Electronic Supplementary Information (ESI)

Dye-sensitized solar cells based on a 1D/3D double-layered ZnO photoanode with improved photovoltaic performance

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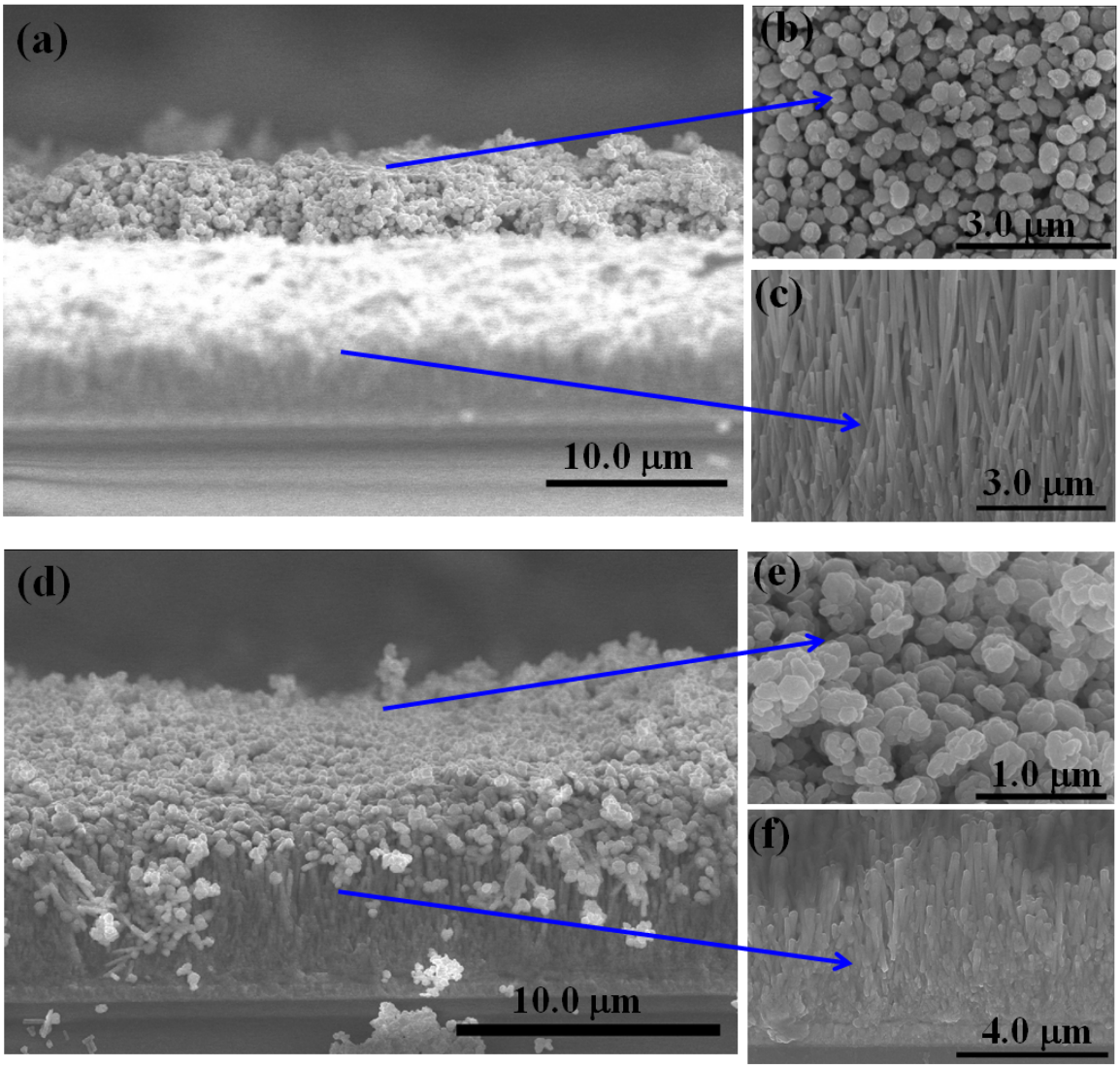

Fig. S1 (a, d) Cross-sectional SEM image view of double-layer ZnO photoanodes; FE- SEM images the each layer of ZnO structures: (c, f) ZnO nanorods; (b) ZnO ellipsoids; (e) ZnO spheres.

Fig. S1 shows the cross-sectional FE-SEM image of ZnO NRs+ellipsoids and ZnO NRs+spheres double layered photoanode film. There is no obvious gap between ZnO ellipsoids or spheres top layer and nanorods active layer, indicating the connectivity between ZnO ellipsoids or spheres and nanorods is quite good, which is suitable for the efficient charge transport from ZnO ellipsoids or spheres to nanorods.

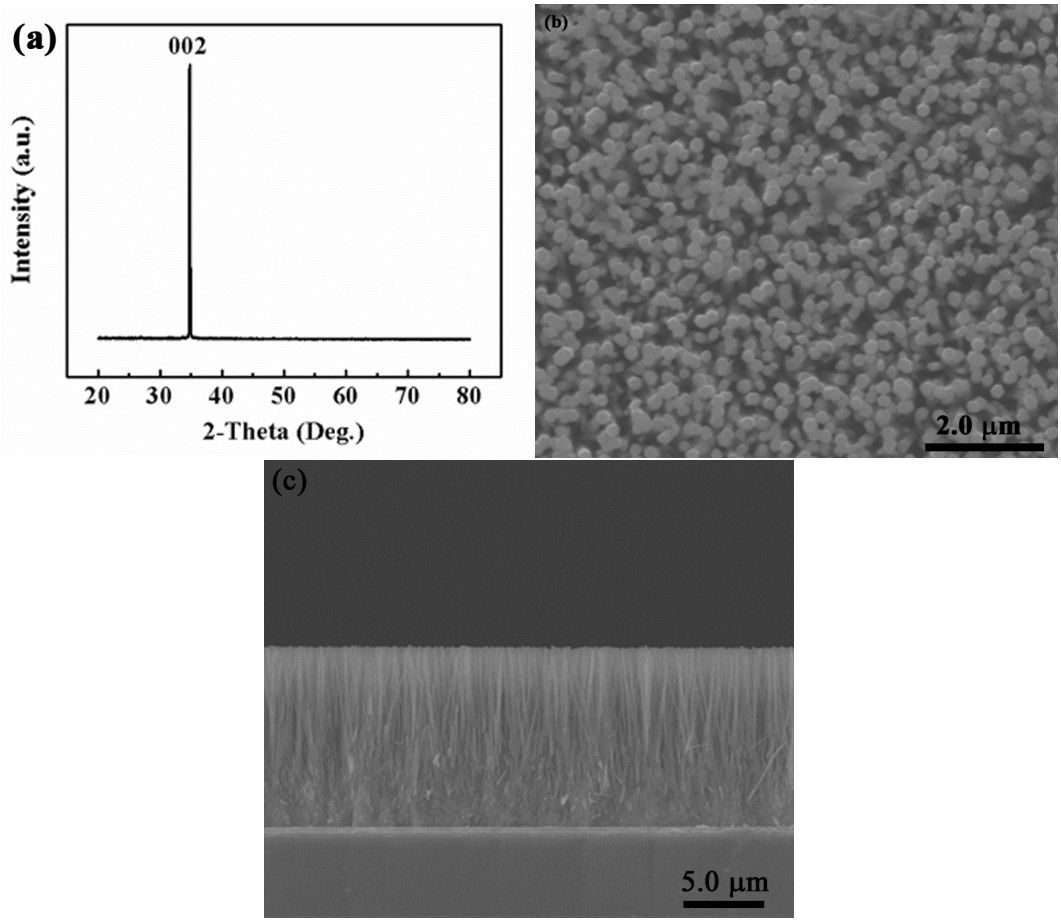

Fig. S2 (a) XRD; (b) Top-view SEM image and (c) Cross-sectional SEM image of ZnO nanoarrys.

Fig. S2a shows the typical XRD patterns of as-synthesized ZnO nanoarrys samples. The diffraction peaks of the as-prepared sample are consistent with the hexagonal structure of ZnO (JCPDS Card No. 65-3411) with cell constants of a=b=3.25 Å and *c* = 5.207 Å, and the stronger peaks of the XRD patterns indicates high crystallinity of the as-prepared ZnO. The morphology of the as-prepared ZnO products are characterized by FE-SEM, shown in Fig. S2b and S2c. The ZnO nanoarrys are ~10 μm in length.

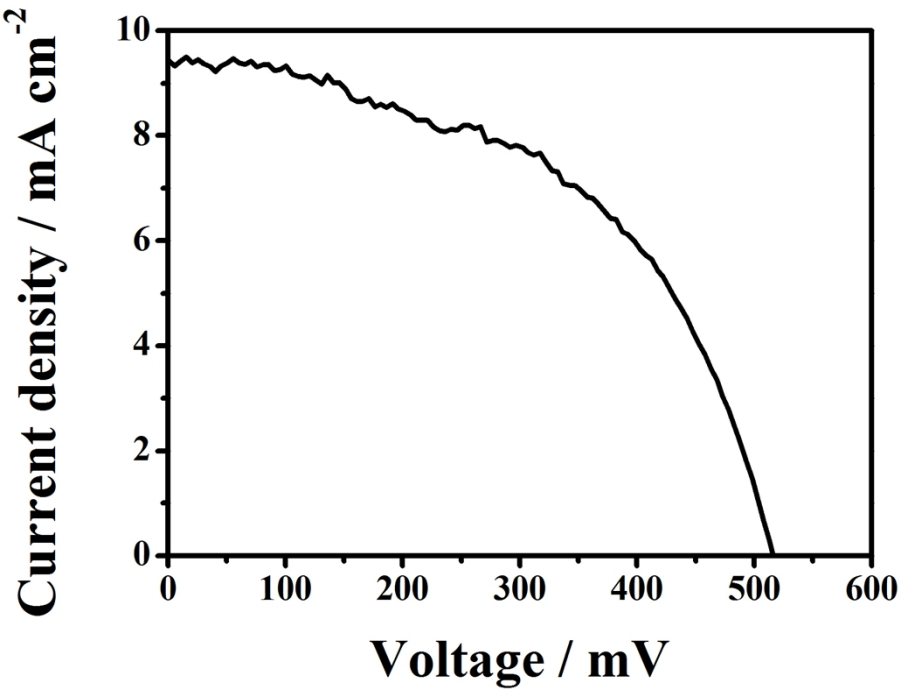

Fig. S3. Photocurrent density-voltage (*J-V*) for DSSCs based on ZnO NRs+9μm ellipsoids (with the same amount of N719 dye molecules to ZnO NRs+5μm spheres).

Table S1. Detailed photovoltaic parameters (Jsc, Voc, FF, and PCE) of DSSCs with different ZnO photoanodes.

DSSCs	J_{SC} / mA cm^{-2}	V_{OC} / mV	η/%	FF	Adsorbed dye/ ×10^{-8} mol cm^{-2}
ZnO NRs +5μm ellipsoids	7.41	588	2.26	0.52	2.26
ZnO NRs+9μm ellipsoids	9.38	516	2.47	0.51	3.19
ZnO NRs+5μm spheres	10.66	555	3.19	0.54	3.20

Table S2. Detailed IMPS and IMVS parameters (τ_d, τ_r, η_{cc}, D_n, and L_n) of DSSCs based on different ZnO photoanodes (Light intensity: 150 W/m^2).

DSSCs	τ_d (ms)	τ_r (ms)	η_{cc}/%	D_n (cm^2/s)	L_n (μm)
ZnO NRs+ellipsoids	1.19	37.04	96.78	4.71×10^{-4}	41.80
ZnO NRs+spheres	1.88	24.05	92.18	2.99×10^{-4}	26.80

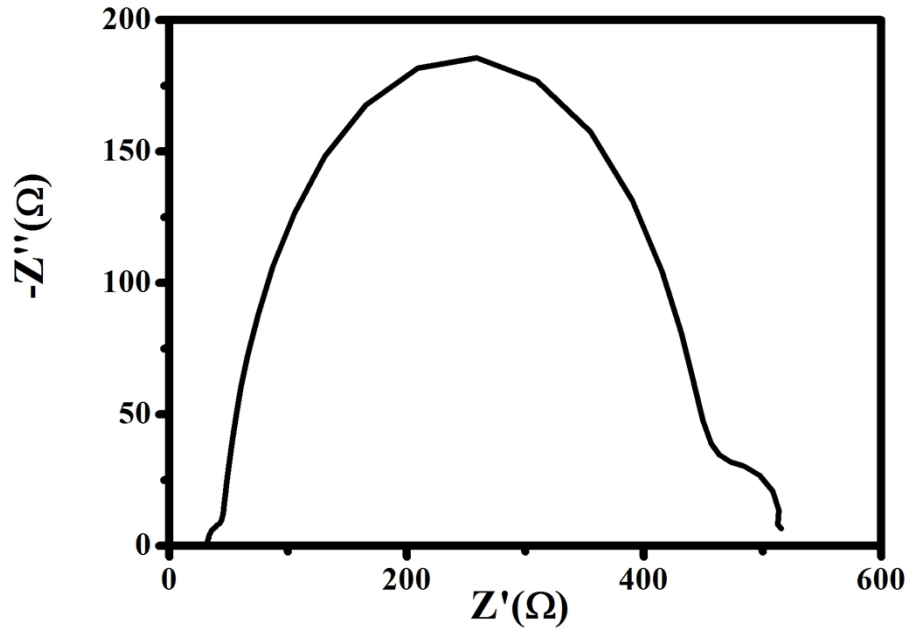

Fig. S4 Impedance spectra (Nyquist polts) of DSSCs based on **ZnO NRs** measured in the dark at 0.6 V bias.