Supporting information

SnO_2 nanorod@TiO_2 Hybrid Materials for Dye−Sensitized Solar Cells

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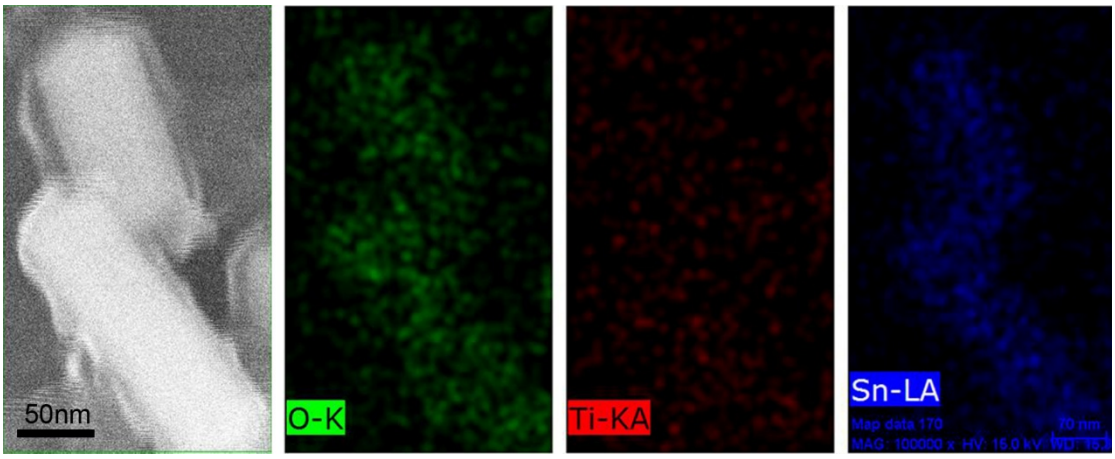

Fig. S1 EDS mapping of SnO_2 nanorod@TiO_2 for elements O, Ti, Sn

The EDS mapping of SnO_2 nanorod@TiO_2 hybrid materials is shown in Fig. S1, noting the successfully synthesis of hybrid structure. SnO_2 nanorods are uniformly coated by TiO_2.

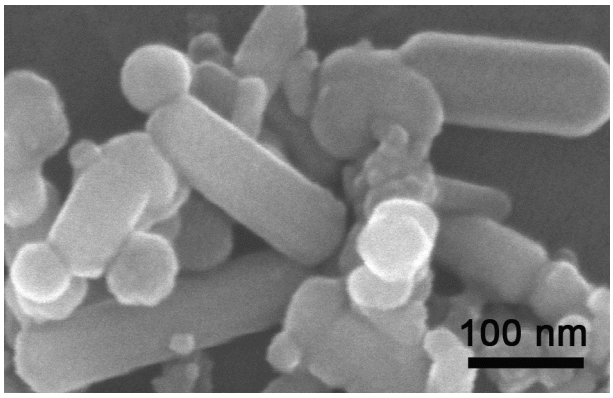

Fig. S2 SEM image of SnO_2 nanorod@TiO_2 after annealing at 450 ^oC

The SEM image of SnO_2 nanorod@TiO_2 after annealing at 450 ^oC for 30 min has been given in Fig. S2, suggesting the morphology of SnO_2 nanorod@TiO_2 hybrid materials has not obviously changed in the annealing process.

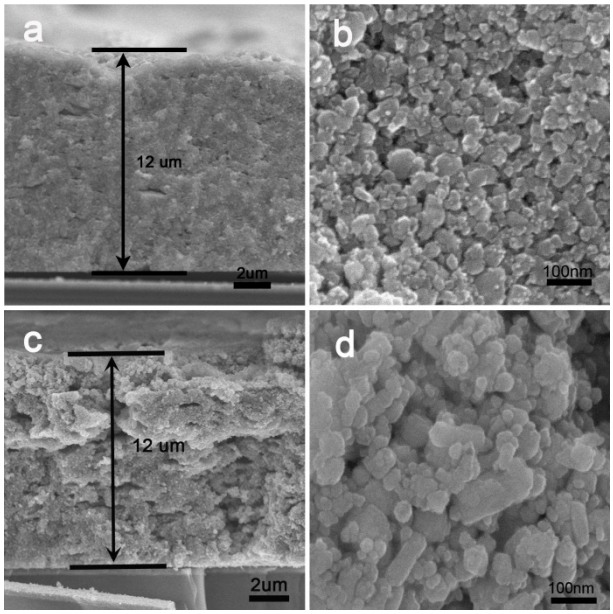

Fig. S3 SEM of photoelectrode films after $TiCl_4$ treated (a) cross-sectional SEM image of P25 film, (b) top-view SEM image of P25 film, (c) cross-sectional SEM image of SnO_2 nanorod@TiO_2 film, (d) top-view SEM image of SnO_2 nanorod@TiO_2 film

Fig S4 shows the cross-sectional and top-view SEM images of P25 and and SnO_2 nanorod@TiO_2 films after $TiCl_4$ treated. From the cross-sectional images it can be observed the thicknesses of the films are about 12 μm, and the films are both porous. The top-view of the P25 film shows a uniform film made up of P25 nanoparticles. The morphology of the SnO_2 nanorod@TiO_2 materials has not been obviously changed, during the fabrication process of DSCs (Fig. S4d).

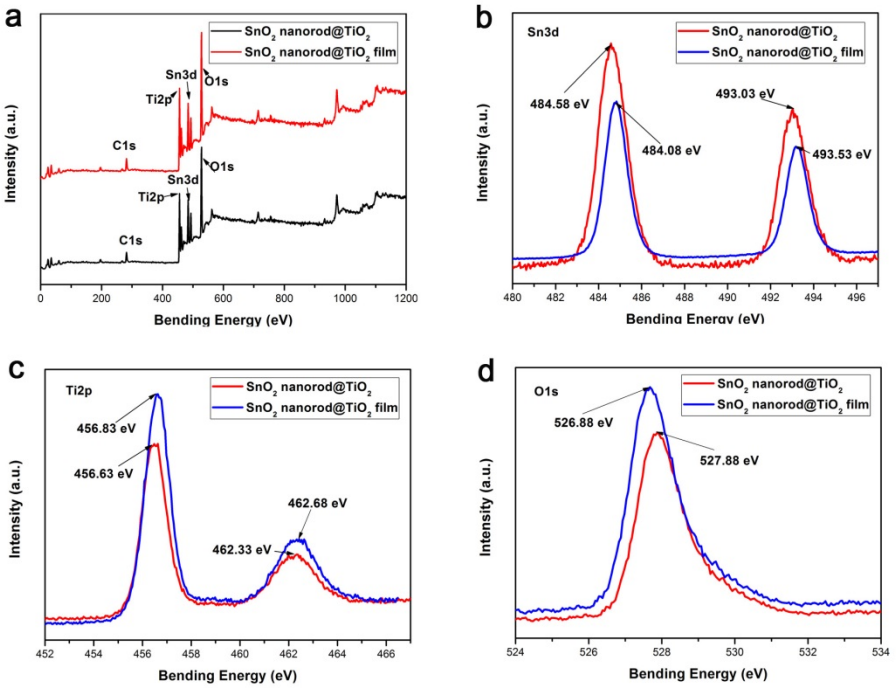

Fig. S4 High resolution XPS spectra of SnO_2 nanorod@TiO_2 and SnO_2 nanorod@TiO_2 film after $TiCl_4$ treated (a) Ti, O, Sn, C, (b) Sn3d, (c) Ti2p, (d) O1s.

High resolution XPS spectra of SnO_2 nanorod@TiO_2 and SnO_2 nanorod@TiO_2 film are shown in Fig. S5. The peaks of xps spectra have not been obviously changed after the DSCs fabrication process. The positions of the peaks (Sn 3d, Ti2p, O1s) are almost the same, however the intensity of the peaks are different. The peak intensity of Sn 3d got weaker, while that of Ti2p and O1s got stronger after fabricating into films. That is probably because of the $TiCl_4$ treated and the annealing process.

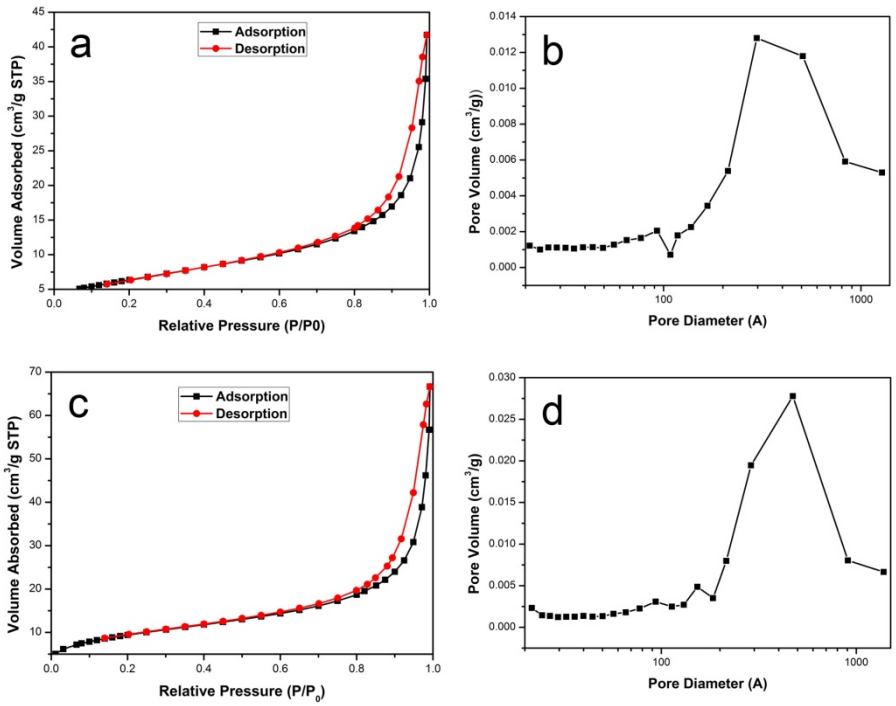

Fig. S5 (a) Nitrogen adsorption-desorption isotherms of SnO_2 nanorod@TiO_2, (b) corresponding pore size distribution of SnO_2 nanorod@TiO_2, (c) Nitrogen adsorption-desorption isotherms of SnO_2 nanorods, (d) corresponding pore size distribution of SnO_2 nanorods.

Fig. S3 shows the nitrogen adsorption-desorption isotherms and the BJH analysis of desorption isotherms of the samples. The BET specific surface area of SnO_2 nanorod@TiO_2 hybrid material is 34.7 m^2/g (Fig. S3c), much higher than that of SnO_2 nanorods (11.9 m^2/g, Fig. S3a). This is mainly owing to the high pore volume of SnO_2 nanorod@TiO_2 hybrid material. The total pore volume of SnO_2 nanorod@TiO_2 is 0.123 cm^3/g (Fig. S3d), while that of SnO_2 nanorods is only 0.061 cm^3/g (Fig. S3b). In addition, there are some TiO_2 nanoparticles existing on the surface of the SnO_2 nanorod@TiO_2 hybrid materials, owing to the excessive of $TiCl_4$ vapor gas.

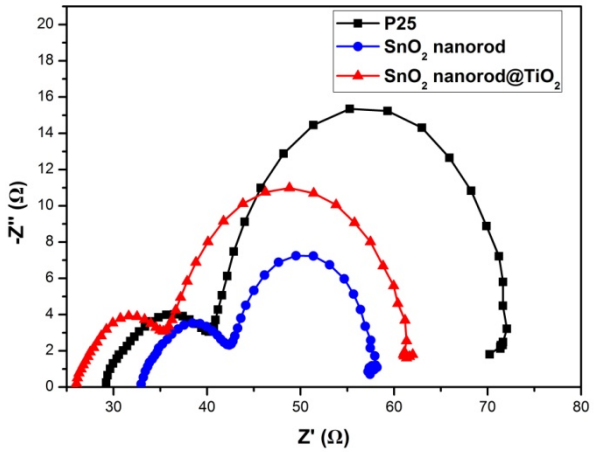

Fig. S6. Nyquist diagrams of the EIS under illumination for photoelectrode based on P25, SnO_2 nanorods and SnO_2 nanorod@TiO_2

Electron transport properties were investigated using electrochemical impedance spectroscopy (EIS) under illumination. As shown in Fig. S6, two well-defined semicircles in the Nyquist plots represent the charge transfer resistance of the redox reaction of I^-/I^{3-} at the Pt/electrolyte interface (at high frequencies) and at the photoelectrode/electrolyte interface (at low frequencies), of which a smaller diameter circle indicates faster charge transfer. The semicircle for SnO_2 nanorods electrode has the smallest diameter, showing the highest charge transfer ability. However the dye loading capacity of SnO_2 nanorods anode is much lower, so the power conversion efficiency is the lowest. The semicircle for the SnO_2 nanorod@TiO_2 electrode has a bigger diameter than SnO_2 nanorods electrode, but much smaller diameter than that of P25, indicating SnO_2 nanorod@TiO_2 have much faster charge transfer ability than P25.

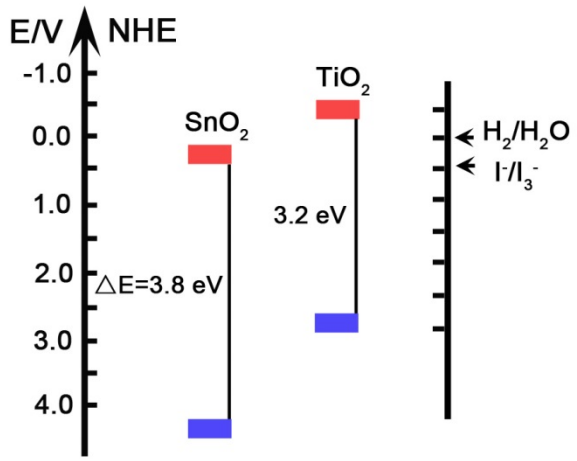

Fig. S7. Band positions of conventional SnO_2 and TiO_2

The band Band positions of conventional SnO_2 and TiO_2 are given in Fig. S6.[1] It is obviously that the conduction band edge of SnO_2 is much positive than that of TiO_2. Therefore in our experiment the electrons in TiO_2 can be easily injected into the SnO_2 nanorods, leading to fast electron separation to the current-collecting surface.

Reference

(1) J. W. Gong, J. Liang, K. Sumathy, Renew. Sust. Energ. Rev., 2012, **16**, 5848.