Supporting Information

Photonic Sintering of ZnO Nanosheet Photoanode using Flash White Light combined with Deep-UV Irradiation for Dye-Sensitized Solar Cells

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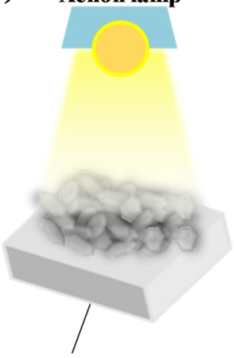
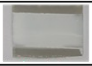
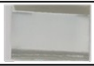
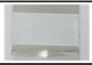
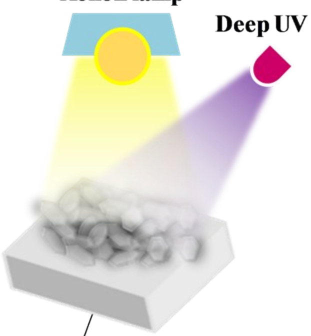
a) (FWL)



Pulse condition	Energy [J/cm^2]	Before irradiation	After irradiation
Single pulse; On-time : 20 ms; Pulse # : 1 pulse	15		
	20		
	25		
	30		
	35		

b) FWL + deep UV(Photonic sintering)



Flash white light			Deep UV	Sample Image
Energy [J/cm^2]	Pulse number	Pulse duration [msec]	Power [mW/cm^2]	
20	1	20	0	
20	1	20	0.75	
20	1	20	1.5	
20	1	20	30	

Figure S1.(a) Experimental details and phtoimages of ZnO NS photoanod sintered using flash white light (FWL)sintering with various pulse energy.(b) ZnO NS sintered using FWL combined deep UV(Photonic sintering) .

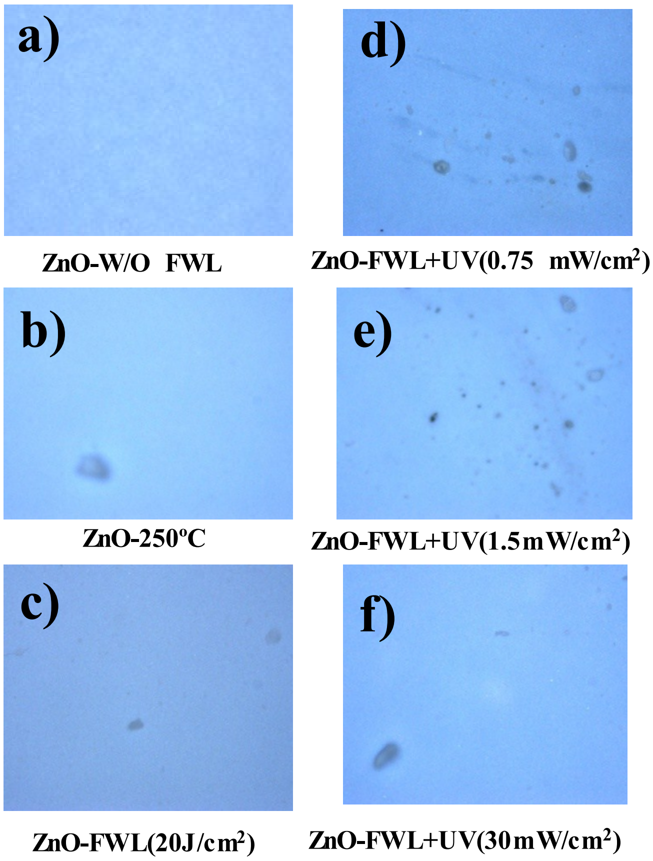
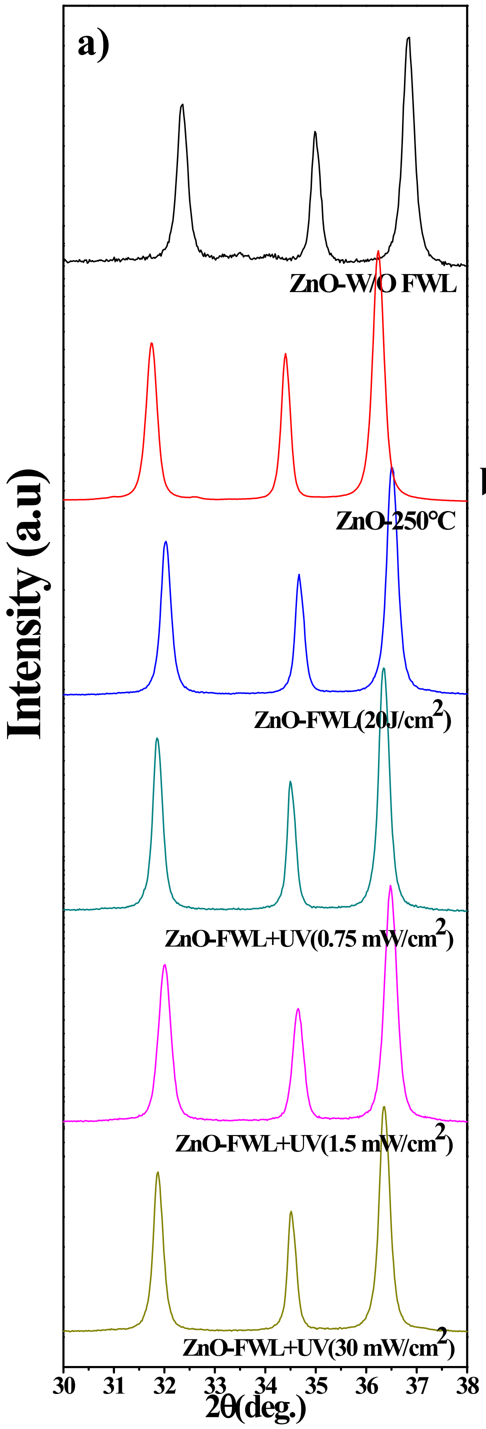


Figure S2. Optical microscopy images of ZnO NS (a) pristine, (b) thermal sintering, (c)FWL sintering at 20J/cm^2 energy, d),e),and f) photonic sintered ZnO- A,B and C respectively).



b)

Name	Plane
	(101)
ZnO-W/O-FWL	31.22
ZnO-250℃	28.12
ZnO-20J/cm²	30.14
ZnO-FWL+UV(0.75 mW/cm²)	30.43
ZnO-FWL+UV(1.5 mW/cm²)	31.21
ZnO-FWL+UV(30 mW/cm²)	36.21

Figure S3. (a) The expanded XRD pattern of ZnO NS between 30º to40º to show the peak shift. (b)Crystal size of ZnO NS calculated using (101) plane.

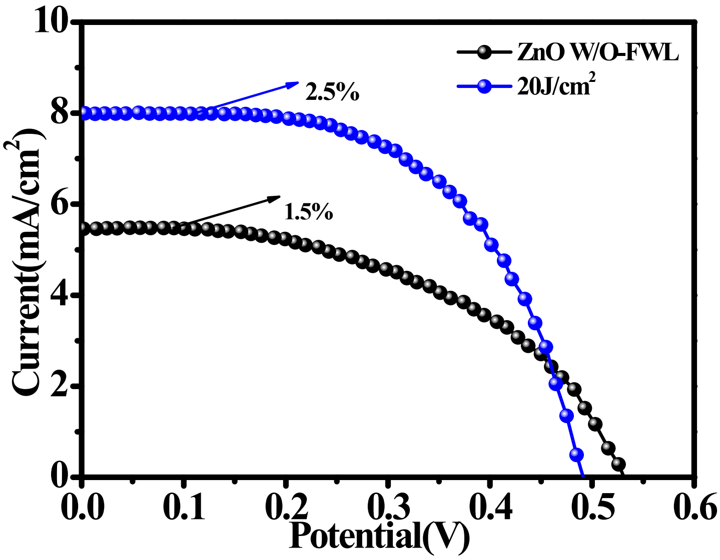


Figure S4. *J-V* curves of DSSCs consisting of a pristine ZnO NS and with FWL sintered ZnO NS.

Table S1. Detailed photovoltaic parameters summarized from the *J-V* curves in Figure 2.

Sample name	V_{oc} (V)	J_{sc} (mA/cm^2)	*FF*	PCE (η %)
ZnO-W/O FWL	0.55	5.4	0.50	1.5
FWL (15 J/cm^2)	0.53	6.9	0.56	2.0
FWL (20J/cm^2)	**0.56**	**6.7**	**0.65**	**2.5**
FWL (25J/cm^2)	0.53	5.1	0.42	1.1
FWL (30J/cm^2)	0.56	4.6	0.46	1.2
FWL (35J/cm^2)	0.52	5.3	0.46	1.3

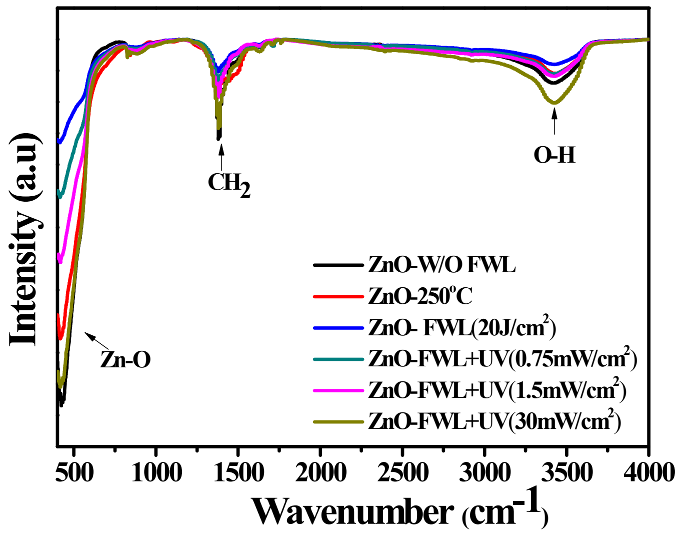


Figure S5. FTIR spectra of ZnO NS W/O FWL, thermal sintering and after photonic sintering.

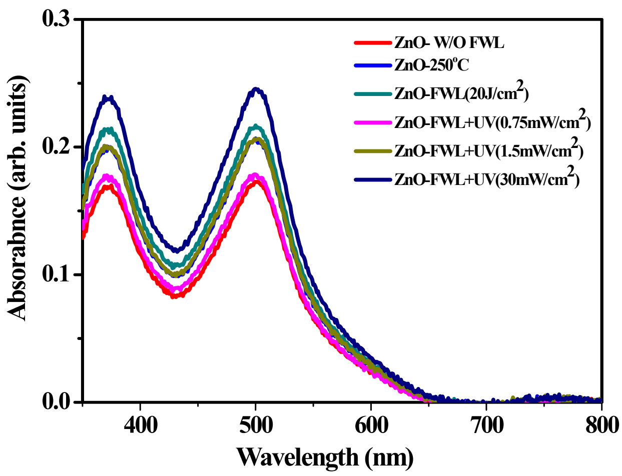


Figure S6. UV-vis absorption spectra of N 719-sentitized ZnO NS photoanode with thermal sintering, FWL sintering and without photonic sintering respectively.

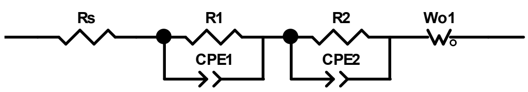


Figure S7. An equivalent circuit used for fitting the Nyquist plot.

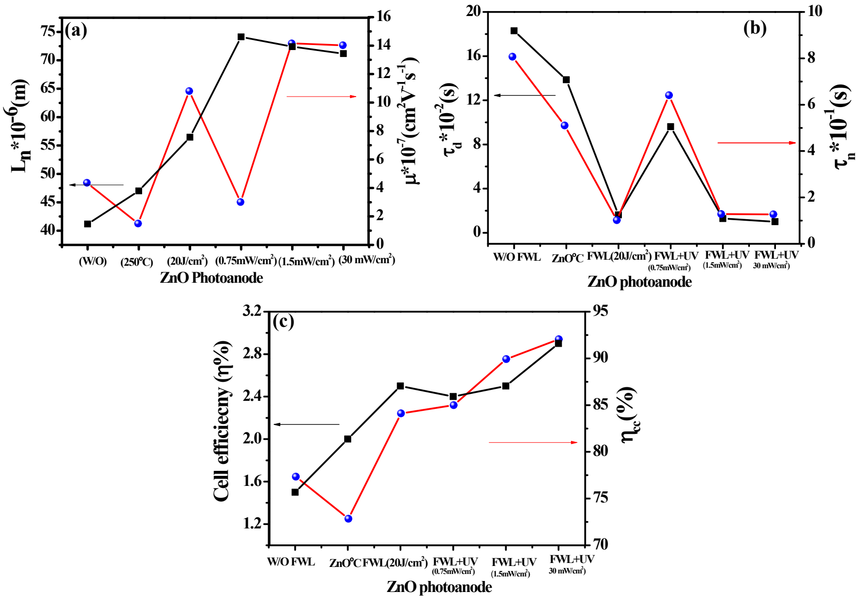


Figure S8. Represents diffusion length (L_n), and mobility(μ) (a), transit time($τ_d$), and electron life time ($τ_n$) (b)and charge collection efficiency ($η_{cc\%}$) and cell efficiency (η%) of ZnO NS photo anode(c) respectively.

Table S2. Electrochemical parameters calculated by using EIS for before and after photonic sintering ZnO NS.

Name	Efficiency (η %)	*f* (ω)	R_t (R_1)	R_{ct} (R_2)	$τ_n$ *10^{-1} (s)	$τ_d$*10^{-2} (s)	$η_{cc}$ (%)	L_nx10^{-6} (m)	D_nx10^{-10}	μx10^{-7} (cm^{2}V^{-1}s^{-1})
ZnO-W/O FWL	1.5	1.24	1.48	6.53	8.07	18.29	77.34	41.17	126	4.91
ZnO-250°C	2.0	1.96	2.04	7.51	5.10	13.85	72.84	47.01	43	1.68
ZnO-FWL(20J/cm^2)	2.5	9.85	1.05	6.61	1.02	01.62	84.12	56.45	312	12.15
ZnO-FWL+UV(0.75mW/cm^2)	2.4	1.56	0.91	6.07	6.41	09.60	85.00	74.12	86	3.38
ZnO-FWL+UV(1.5mW/cm^2)	2.5	7.83	0.55	5.45	1.28	01.29	89.92	72.40	410	15.93
ZnO-FWL+UV(30mW/cm^2)	2.9	7.84	0.51	6.44	1.27	01.01	92.04	71.18	406	15.78

The EIS measurement were performed to analyse the electron transport behaviour in the DSSCs, which distinguish the charge transport resistance of device. Using EIS, electron mobily, diffusion length, electron life time, diffusion coefficient was calculated which is shown Table S2.[1-6]

References

1. J. Bisquert, F. Fabregat-Santiago, I. Mora-Seró, G. Garcia-Belmonte and S. Giménez, *J. Phys. Chem. C*, 2009, **113**, 17278-17290.
2. C.-Y. Lin, Y.-H. Lai, H.-W. Chen, J.-G. Chen, C.-W. Kung, R. Vittal and K.-C. Ho, *Energy Environ. Sci.*, 2011, **4**, 3448 -3455.
3. S. S. Bhande, D. V. Shinde, S. F. Shaikh, S. B. Ambade, R. B. Ambade, R. S. Mane, Inamuddin, M. Naushad and S.-H. Han, *RSC Adv.*, 2014, **4**, 20527–20530.
4. V. Zardetto, F. Di Giacomo, D. Garcia-Alonso, W. Keuning, M. Creatore, C. Mazzuca, A. Reale, A. Di Carlo, T.M. Brown, *Adv. Energy Mater*., 3 (2013), pp. 1292–1298.
5. Y. Shi, C. Zhu, L. Wang, C. Zhao, W. Li, K. K. Fung, T. Ma, A. Hagfeldt and N. Wang, *Chem. Mater.*, 2013, **25**, 1000-1012.
6. G. Mincuzzi, L. Vesce, M. Liberatore, A. Reale, A. Di Carlo and T. M. Brown, *IEEE Trans. Electron Devices*, 2011, **58**, 3179–3188