Electronic Supplementary Information

For

Formation of crystalline nanotube/nanoparticle hybrid by post water-treatment of thin amorphous TiO_2 layer decorated on TiO_2 nanotube array for efficient photoanode in dye-sensitized solar cells

Sajith Kurian,[‡ a] P. Sudhagar,[‡ b] Jaesang Lee,[a] Donghoon Song,[b] Woohyung Choi,[b] Sanghun Lee,[a] Yong Soo Kang,[b]*and Hyeongtag Jeon [a]*

[a] Division of Material Science and Engineering, Hanyang University, Seoul, South Korea

[b] WCU Program Department of Energy Engineering and Center for Next Generation Dye-sensitized Solar Cells, Hanyang University, Seoul 133 791, South Korea

S1. X-ray diffraction analysis

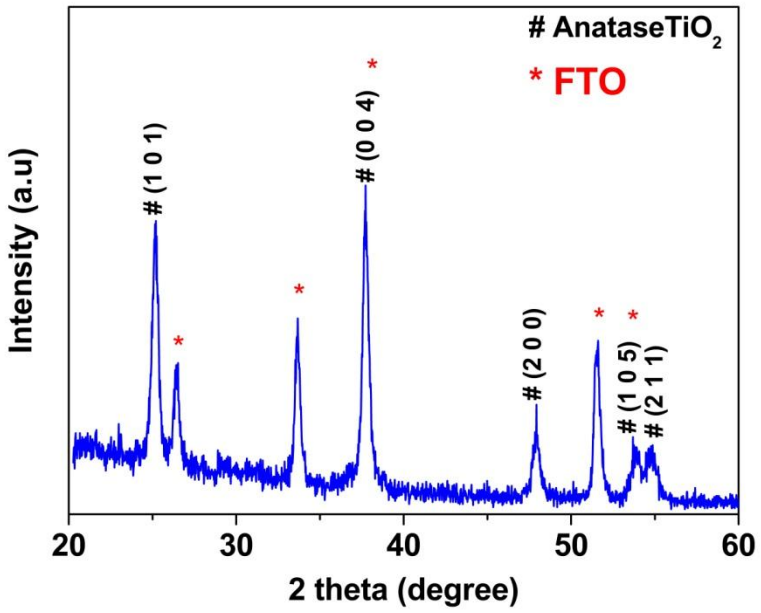

Figure S1. XRD profile of anodized TiO_2 NT arrays (TNTAs) after sintering at 450 °C.

S2. Surface morphology analysis

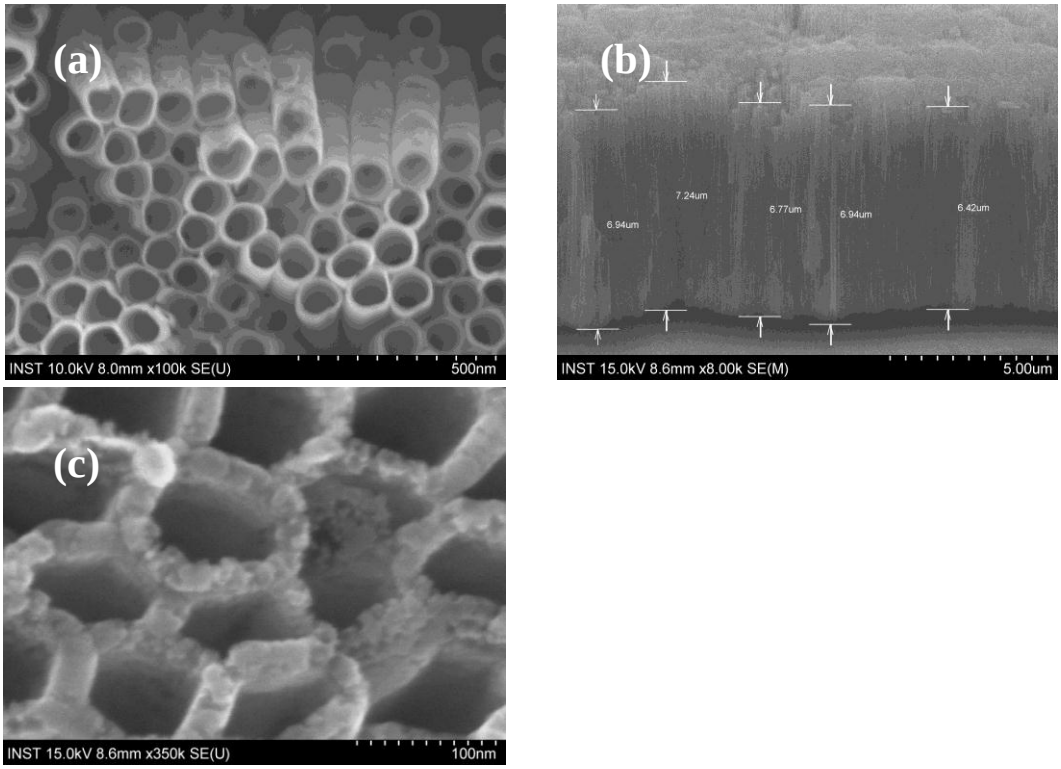

Figure S2. (a) Titled view of anodized TiO_2 NT arrays, (b) cross sectional image of the annealed TiO_2 NT array (TNTA) and (c) 48 h water-treated thin amorphous ALD layer, coated on the TiO_2 NT array.

S3. TEM analysis

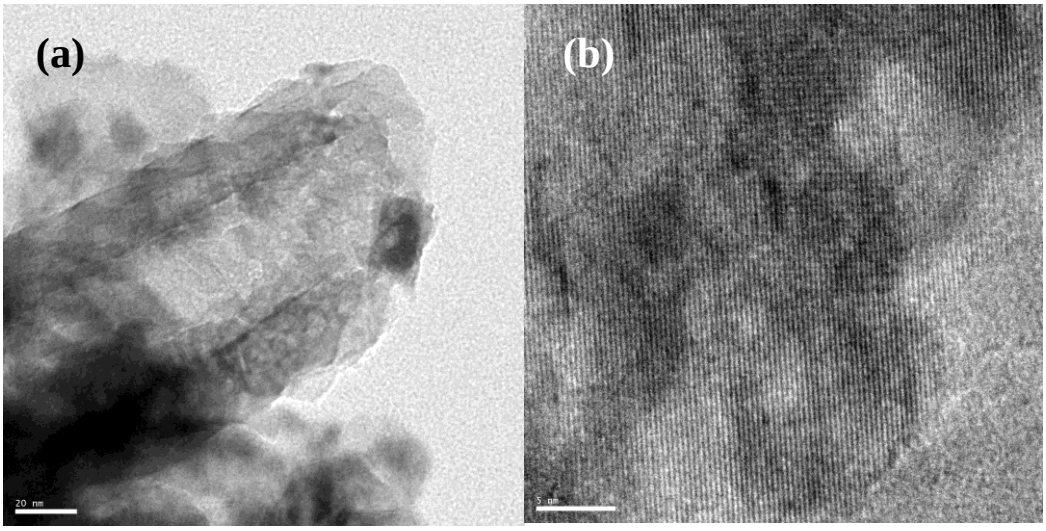

Figure S3. (a) TEM images of the water-treated nanotube array after 24 h and (b) high resolution HR-TEM image of (a).

S4. Photovoltaic measurements

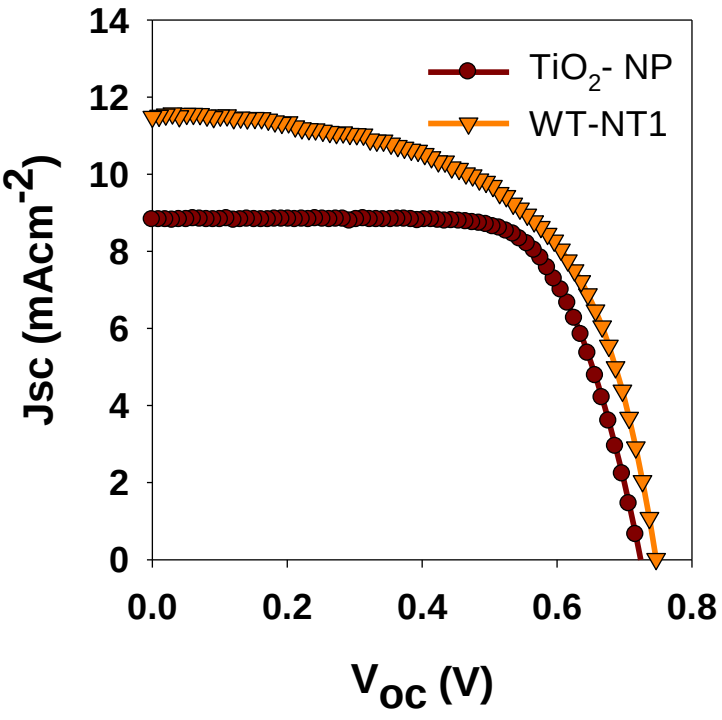

Figure S4. JV plots of DSSCs with different photoanodes

Table S1. Solar cells parameters of DSSCs with different photoanodes (active area of the device 0.25 cm^2, without mask) under 1 sun condition.

Photoanode	V_{oc} (V)	J_{sc} ($mAcm^{-2}$)	FF (%)	Efficiency (%)
WT1-NT	0.72	11.7	57.2	4.9
TiO_2-NP	0.72	8.8	71.3	4.5

TiO_2 NP: mesoporous TiO_2 particulate film (~7 micron thickness) was prepared using a commercially available TiO_2 paste (18 NR-T, Dyesol). This was done using a doctor blade technique and subsequently the particles were sintered at 450 ºC for 30 minutes in ambient atmosphere.

Under identical conditions (similar thickness, electrolyte, counter electrode, dye), water treated TiO_2 nanotube electrode (NT/NP) show high photocurrent density (11.7 $mAcm^{-2}$) than that of conventional TiO_2 nanoparticulate electrodes (8.8 $mAcm^{-2}$). This may ascribed to the few reasons (a) high dye loading (b) high scattering effect and (c) efficient charge collection. On the other hand, the formation of NP sites on NT electrodes under water treatment introduces new interfaces which reduce the fill factor of the device.