Electronic Supplementary information for

Quantification of effective thermal conductivity in the annealing process of $Cu_2ZnSn(S,Se)_4$ solar cells with 9.7% efficiency fabricated by magnetron sputtering

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Table S1 Chemical composition and compositional ratio of the CZTSSe absorber films.

	Elemental Component					Compositional Ratio			
	Cu (at%)	Zn (at%)	Sn (at%)	Se (at%)	S (at%)	Cu/ (Zn + Sn)	Zn/Sn	(Se + S)/ Metal	Se/S
CZTSSe HTC-1	22.66	13.18	12.35	38.91	12.9	0.89	1.07	1.08	3.02
CZTSSe HTC-2	22.74	14.82	12.17	36.04	14.24	0.84	1.22	1.01	2.53
CZTSSe HTC-3	21.7	15.45	12.07	36.44	14.34	0.79	1.28	1.03	2.54
CZTSSe LTC-1	23.84	12.63	12.01	34.11	17.4	0.97	1.05	1.06	1.96
CZTSSe LTC-2	22.42	15.23	11.98	32.42	17.95	0.82	1.27	1.01	1.81
CZTSSe LTC-3	22.18	16.22	11.05	32.75	17.8	0.81	1.47	1.02	1.84

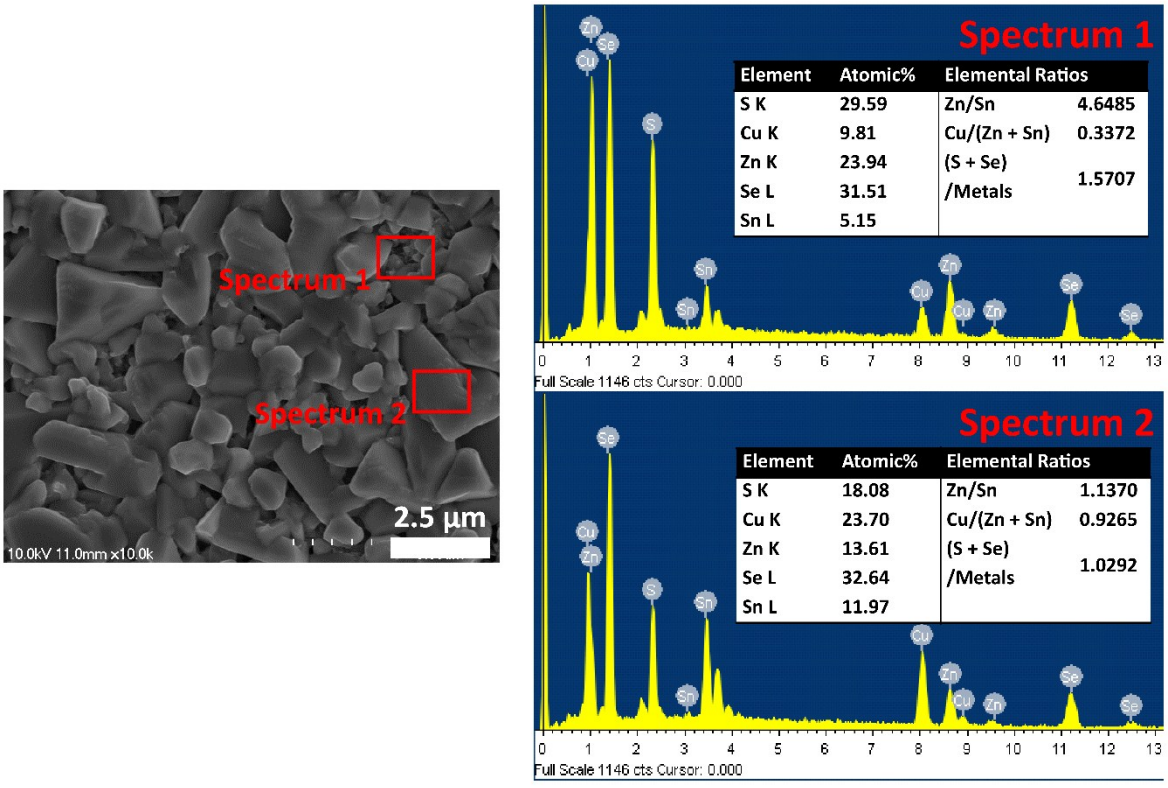

Fig. S1 EDX spectra and atomic composition of CZTSSe LTC-2 absorber film. Spectrum 1 shows that small grains were mainly formed by Zn, S, and Se, and Spectrum 2 shows that the compositional ratio of the large grains were found to be Zn/Sn = 1.14, and Cu/(Zn + Sn) = 0.93 (Cu-poor and Zn-rich).

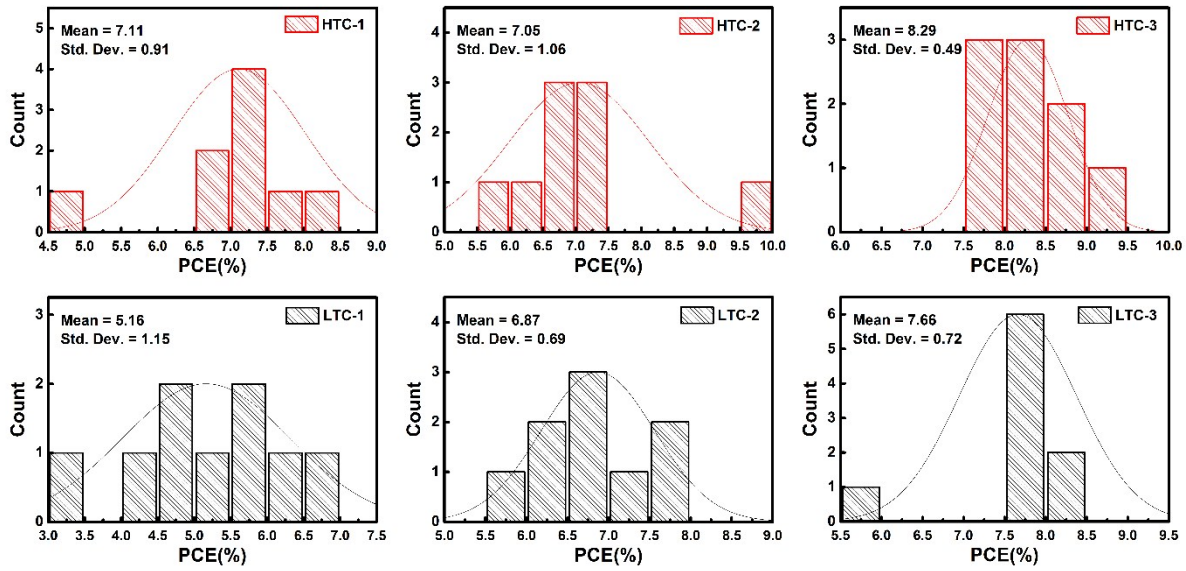

Fig. S2 Histograms showing power conversion efficiency and the normal distribution curve of the six solar cells.

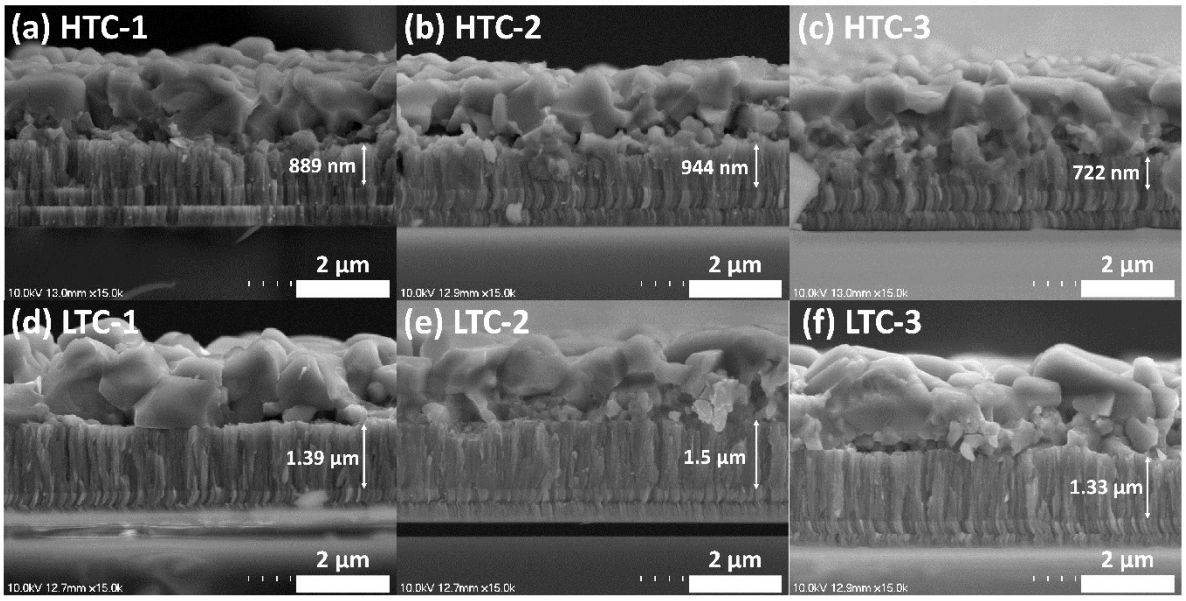

Fig. S3 Cross-sectional SEM images of the CZTSSe absorber layers fabricated by sulfo-selenization with either an HTC (a– c) or an LTC (d– f) graphite box. The thickness of $Mo(S,Se)_2$ is (a) 889 nm, (b) 944 nm, (c) 722 nm, (d) 1.39 μm, (e) 1.5 μm, and (f) 1.33 μm.

(별표 제4호 나-02)

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Test Results

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[Appendix 1]

Chonnam National University
CZTSSe solar cell

Device ID : CZTSSe #1
Date of Test : April 25, 2017
Simulator : WACOM, WXS-155S-L2 (Class-AAA)
Reference solar cell : KIER-SS-UF #1
Test condition : STC (AM1.5G, 100 mW/cm^2, 25.0 ± 1.0 °C)

Device Area : 0.190 16 cm^2 (active area)
Sample Type : CZTSSe solar cell (glass substrate)

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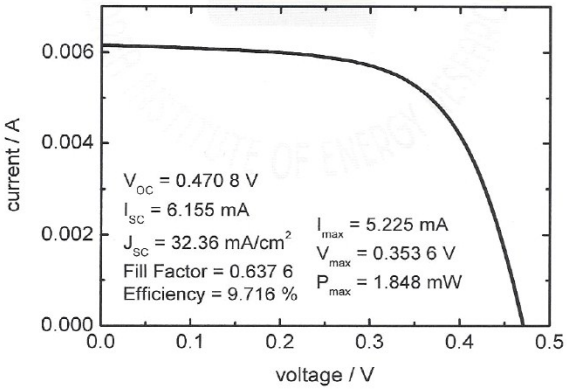

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Fig. S4 Certificated power conversion efficiency of the best performing CZTSSe solar cell (CZTSSe HTC-2).