Electronic Supplementary Material (ESI) for Journal of Materials Chemistry A

Electronic Supplementary Information

In situ Au-catalysis fabrication of branch-type SnO_2 nanowires by a continuous gas-phase route for dye-sensitized solar cells

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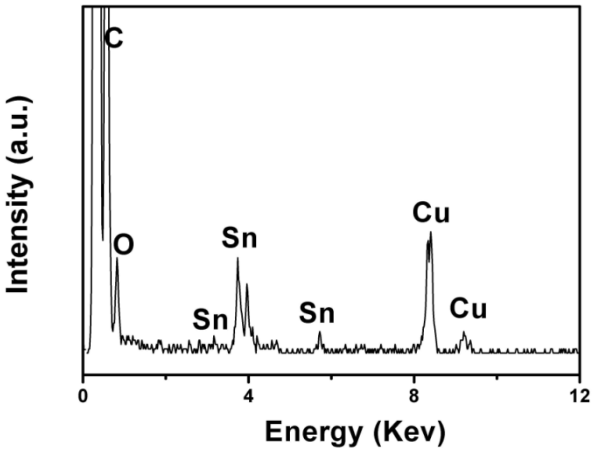

Fig. S1 EDS of as-prepared SnO_2 nanowires. Cu element derives from the copper mesh for TEM.

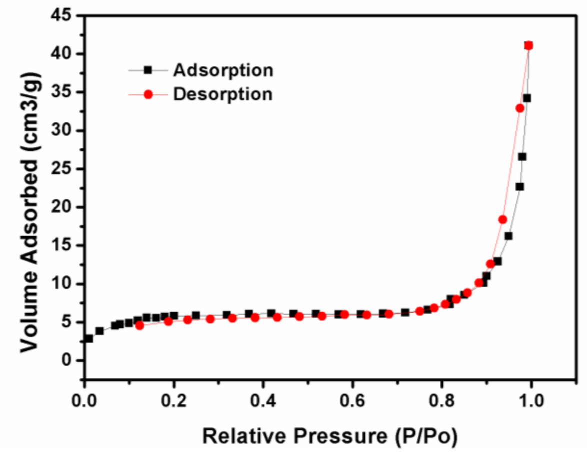

Fig. S2 The nitrogen adsorption-desorption curve of as-prepared SnO_2 nanowires.

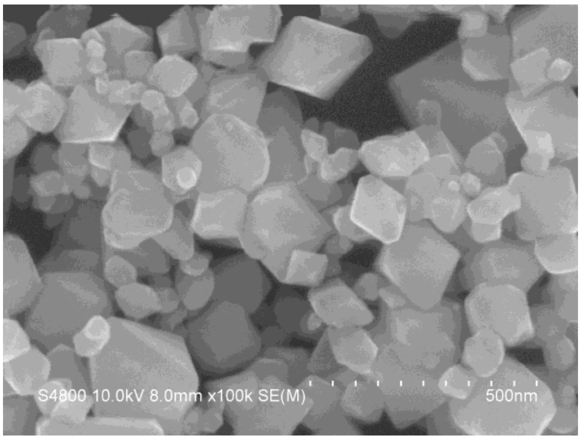

Fig. S3 SEM image of as-synthesized SnO_2 octahedral by FSP (precursor without $HAuCl_4$)

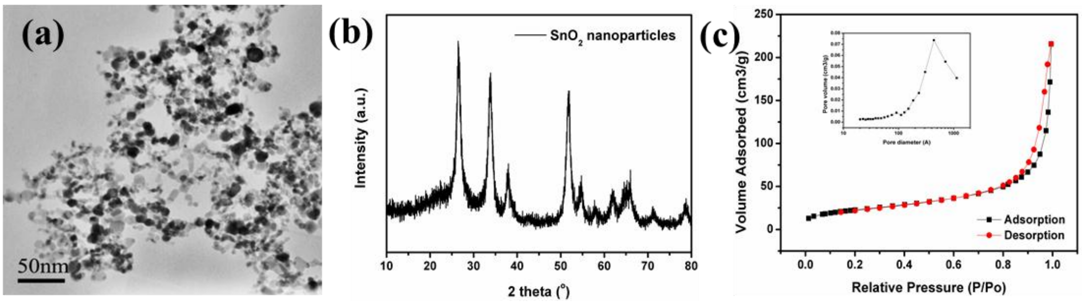

Fig. S4 TEM image of SnO_2 nanoparticles synthesized by FSP route (a); XRD pattern of as-prepared SnO_2 nanoparticles, all diffraction peaks are matched with rutile SnO_2 JCPDS 41-1445 (b);Nitrogen adsorption-desorption spectrum of SnO_2 nanoparticles (c). The specific surface area of SnO_2 nanoparticles is 78.8 m^2g^{-1}.

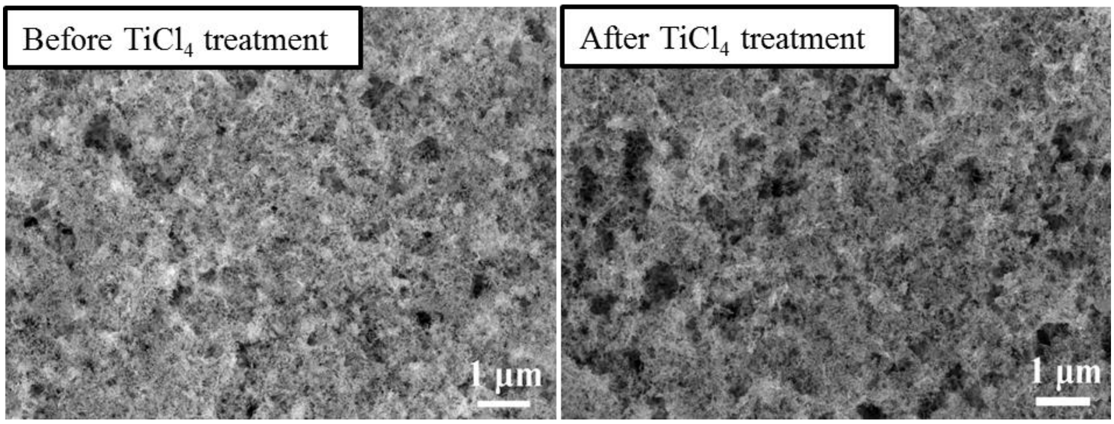

Fig. S5 SEM image of SnO_2 nanowires photoanode porous film (before and after $TiCl_4$ post-treatment)

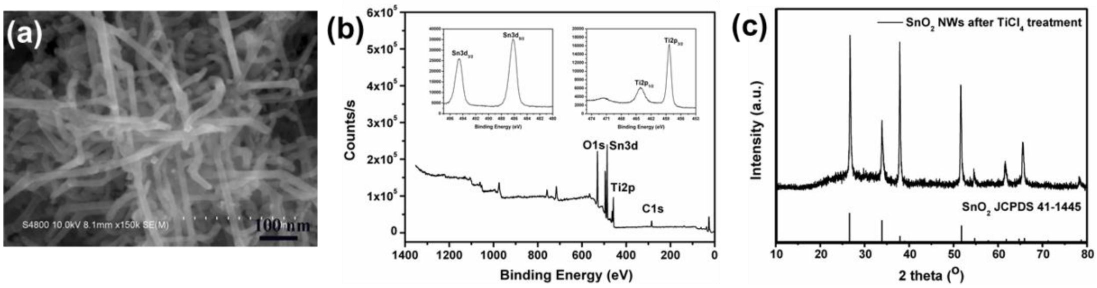

Fig. S6 SEM image of Branch-type SnO_2 nanowires photoanode film after $TiCl_4$ post-treatment (a); XPS spectrum of Branch-type SnO_2 NWs film after $TiCl_4$ treatment, insets are high-resolution XPS of Sn3d, Ti2p, respectively (b); XRD pattern of branch-type SnO_2 NWs photoanode film after TiCl4 post-treatment (c).

As shown in Fig. S6a, the branch-type SnO_2 nanowires after $TiCl_4$ treatment still remain the original 1-D nanowire structure. It has been reported that $TiCl_4$ treatment results in a ultrathin TiO_2 shell layer on the surface of SnO_2.[1,2] The thickness of TiO_2 layer is about 1~2 nm, determining the unidentified differences from the SEM images before and after $TiCl_4$ treatment. X-ray photoelectron spectroscopy (XPS) analysis of SnO_2 nanowires DSSCs films after $TiCl_4$ treatment was characterized from 0 to 1300 eV (Fig. S6b). It can be observed that C1s, O1s, Ti2p and Sn3d peaks were detected and high-resolution spectra of Ti and Sn are shown in the inset. The peaks located at 458.5 and 463.9 eV in the Ti2p scan should be attributed to the levels of $Ti2p_{3/2}$ and $Ti2p_{1/2}$ spin-orbital splitting photoelectrons in the Ti^{4+} chemical state, respectively. The Sn peaks of $Sn3d_{5/2}$ and $Sn3d_{3/2}$ can be assigned to Sn^{2+}/Sn^{4+} chemical states. Fig. S6c shows the XRD pattern of SnO_2 nanowires films after $TiCl_4$ treatment. The diffraction peaks are all well matched with rutile SnO_2 (JCPDS No.14-1445). The intensity of SnO_2 characteristic peaks is different from the XRD pattern of as-prepared branch-type SnO_2 nanowires, which may be ascribed to disturb of the FTO surface. There are no diffraction peaks associated with anatase or rutile TiO_2 which could not preciously proves the TiO_2 layer is amorphous or crystallites owing to the extremely ultrathin layer[3] although many literatures suggest the anatase TiO_2 under the condition of annealing at about 400 ^{o}C.[4,5] Combining the results of XPS and XRD, we could draw the conclusion that $TiCl_4$ post-treatment has not changed the chemical composition and crystallinity of SnO_2 nanowires.

As summarized in Table 1, the introduction of TiO_2 layer on SnO_2 nanowires causes the η ,Voc, Jsc, FF increased from 1.16 to 4.23%, 358.1 to 737.4 eV, 6.93 to 10.60 mA cm^{-2} and 46.6 to 54.7%. The dye-loading of SnO_2 nanowires cells after $TiCl_4$ treatment is also increasd by 51.9% (3.91 to 5.94 $\times 10^{-8}$ mol cm^{-2}). The SnO_2 with band edge of 300 mV more positive than of TiO_2 could lead to a decreased Voc. The higher Jsc and FF may be attributed to energy barrier formed at the surface SnO_2/TiO_2, which will be investigated in the future. The remarkable enhancement on the photovoltaic performance of SnO_2-based DSSCs cells after $TiCl_4$ treatment successfully confirms that $TiCl_4$ solution post-treatment effectively overcome some defects of SnO_2 cells, especially for the limited Voc and dye-loading.

Reference

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