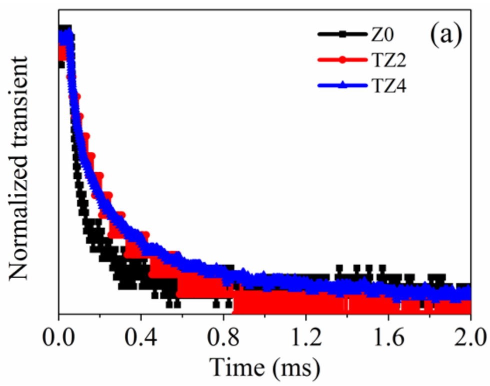
R_{Pt}: charge-transfer resistance at the counter electrode (Pt coated ITO)

C_{Pt}: double-layer capacitance at the counter electrode (Pt coated ITO)

Z_d: Warburg element showing the Nernst diffusion of I_3^- in electrolyte

Electron transport

Measurements of electron transport time followed procedures reported in Ref. [6]. A square-wave pulse was applied to a white-light LED, used to illuminate the DSSCs. The modulation amplitude produced a <10% change in DSSC current. The current was determined by ohm law and an average of 5 photocurrent transient signals was recorded for each test.



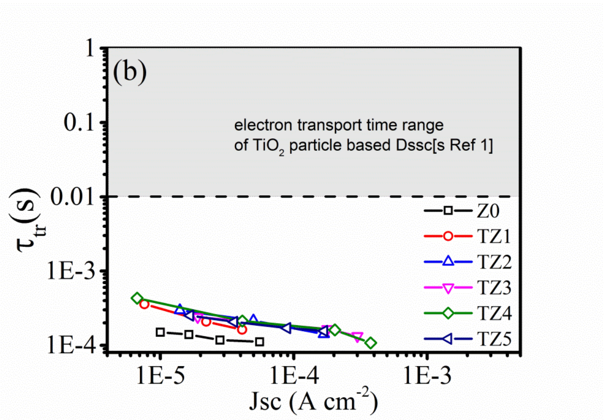


Figure S-4. (a) Representative transient photo current decay at a short circuit work condition of Z0, TZ2 and TZ4 (b) Fitted electron transport time constants (τ_{tr}) versus short circuit current for all the samples.

Fig. S-4(a) shows representative transient photo current decay at a short circuit work condition for Z0, TZ2, and TZ4. Each transient is fitted by the following equation:

$$y = y_0 + Ae^{-t/}\tau_{tr}$$

where τtr is the characteristic time for electron transport. The values of characteristic time for τtr under a range of light intensities are plotted against the corresponding short-circuit current density J_{SC} in Fig. S-4(b).

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