Electronic Supplementary Information

Efficient energy harvesting in SnO_2 based dye-sensitized solar cell utilizing nano-amassed mesoporous zinc oxide hollow microspheres as synergy boosters

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XII. Table S4: EIS fitting parameter for DSSCs

I. FESEM image of SnO_2 nanoparticles based photoanode.

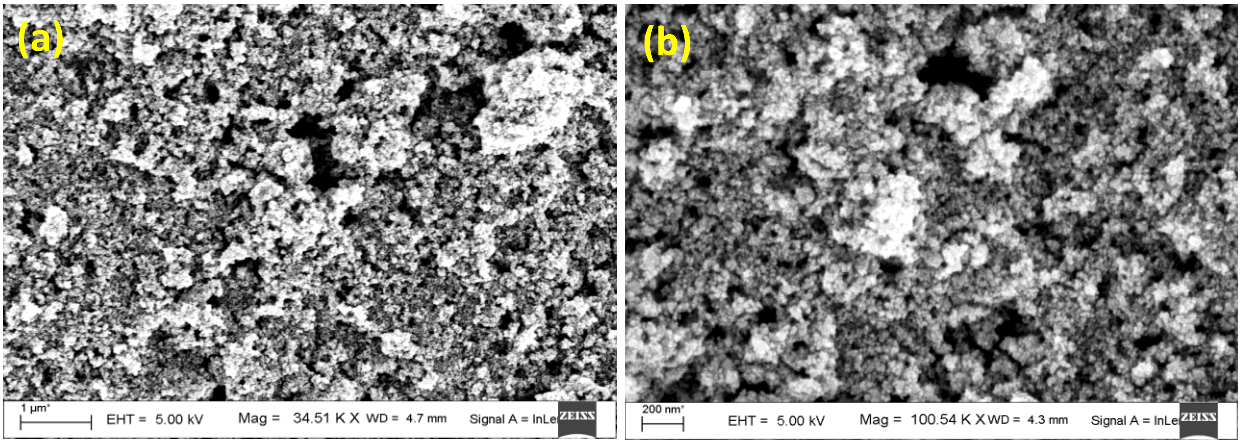

Figure S1. Low resolution (a) and high resolution (b) FESEM images of SnO_2 nanoparticle based photonode

II. Cross-sectional FESEM image of champion photoanode (SZ_{20})

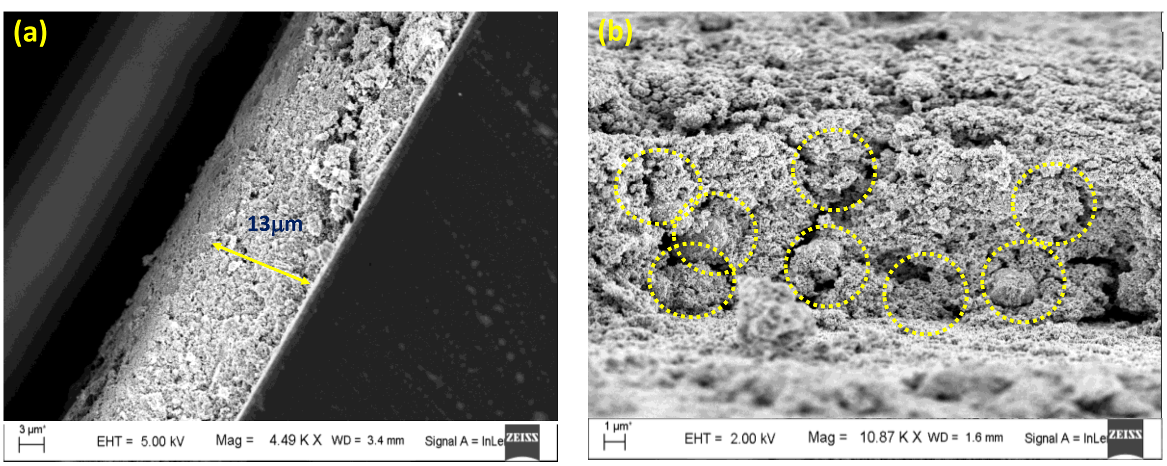

Figure S2. (a) Lower magnification and (b) Higher magnifiation cross-sectional FESEM image of photoanode SZ_{20}.

III. Top View FESEM image of champion photoanode (SZ_{20})

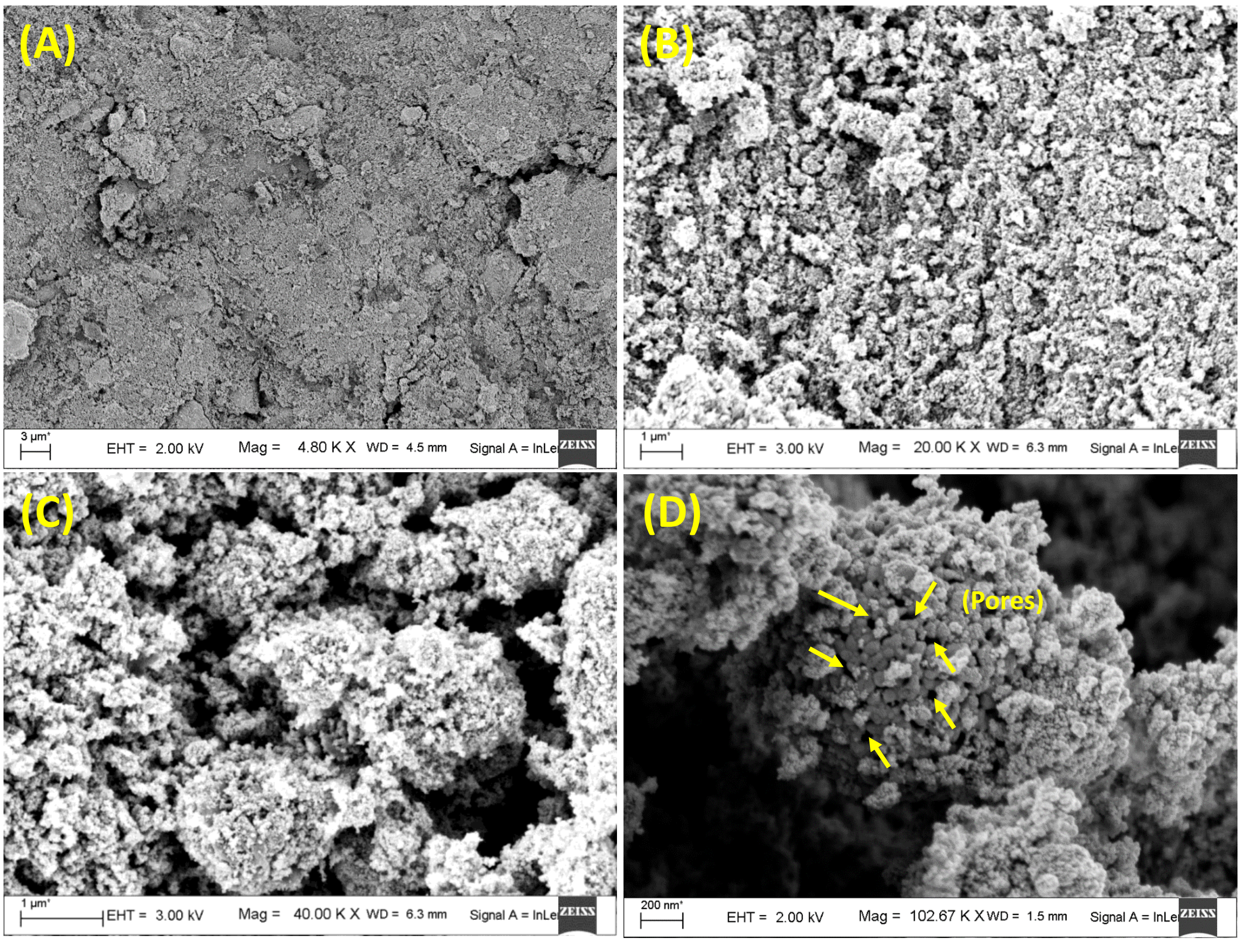

Figure S3. (a) Lower magnification and (b,c,d) Higher magnifiation top-view FESEM image of photoanode SZ_{20}.

IV. High-magnification TEM images of *meso*-ZnO hollow spheres

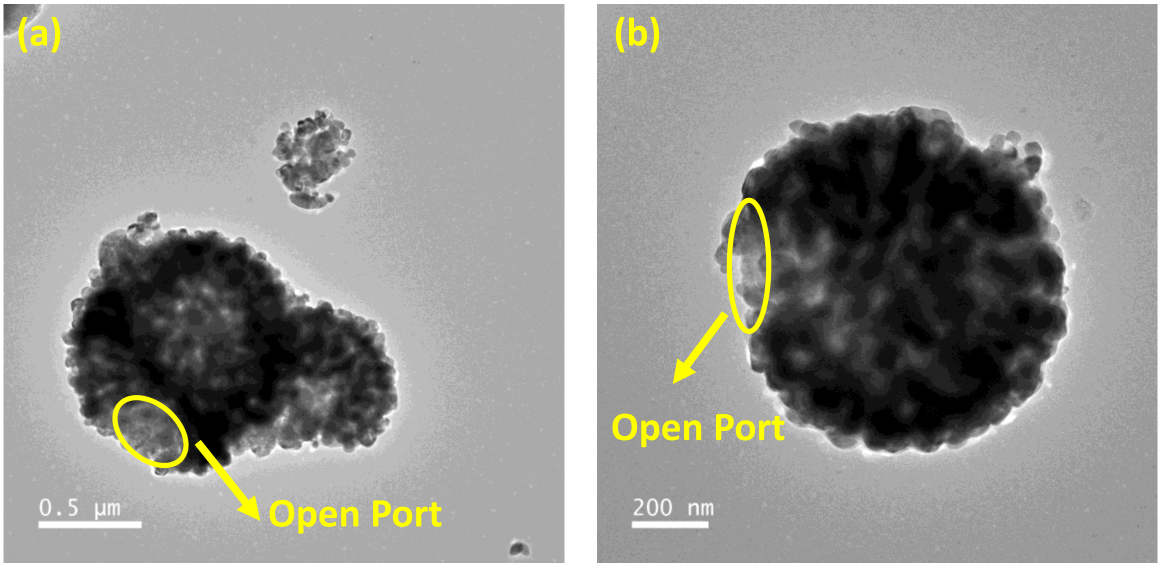

Figure S4. (a,b) Higher magnifiation TEM images of *meso*-ZnO Hollow spheres.

V. BET surface area analysis of SnO_2 nanoparticle.

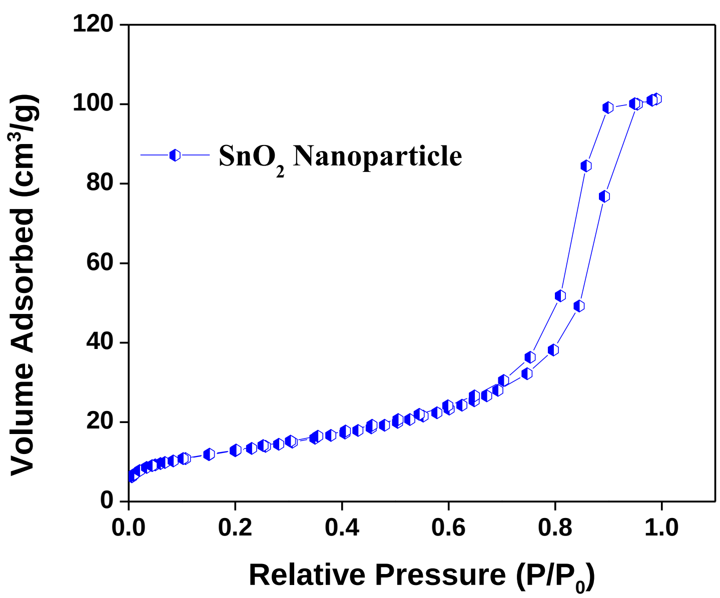

Figure S5: Nitrogen adsorption-desorption isotherms for SnO_2 nanoparticle.

VI. Current density-Voltage (J_{sc}-V) curve for bare ZnO HS based DSSC.

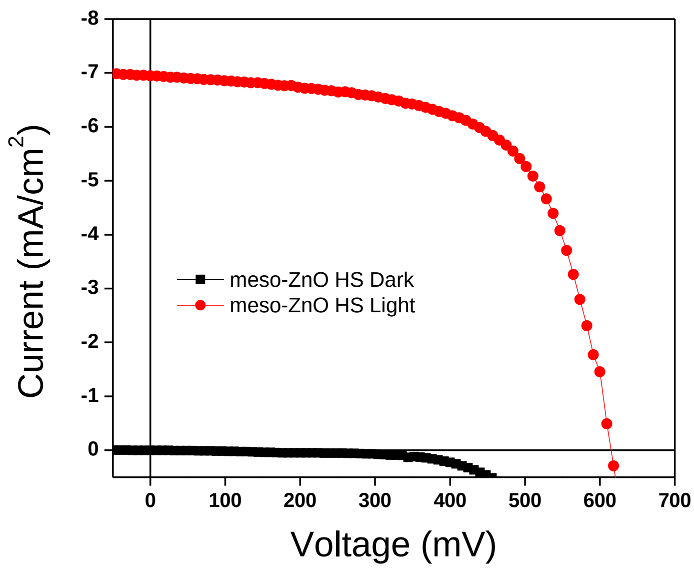

Figure S6: Short circuit current density- Voltage curve for bare ZnO HS DSSC

VII: Photovoltaic parameters of ZnO HS based DSSC

Table S1: Short-Circuit Photocurrent Density (J_{sc}),[a] Open-Circuit Voltage (V_{oc}),[a] Fill Factor (FF),[a] Power Conversion Efficiency (PCE, η) for the ZnO HS based fabricated DSSCs employing I^-/I_3^- Redox couple.

Device	J_{sc} (mA/cm^2)	V_{oc} (mV)	FF (%)	PCE (%)
Meso-ZnO HS	6.95 (±0.3)	616 (±8)	63.1 (±1.3)	2.71

[a]Data reported are the results of the best performed devices out of a minimum of five devices. The standard deviations for evaluated for five devices are included.

VIII: Chemisorption analysis

Table S2: Amount of dye chemisorbed for various photoanodes.

Photoanodes	Dye Adsorbed (mol.cm^{-2})

SnO_2	4.21×10^{-8}
SnO_2 NP_ZnO HS (9:1), SZ_{10}.	4.78×10^{-8}
SnO_2 NP_ZnO HS (8:2), SZ_{20}.	4.91×10^{-8}
SnO_2 NP_ZnO HS (7:3), SZ_{30}.	4.46×10^{-8}

Quantity of dye chemisorbed onto the photoanodes was estimated by employing a dye adsorption−desorption process using a 0.1 mM NaOH in equal proportion of ethanol/water (1:1, v/v). Briefly, each of the dye sensitized photoanodes were immersed in a 0.1mM NaOH solution in 1:1 ethanol: water mixture. The dipped photoanodes were then removed from the solution after complete desorption and the UV-vis absorption was recorded. The concentration of the dye desorbed per sq. cm area was then evaluated using Beer's law. [1]

IX. Energy dispersive X-ray spectroscopy (EDS) Analysis.

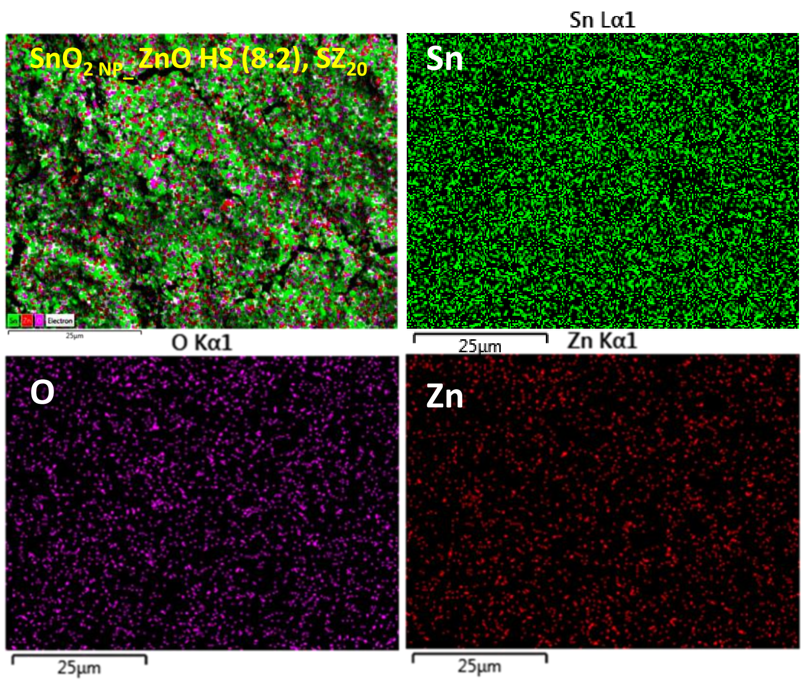

Figure S7: Energy dispersive X-ray spectroscopy (EDS) mapping of the best performing composite photoanode i.e. SnO_2 NP_ZnO HS (8:2), SZ_{20}.

X: A comparative study of various SnO_2_ZnO based Photovoltaics

Table S3: A comparative study of various SnO_2_ZnO based Photovoltaics.

Primary photoanode material used	**Secondary /Composite Material used**	**Sensitizer Used**	**PCE, η (%)**	**Reference**
SnO_2 nanoparticle	ZnO nanorod overlayer	N719	~2.62 %	2
SnO_2 nanoparticles	ZnO nanotetrapods	N719	~ 4.91 %	3
SnO_2 nanoparticles	ZnO microparticles	N719	~4.96 %	4
SnO_2	Li Doped ZnO nanoparticles (LZN)	N719	~2.06%	5
SnO_2 Nanoparticles	ZnO Nanotetrapods	N719	~6.31 %	6
SnO_2 Nanoparticle	ZnO Nanoparticle	D149	~3.6 %	7
SnO_2 Nanoparticle	ZnO Nanoparticle	N3	~ 1.5 %	7
SnO_2 Nanoparticle	**ZnO Hollow Sphere**	**N719**	**~4.37 %**	**Present Work**

XI: Stability tests of SnO_2 and SZ_{20} based DSSCs

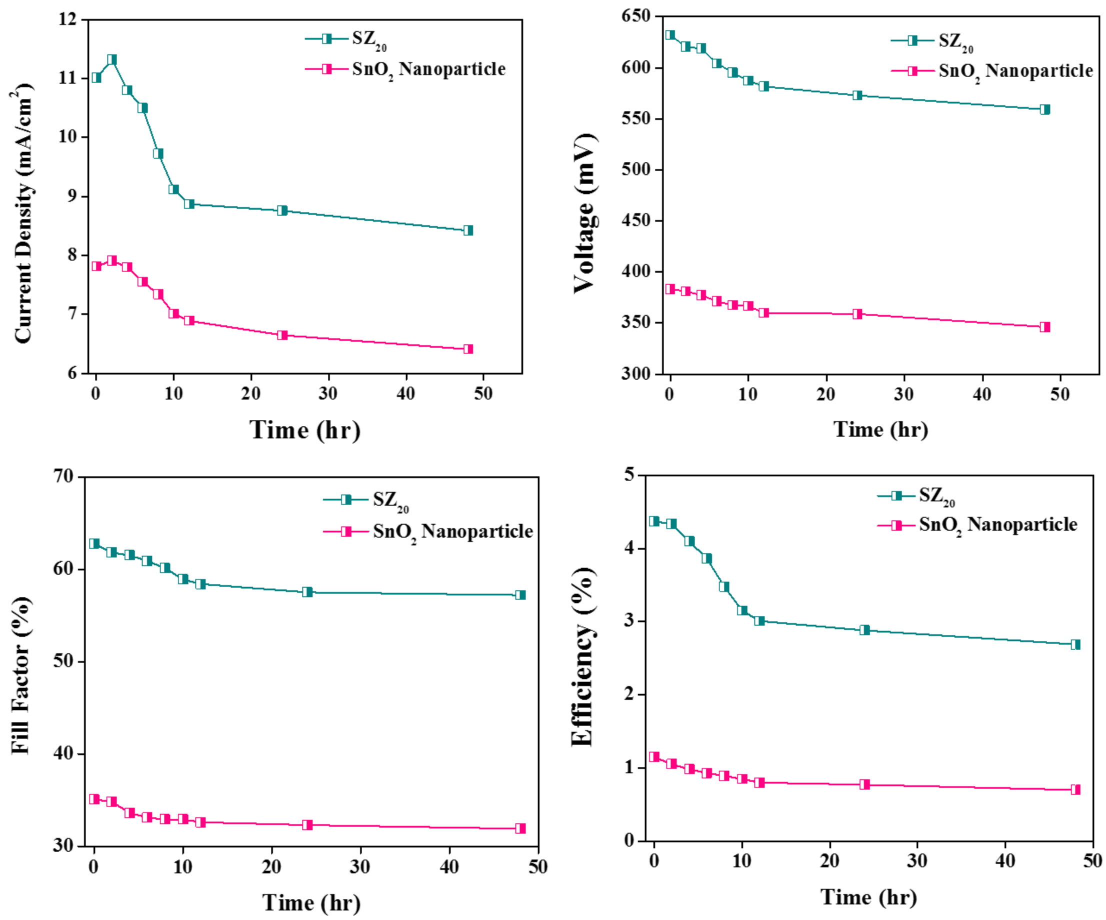

Figure S8: Stability tests for SnO_2 and SZ_{20} based DSSCs.

Figure S8 depicts the stability tests for the fabricated SnO_2 NP based and the best performed composite device i.e. SnO_2 NP_ZnO HS (8:2), SZ_{20} and here and included in the supporting information of the revised version. In order to check the stability of the devices, dependence of photovoltaic parameters such as short circuit current density (J_{sc}), open circuit voltage (V_{oc}), Fill factor (FF) and the power conversion efficiency (η) on time durations (over 48 h) are shown in Fig. R1. The photovoltaic characteristics are collected at an interval of 2h for 12h and then up to 48h in ambient condition and it has been found that SnO_2 NP based and SZ_{20} based devices show a ~39.1% and ~38.4% reduction of efficacy respectively after 48h duration.

XII: Table S4: EIS fitting parameters for devices

DSSC photoanode	R_s [a] (Ohm)	R_{ct1} [a] (Ohm)
SnO_2 NP	22.51	3.97
SnO_2 NP _ ZnO HS (9:1), SZ_{10}	21.83	4.17
SnO_2 NP _ ZnO HS (8:2), SZ_{20}	**20.11**	**3.91**
SnO_2 NP _ ZnO HS (7:3), SZ_{30}	21.65	4.06

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