Electronic Supplementary Information

Zinc-doped SnO_2 nanocrystals as photoanode materials for highly efficient dye-sensitized solar cells

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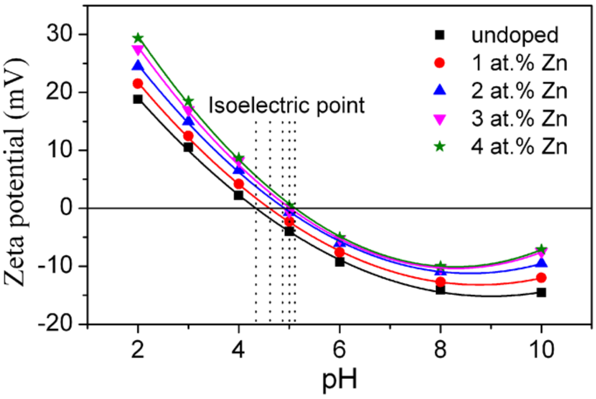

Fig. S1 The pH-dependent zeta-potential of the undoped and Zn-doped SnO_2 nanoparticles.

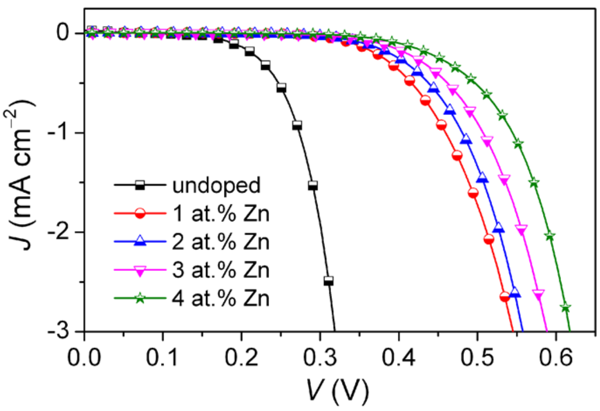

Fig. S2 *J*–*V* characteristics of the undoped and Zn-doped SnO_2 based cells measured in the dark.

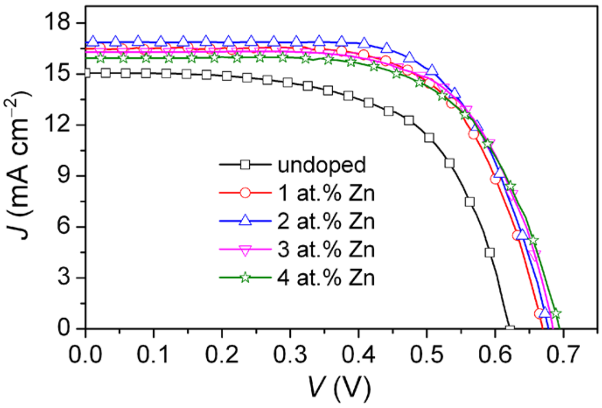

Fig. S3 *J*–*V* characteristics of the undoped and Zn-doped SnO_2 based cells with the $TiCl_4$ treatment under an irradiance of 100 mW cm^{-2} simulated AM1.5G sunlight.

Table S1 Comparison of the photovoltaic performance of the DSCs based on SnO_2 photoanodes with various morphologies.

Morphology	Synthetic method or manufacturer	Diameter	Film thickness	η (%) (no surface treatment)	η (%) (after surface treatment)	Reference
SnO_2 nanoparticles	Alfa Aesar	15 nm	4 μm	0.76	Al_2O_3/3.7	S1
SnO_2 nanoparticles	Alfa Aesar	15-140 nm	8 μm	1.2	$Zn(CH_3COO)_2$/5.1	S2
SnO_2 nanoparticles	Alfa Aesar	15 nm	–	1.7	$CaCO_3$/5.4	S3
SnO_2 nanopowder	Sigma-Aldrich	<100 nm	8 μm	3.65	MgO/6.40	S4
SnO_2 nanoparticles	Alfa Aesar	3-5nm	10 μm	1.74	MgO/7.21	S5
SnO_2 nanowires	Reactive vapor transport	20-200 nm	25-30 μm	2.1	$TiCl_4$/4.1	S6
SnO_2 nanofibers	–	200 nm	8.7 μm	–	$TiCl_4$/4.63	S7
SnO_2 nanotubes	Electrospinning	110 nm	13 μm	0.99	$TiCl_4$/5.11	S8
SnO_2 nanoflowers	Hydrothermal	1 μm	–	1.05	$TiCl_4$/5.60	S9
SnO_2 hollow microspheres	Hydrothermal	1-2 μm	10 μm	1.4	$TiCl_4$/5.65	S10
SnO_2 hollow nanospheres	Hydrothermal	200 nm	–	0.86	$TiCl_4$/6.02	S11
Mesoporous SnO_2 agglomerates	Molten salt method	200-600 nm	8 μm	3.05	$TiCl_4$/6.23	S12
SnO_2 octahedra	Sonochemical	0.5-1.8μm	13.2 μm	–	$TiCl_4$/6.8	S13
Mg-doped SnO_2 nanoparticles	Hydrothermal	100 nm	–	2.03	$TiCl_4$/4.15	S14
Zn-doped SnO_2 nanoflowers	Hydrothermal	1 μm	10 μm	3.00	$TiCl_4$/6.78	S15
Al-doped SnO_2 nanocrystals	Hydrothermal	11.6-15.9 nm	8 μm	3.56	$TiCl_4$/6.91	S16
Zn-doped SnO_2 nanocrystals	Hydrothermal	15 nm	8.5 μm	4.18	$TiCl_4$/7.70	Our work
			8.5+5 μm	–	$TiCl_4$/8.23 (with a scattering layer)	

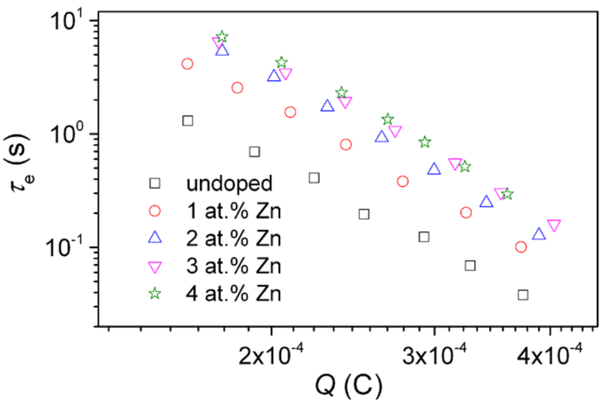

Fig. S4 Pots of lifetime of photoinjected electrons in the DSCs based on undoped and Zn-doped SnO_2 photoanodes with $TiCl_4$ treatment as a function of charge.

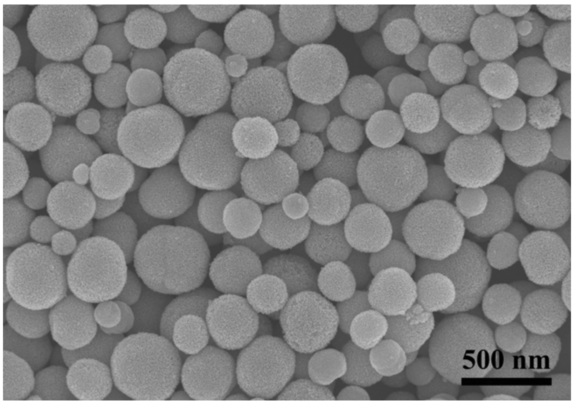

Fig. S5 FESEM image of SnO_2 spheres.

References

S1 C. Prasittichai and J. T. Hupp, J. Phys. Chem. Lett., 2010,**1**, 1611−1615.

S2 A. Kay and M. Grätzel, *Chem. Mater.*, 2002, **14**, 2930−2935.

S3 K. A. T. A. Perera, S. G. Anuradha, G. R. A. Kumara, M. L. Paranawitharana, R. M. G. Rajapakse and H. M. N. Bandara, *Electrochim. Acta*, 2011, **56**, 4135−4138.

S4 P. Docampo, P. Tiwana, N. Sakai, H. Miura, L. Herz, T. Murakami and H. J. Snaith, *J. Phys. Chem. C*, 2012, **116**, 22840−22846.

S5 M. K. I. Senevirathna, P. K. D. D. P. Pitigala, E. V. A. Premalal, K. Tennakone, G. R. A. Kumara and A. Konno, *Sol. Energy Mater. Sol. Cells*, 2007, **91**, 544−547.

S6 S. Gubbala, V. Chakrapani, V. Kumar and M. K. Sunkara, *Adv. Funct. Mater.*, 2008, **18**, 2411−2418.

S7 R. Kasaudhan, H. Elbohy, S. Sigdel, H. Qiao, Q. Wei and Q. Qiao, *IEEE Electron. Device Lett.*, 2014, **35**, 578−580.

S8 C. Gao, X. Li, B. Lu, L. Chen, Y. Wang, F. Teng, J. Wang, Z. Zhang, X. Pan and E. Xie, *Nanoscale*, 2012, **4**, 3475−3481.

S9 H. Niu, S. Zhang, R. Wang, Z. Guo, X. Shang, W. Gan, S. Qin, L. Wan and J. Xu, *J. Phys. Chem. C*, 2014, **118**, 3504−3513.

S10 J. Qian, P. Liu, Y. Xiao, Y. Jiang, Y. Cao, X. Ai and H. Yang, *Adv. Mater.*, 2009, **21**, 3663−3667.

S11 H. Wang, B. Li, J. Gao, M. Tang, H. Feng, J. Li and L. Guo, CrystEngComm, 2012, **14**, 5177−5181.

S12 P. Zhu, M. V. Reddy, Y. Wu, S. Peng, S. Yang, A. S. Nair, K. P. Loh, B. V. R. Chowdari and S. Ramakrishna, *Chem. Commun.*, 2012, **48**, 10865−10867.

S13 Y.-F. Wang, K.-N. Li, C.-L. Liang, Y.-F. Hou, C.-Y. Su and D.-B. Kuang, *J. Mater. Chem.*, 2012, **22**, 21495−21501.

S14 H. Pang, H. Yang, C. X. Guo and C. M. Li, *ACS Appl. Mater. Interfaces*, 2012, **4**, 6261−6265.

S15 X. Dou, D. Sabba, N. Mathews, L. H. Wong, Y. M. Lam and S. Mhaisalkar, *Chem. Mater.*, 2011, **23**, 3938−3945.

S16 Y. Duan, J. Zheng, N. Fu, Y. Fang, T. Liu, Q. Zhang, X. Zhou, Y. Lin and F. Pan, *J. Mater. Chem. A*, 2015, DOI: 10.1039/C4TA05923A.