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 # Supporting Information

An Efficient $Cu_2Zn_{1-x}In_xSn(S,Se)_4$ Multicomponent Photocathode via One-Step Hydrothermal Approach for Thin Film Solar Cell

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Table S1: Preparative parameters for hydrothermal synthesis of the $Cu_2Zn_{1-x}In_xSn(S,Se)_4$ thin films.

Sr. No.	Sample Code	In^{3+} ion concentration (M/mL)	Composition	pH	Temperature
1	I_1	0.00	$Cu_2ZnSn(S,Se)_4$	8.2 ± 0.2	$180 \pm 2^{\circ}C$
2	I_2	0.025	$Cu_2Zn_{0.075}In_{0.025}Sn(S,Se)_4$		
3	I_3	0.05	$Cu_2Zn_{0.05}In_{0.05}Sn(S,Se)_4$		
4	I_4	0.075	$Cu_2Zn_{0.025}In_{0.075}Sn(S,Se)_4$		

Table S2: Compositional data for $Cu_2Zn_{1-x}In_xSn(S,Se)_4$ thin films temperature.

Sample Code	Cu	Zn	In	Sn	S	Se	$\frac{(Zn+In)}{Sn}$	$\frac{Cu}{(Zn+In+Sn)}$	$\frac{(Cu+Zn+In+Sn)}{(S+Se)}$
I_1	25.4	14.4	0.0	14.2	23.5	22.5	1.11	0.84	1.24
I_2	25.7	11.6	4.2	14.4	22.1	22	1.09	0.85	1.26
I_3	25.9	10.4	5.6	13.8	21.5	22.8	1.15	0.86	1.25
I_4	**26.2**	**10.1**	**6.2**	**13.4**	**20.3**	**25.8**	**1.21**	**0.88**	**1.18**

Figure S1. Plot of thickness associated with band gap energy of $Cu_2Zn_{1-x}In_xSn(S,Se)_4$ films as a function of In^{3+} ion concentration.

The thickness of the CZITSSe films is analyzed with surface profilometer. The thickness of the CZITSSe thin films was increased from 540 to 645 nm as function of In^{3+} ion concentration. As a thickness of films increases, the band gap energy was decreased from 1.42 to 1.34 eV.

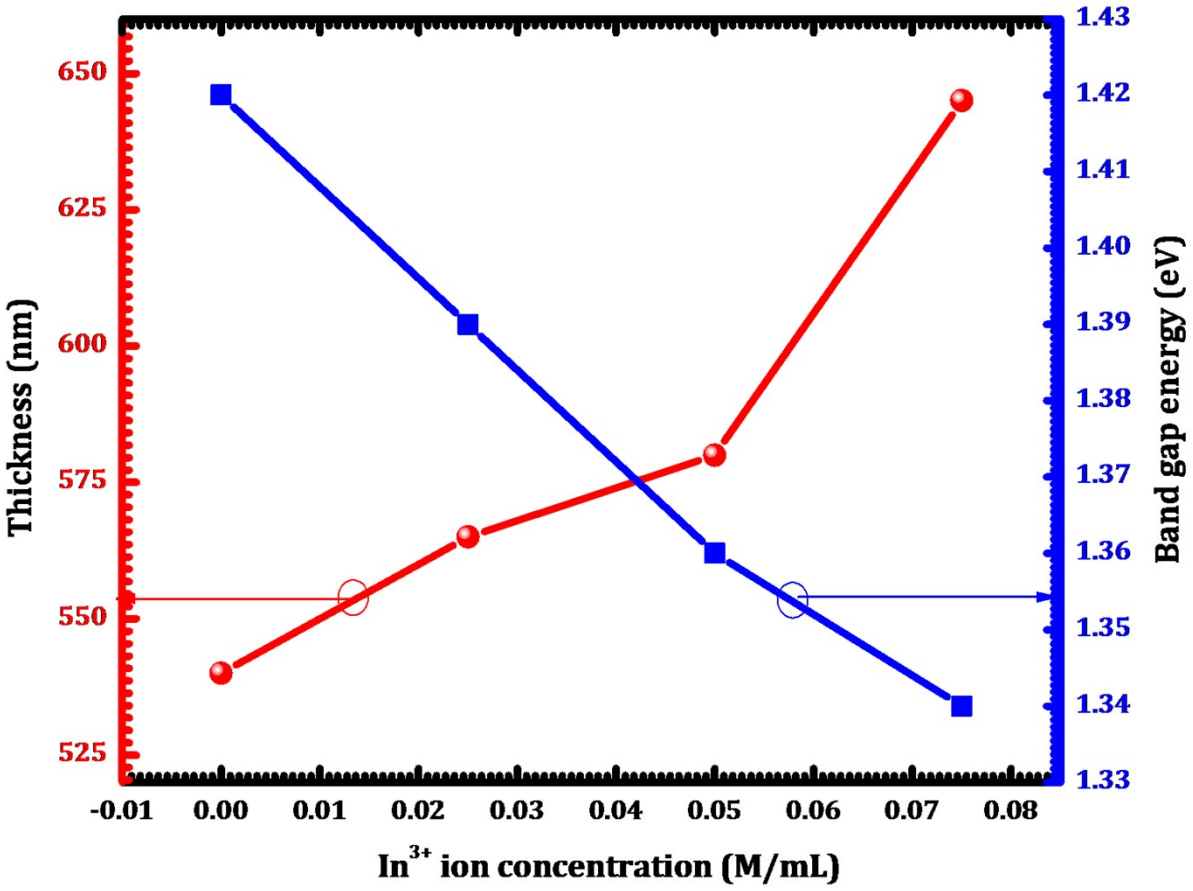

Figure S2: The cross-section SEM images of deposited CZTSSe and In^{3+} doped CZITSSe (I_1-I_4) thin films

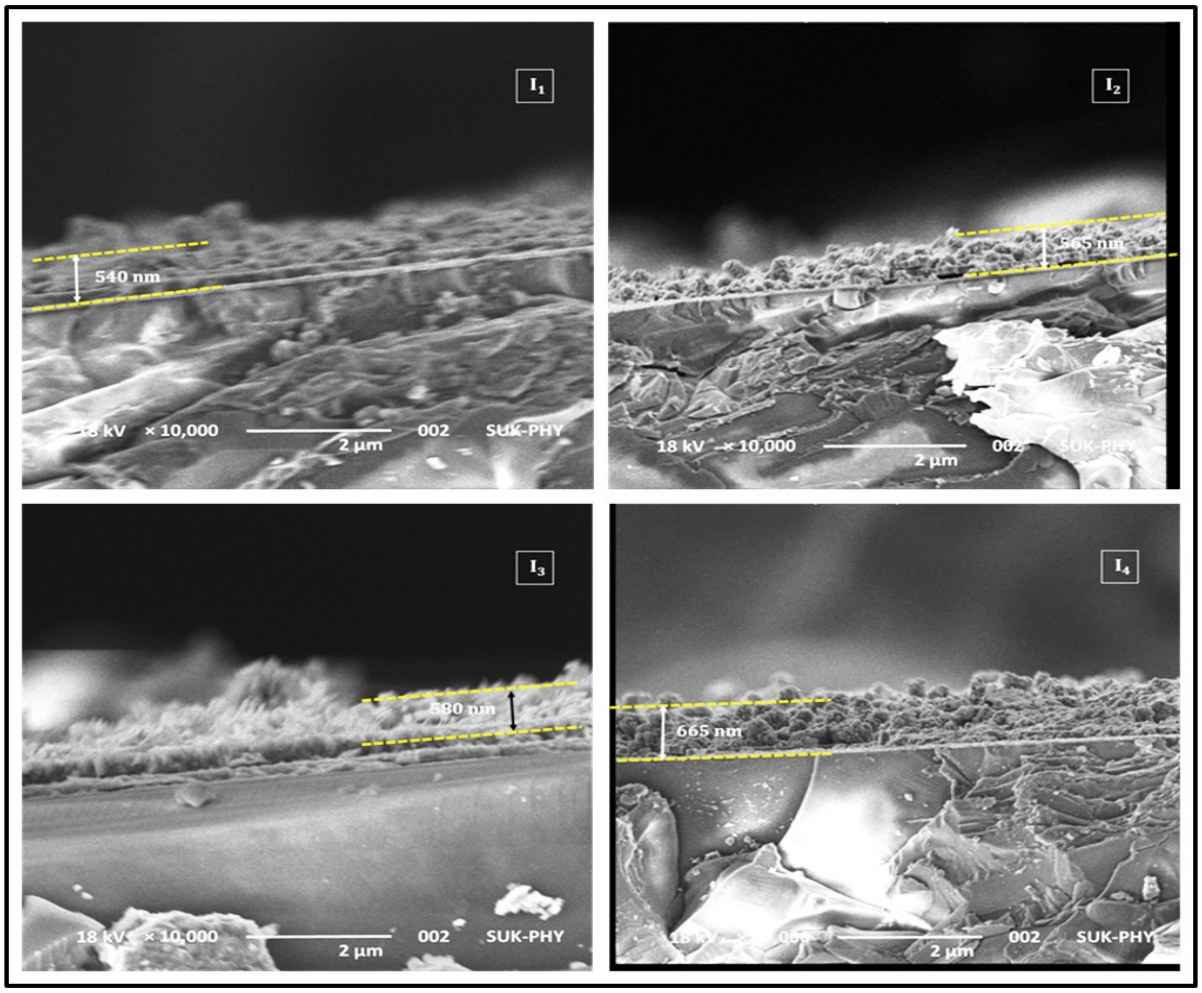

Figure S3: Correlation between J_{sc} corresponding to V_{oc} as a function of In^{3+} ion concentration in photoelectrochemical performance.

Figure S3 (a, b) depicts the correlated data of $Cu_2Zn_{1-x}In_xSn(S,Se)_4$ thin films respectively. As In^{3+} ion concentration increases the short circuit current and open circuit voltage increases.