Electronic Supplementary Information

Metal Sulfide Precursor Aqueous Solutions for Fabrication of $Cu_2ZnSn(S,Se)_4$ Thin Film Solar Cells

Qingwen Tian, Lijian Huang, Wangen Zhao, Yanchun Yang, Gang Wang*, and Daocheng Pan*

State Key Laboratory of Rare Earth Resource Utilization, Changchun Institute of Applied Chemistry, Chinese Academy of Sciences, 5625 Renmin Street, Changchun Jilin, 130022, China, University of Chinese Academy of Sciences, Beijing 100039, P. R. China

*E-mail: wsu@ciac.ac.cn and pan@ciac.ac.cn

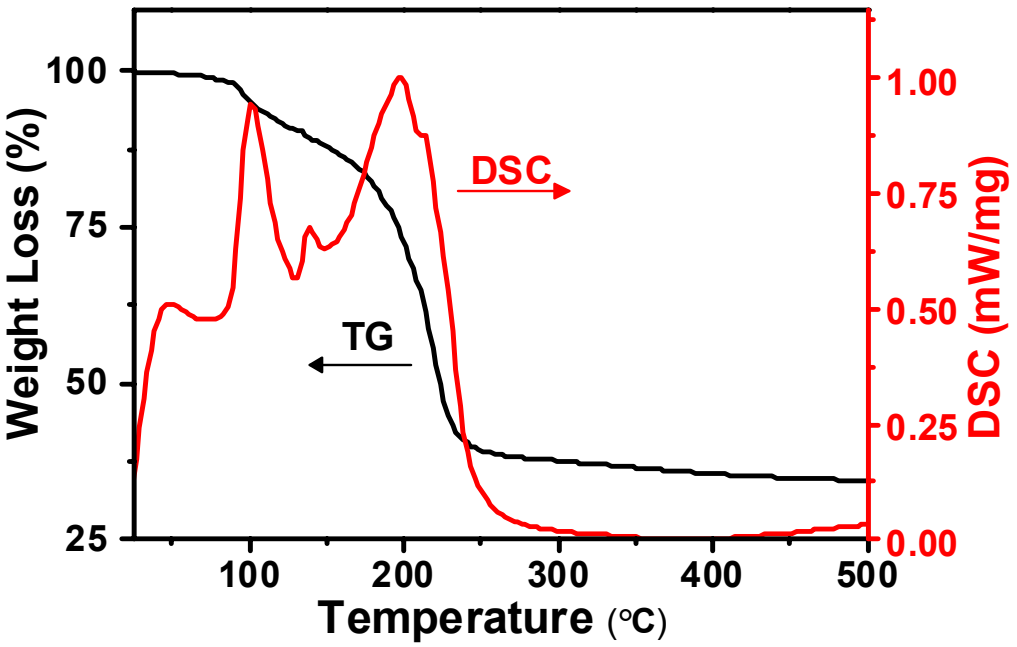

Figure S1. Thermogravimetric analysis and the corresponding differential scanning calorimetry curves of the CZTS precursor.

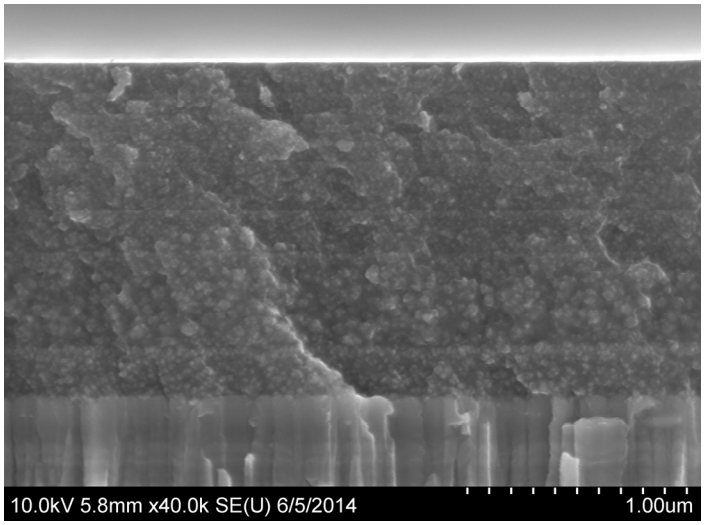

Figure S2. Cross-sectional SEM image of as-deposited CZTS nanocrystal thin film.

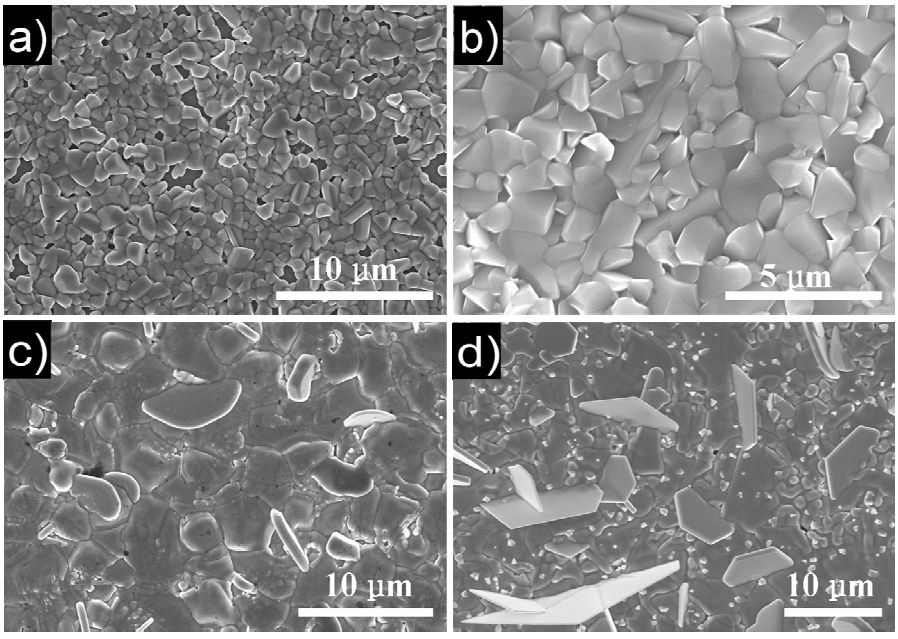

Figure S3. SEM images of the selenized CZTSSe thin films on Mo-coated SLG substrates with different (Cu/(Zn+Sn) ratios (a: 0.75:1; b: 0.8:1; c: 0.85:1; d: 1.2:1) while Zn/Sn ratio was fixed at 1.2:1.

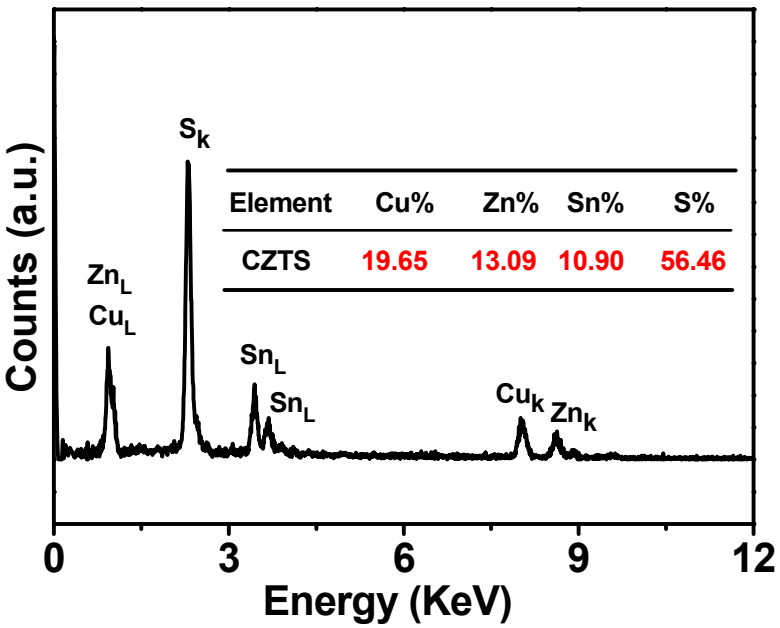

Figure S4. EDX spectrum and chemical composition of as-prepared CZTS thin film.

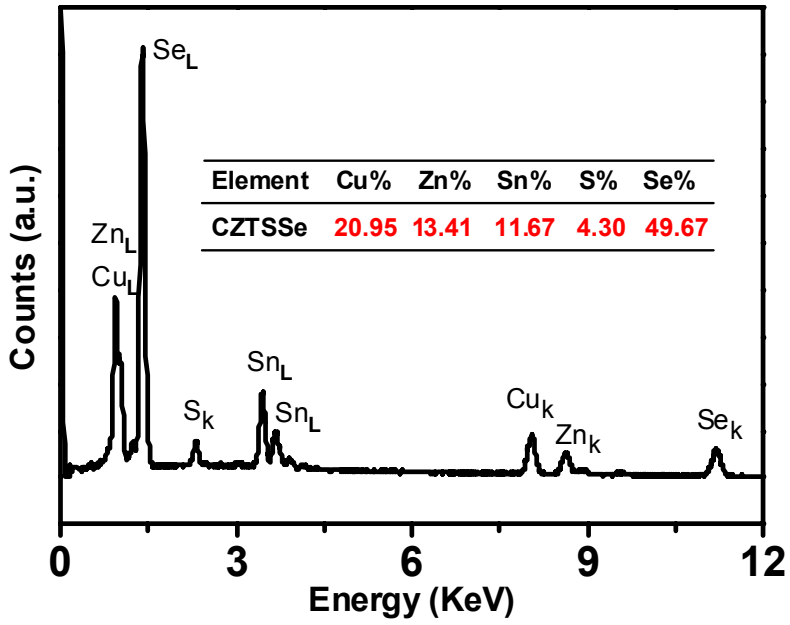

Figure S5. EDX spectrum and chemical composition of selenized CZTSSe thin film.

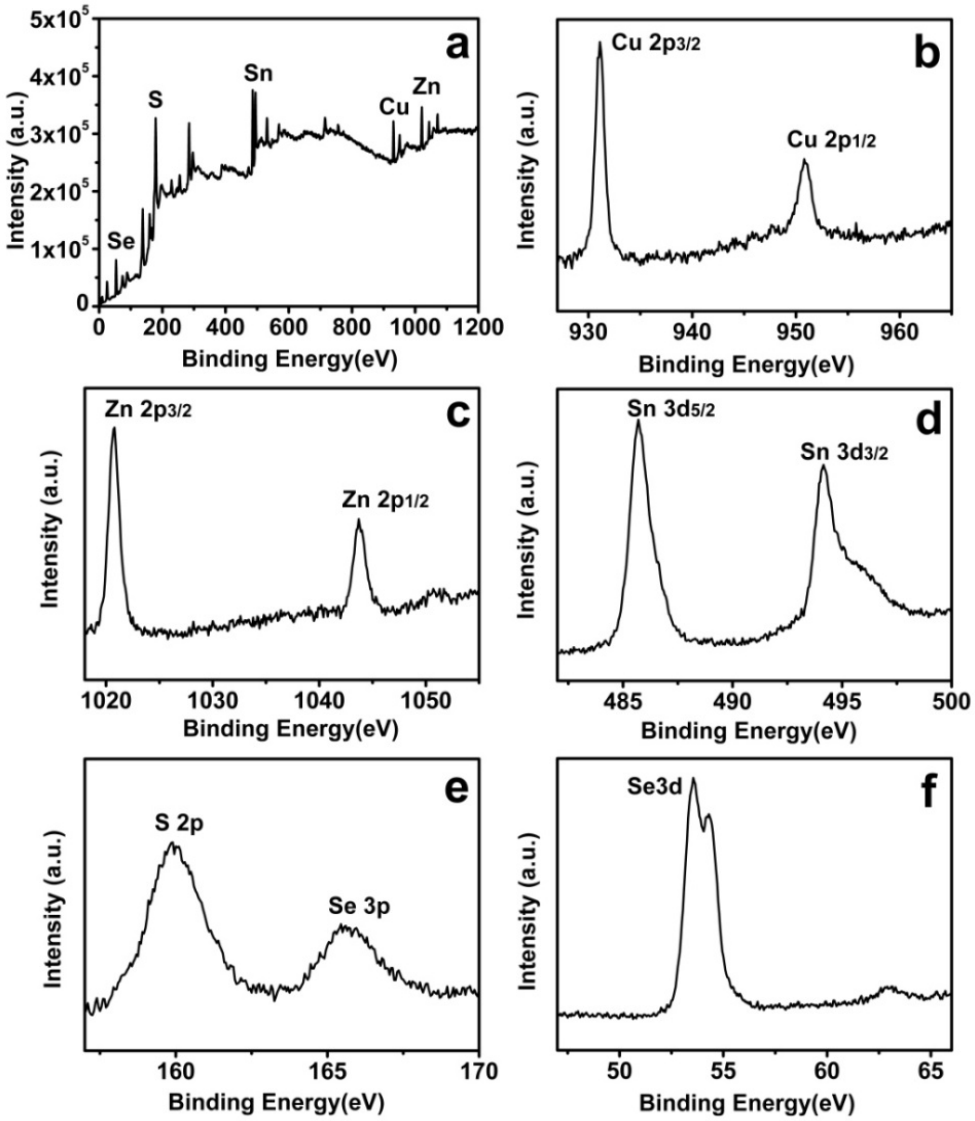

Figure S6. XPS spectra of the selenized CZTSSe thin film.

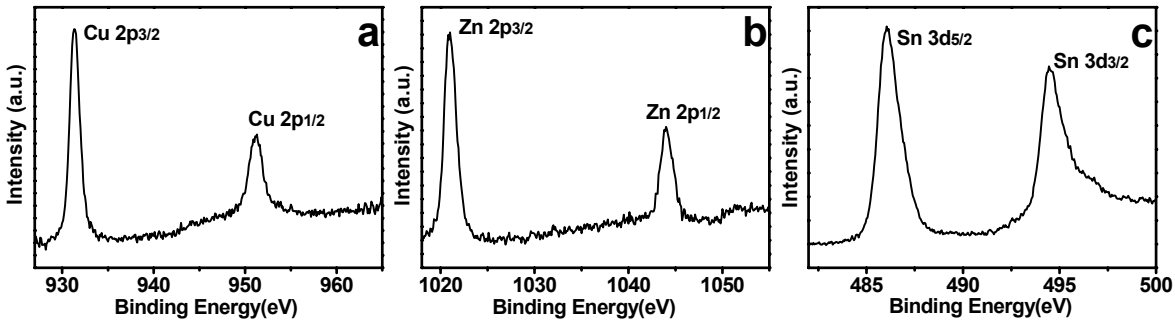

Figure S7. XPS spectra of the as-prepared CZTS thin film.

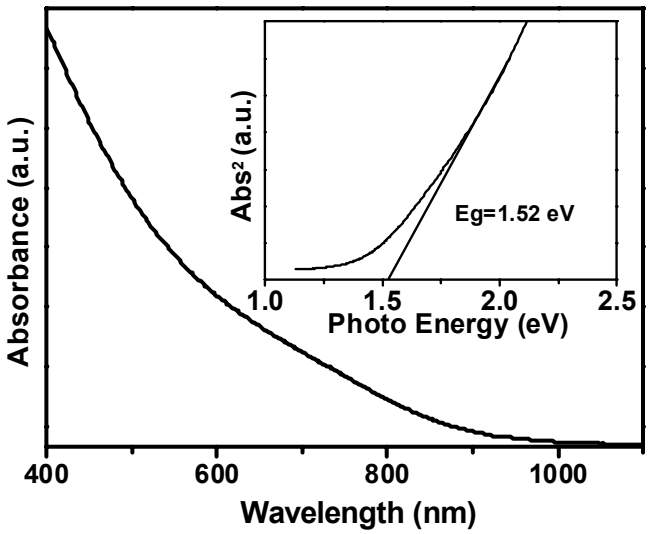

Figure S8. The UV-vis-NIR absorption spectrum of as-deposited Cu_2ZnSnS_4 nanocrystal thin film and its corresponding plot of $(Abs)^2$ *vs* E.

Table S1. The detailed solar cell parameters of nine CZTSSe solar cells.

	V_{oc} (V)	J_{sc} (mA/cm^2)	*FF* (%)	η (%)
1	0.421	30.68	51.24	6.62
2	0.414	30.49	51.30	6.47
3	0.407	30.60	51.70	6.44
4	0.404	30.57	51.24	6.33
5	0.403	30.52	51.11	6.29
6	0.430	28.86	50.56	6.28
7	0.419	29.61	50.35	6.25
8	0.402	30.51	50.95	6.25
9	0.424	29.72	48.67	6.13
Average efficiency (%):				6.34

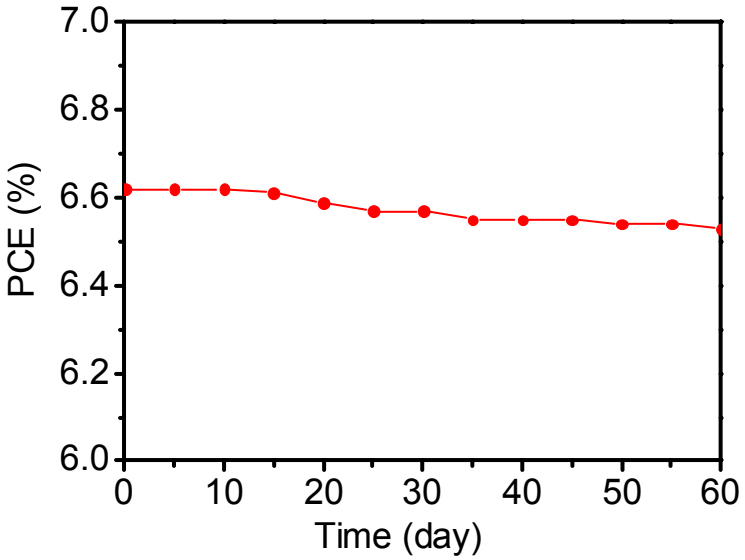

Figure S9. Stability of CZTSSe solar cell stored in air for 60 days.