Supplementary materials for

Enhanced Photoelectric Properties in Dye Sensitized Solar Cells Using TiO_2 Pyramid Arrays

Wei Jiang, Hongzhong Liu*, Lei Yin, Yongsheng Shi, Bangdao Chen

State Key Laboratory for Manufacturing Systems Engineering, Xi'an Jiaotong University, Xi'an 710049, China

* Corresponding author; Fax: 86-29-83399508; Tel: 86-29-83399508; E-mail: hzliu@mail.xjtu.edu.cn

Figure S1 shows the SEM images of inverted pyramid structured silicon mold with a 20 μm period. It can be clearly seen from the pictures that the arrayed structures with inverted pyramid-shaped profiles were successfully obtained in the resultant template.

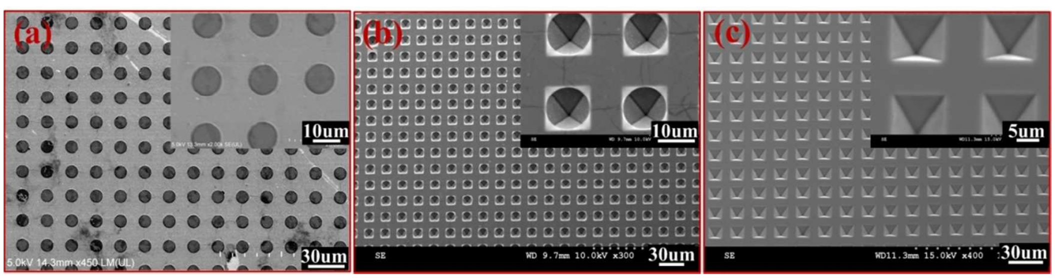

Figure S1. (a) SEM images of micro-hole arrays with a 20 μm period on Cr layer; (b) NaOH etched inverted pyramid arrays with Cr mask; (c) Obtained inverted pyramid arrays mold with removed Cr layer.

Figure S2 shows the SEM pictures of the pyramid patterned photo-anodes with and without scattering layer in a 20 μm period. The pyramid patterned TiO_2 photo-anodes are attained by the method described in the experimental section. It can be clearly seen from the Figure S2-(a), (b) and (c) that, after the soft imprint lithography process, the surface of the active layer is shaped as a periodic arrangement of pyramid arrays with a 20 μm period. And Figure S2-(d), (e) and (f) images display the photo-anodes with coated scattering layer.

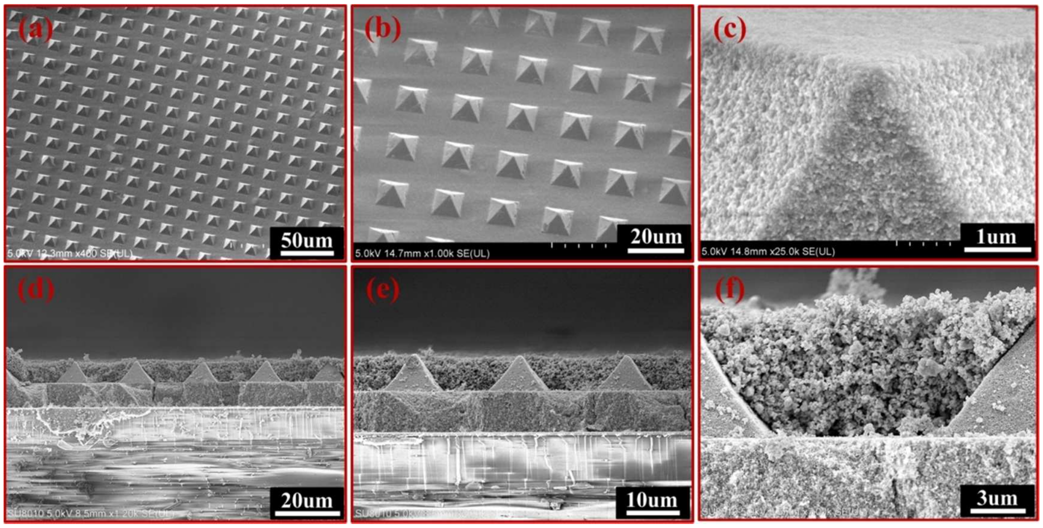

Figure S2. (a) The overview SEM image of pyramid patterned TiO_2 nanoparticles film; b) the top view image of the pyramid arrays with a 20 μm period; c) the enlarged image of the single pyramid composed by TiO_2 nanoparticles. d) The cross sectional image of pyramid structured photo-anode with scattering layer; e) the enlarged cross sectional image; f) the interface between the active layer and scattering layer.

Figure S3 shows the SEM images of inverted pyramid structured silicon mold with a 40 μm period.

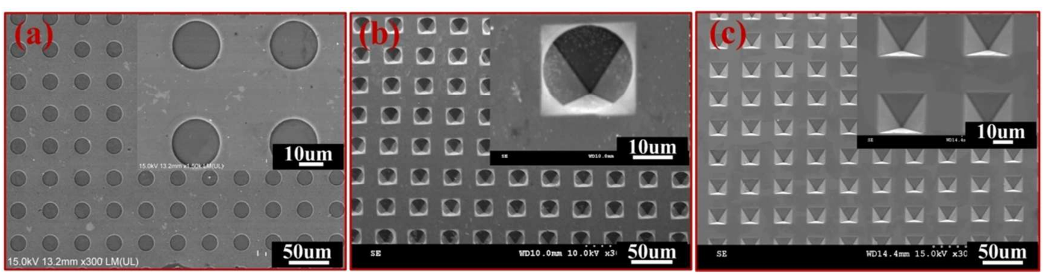

Figure S3. (a) SEM images of micro-hole arrays with a 40 μm period on Cr layer; (b) NaOH etched inverted pyramid arrays with Cr mask; (c) Obtained inverted pyramid arrays mold with removed Cr layer.

Figure S4 shows the SEM pictures of the pyramid patterned photo-anodes with and without scattering layer in a 40 μm period. The pyramid patterned TiO_2 photo-anodes are attained by the method described in the experimental section. In contrast, the pyramid structure with 40 μm period exhibits a different situation, after replication and calcination at 500 °C, the surface of the TiO_2 active layer was damaged with formed cracks and delamination, as shown in the Figure S4a–e. The overlayer also exhibits worse adhesion to the nanocrystalline underlayer and peeling is observed after annealing, as shown in the Figure S4e–f.

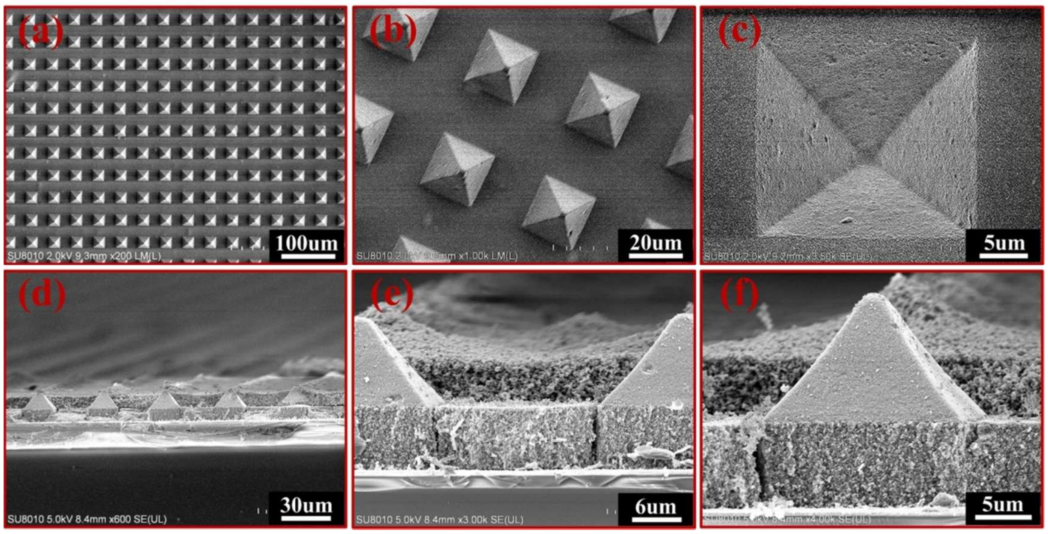

Figure S4. (a) The overview SEM image of pyramid patterned TiO_2 nanoparticles film; b) the top view image of the pyramid arrays with a 40 μm period; c) the enlarged image of the single pyramid composed by TiO_2 nanoparticles. d) The cross sectional image of pyramid structured photo-anode with scattering layer; e) the enlarged cross sectional image; f) the interface between the active layer and scattering layer.

For DSSCs, the film thickness of the TiO_2 nanoparticle photo-anodes are usually less than 20 μm, and the pyramid patterned photo-anodes with a 40 μm period are also in a worse condition. Hence, in the following UV-Vis optical measurements, we just implement the comparative experiments with planar, 4 μm and 20 μm periodical photo-anodes, and the corresponding UV–Vis absorption spectra are shown in Figure S5. As we can see from the Figure S5, the 4μm-PYTP-PYSC photo-anode presents the strongest light absorption intensity in the wavelength from 400 nm to 800 nm. The three TiO_2 photo-anodes without scattering layer exhibit lower light absorption than the three TiO_2 photo-anodes with scattering layer in the visible wavelength, which indicates that the scattering layer can reduce the light transmission loss and reflect the incident light inner the film due to their relatively larger particles. The result also suggests that the light absorption progressively increases with decreased period, and the 4 μm periodical pyramid patterns show much better light absorption regardless of the photo-anodes with or without scattering layer. As the period decreases, the reflected and scattered light can be further increased due to the enhanced density of the TiO_2 pyramid arrays. And the incident light can be reflected inner the pyramid active layer before reaching the scattering layer, thus, leading to much longer optical path lengths. Additionally, either the photo-anodes with scattering layer group or without scattering layer group, the photo-anodes with a much smaller period can absorb more incident photons than the other photo-anodes. It indicates that the periodical pyramid arrays play a critical role in the light absorption of the DSSCs.

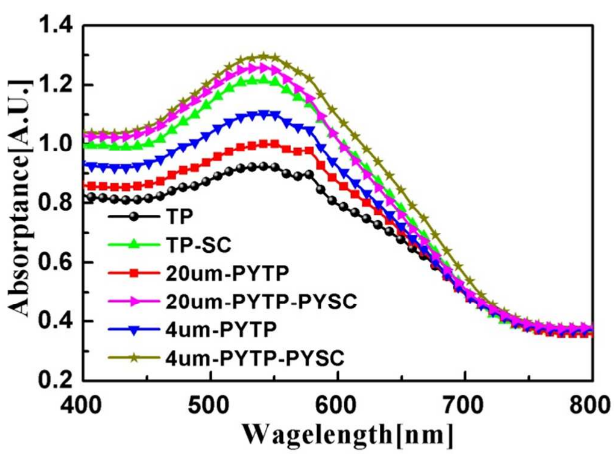

Figure S5. UV-Vis absorption spectra of photo-anodes with different periods.