SUPPLEMENTARY MATERIAL FOR

WIDE BAND GAP KESTERITE ABSORBERS FOR THIN FILM SOLAR CELLS: POTENTIAL AND CHALLENGES FOR THEIR DEPLOYMENT IN TANDEM DEVICES

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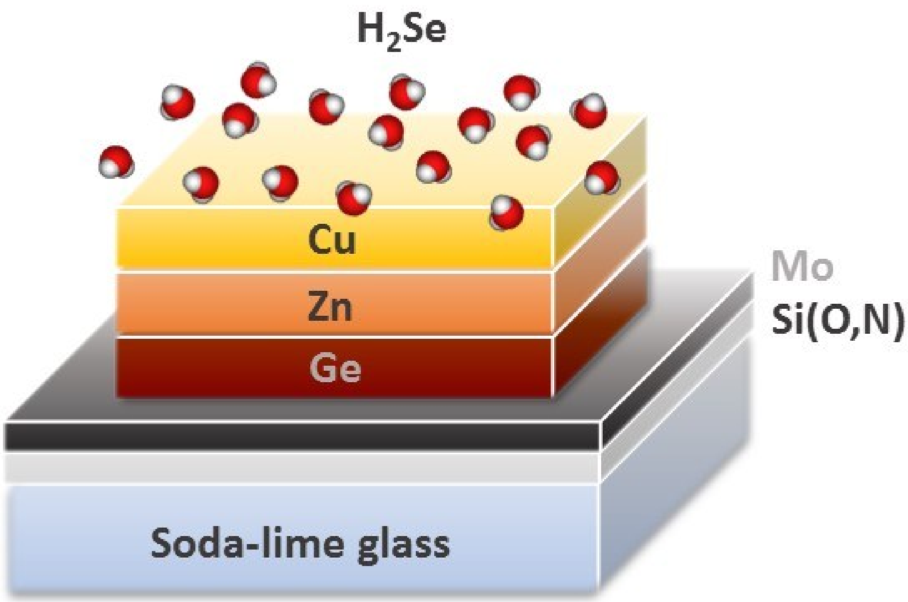

Figure S1: Schematic representation of the two-step selenization process used for EVAP-$Cu_2ZnGeSe_4$ absorber fabrication.

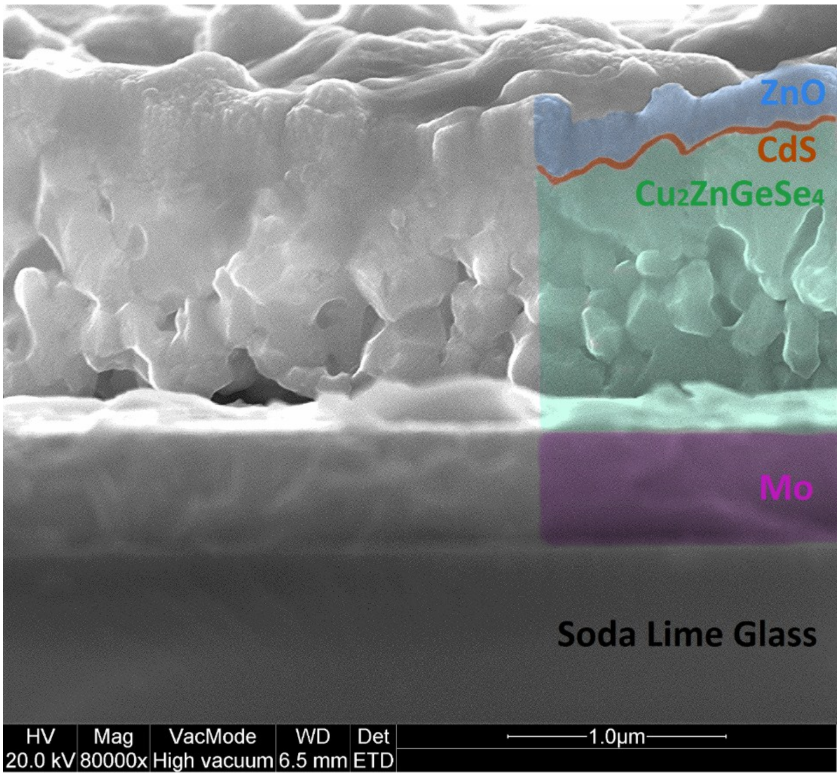

Figure S2: Cross-section scanning electron microscopy image of a finished EVAP-$Cu_2ZnGeSe_4$ solar cell sample, showing the grain morphology of the absorber and contact layer.

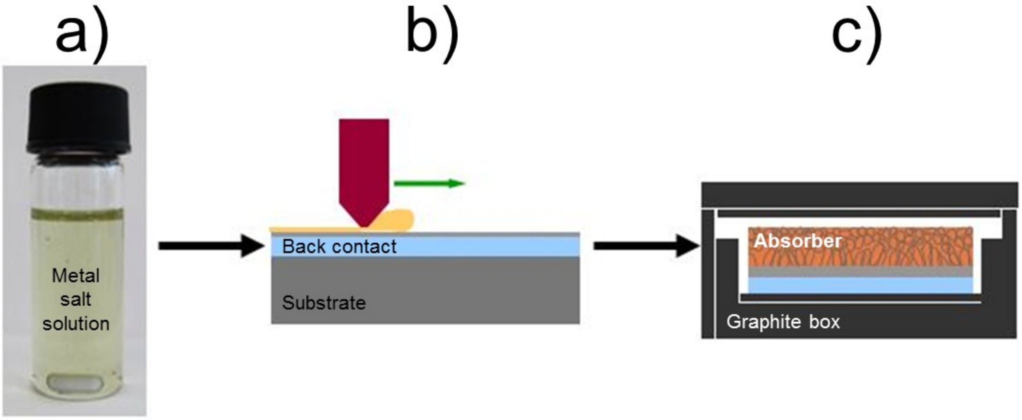

Figure S3: Schematic illustration of the solution process of preparing a SOL-$Cu_2ZnGe(S,Se)_4$ absorber: a) metal salt solution, b) doctor blade coating, c) annealing in Se atmosphere.

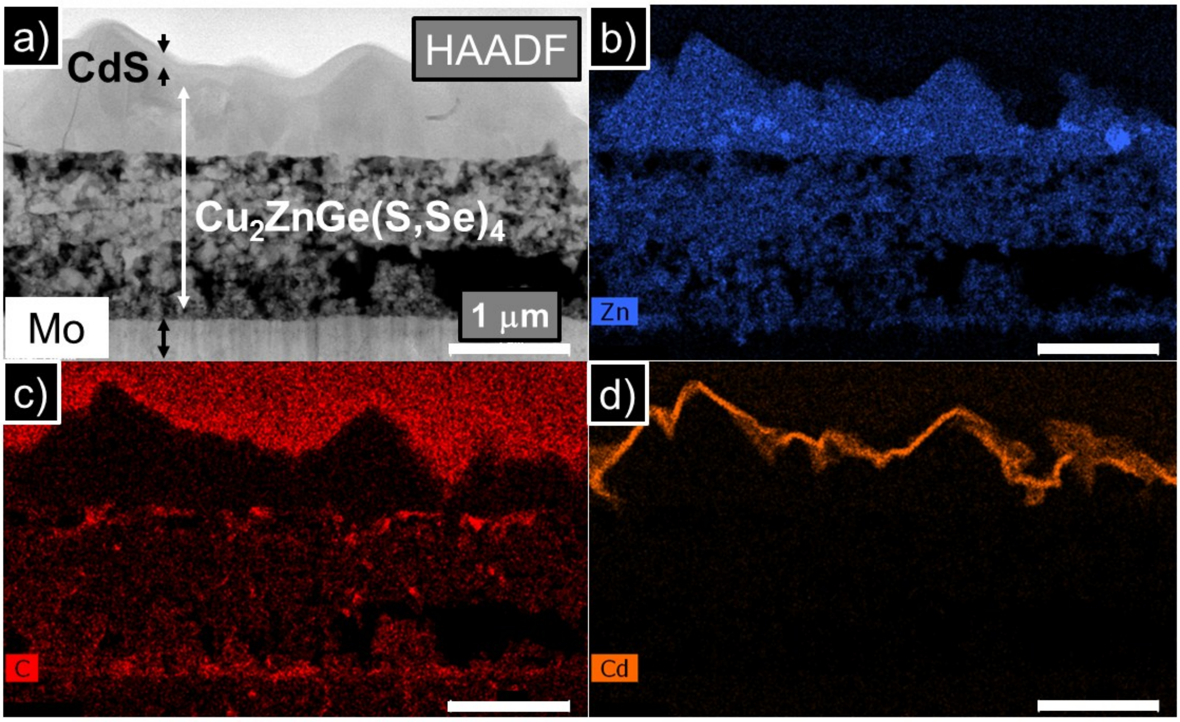

Figure S4: Cross-section high angle annular dark field (HAADF) STEM image of a SOL-$Cu_2ZnGe(S,Se)_4$-based solar cell with CdS buffer and ZnO window (a), and the elemental maps of Zn (b), C (c) and Cd (d).

Buffer layer	V_{OC} (mV)	FF (%)	J_{SC} (mA/cm^2)	E_G (eV)	Eff. (%)
CBD CdS[17]	617	54.1	18.0	1.47	6.0
CBD Zn(O,S)	512	51.2	17.7	1.51	4.6
rf-$Zn(O_{0.6}S_{0.4})$ [17]	730	48.3	13.0	1.54	4.6
ALCVD In_2S_3[17]	469	48.2	14.9	1.49-1.54	3.4
Co-evap. $CdIn_2S_4$[17]	354	49.6	14.7	1.44	2.6

Table S1: Electrical parameters for the most efficient buffer/SOL-$Cu_2ZnGe(S,Se)_4$ solar cells.

Parameter	ZnO:Al	CdS	$Cu_2ZnGe(S,Se)_4$	$MoSe_2$[31]	MoO_3[32]
d (µm)	0.120	0.050	1-2	0.04-0.10	0.04
E_G (eV)	3.3	2.4	1.47-1.5	1.1	2.85
χ (eV)	4.4	4.2	4.54	4.14	2.6
μ_n (cm^2/V.s)	100	100	10	100	100
μ_p (cm^2/V.s)	25	25	2	25	20
N_d (cm^{-3})	10^{18}	$3x10^{17}$	-	-	-
N_A (cm^{-3})	-	-	$2x10^{15}$ / $10^{16(O)}$	10^{16}	10^{18}
R_s ($\Omega.cm^{-1}$)	4.7 / $0.5^{(O)}$				
R_{sh} ($\Omega.cm^{-1}$)	365 / $800^{(O)}$				

Table S2: Parameters used in the simulations at standard solar cell test conditions.

$^{(O)}$ Optimized parameters.

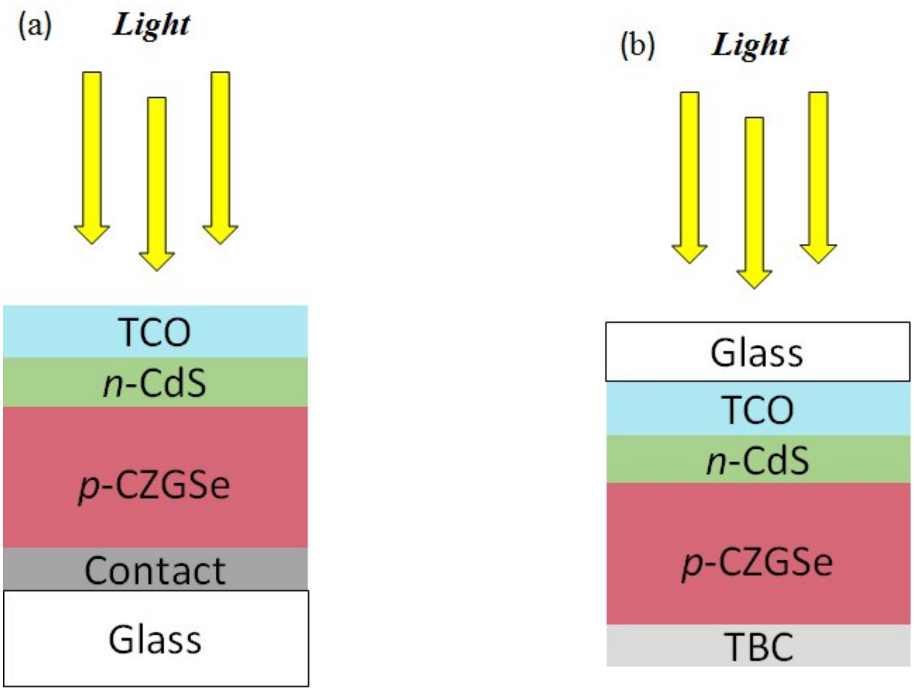

Figure S5: Schematic of the two different configurations considered in the device simulations: (a) substrate and (b) superstrate.

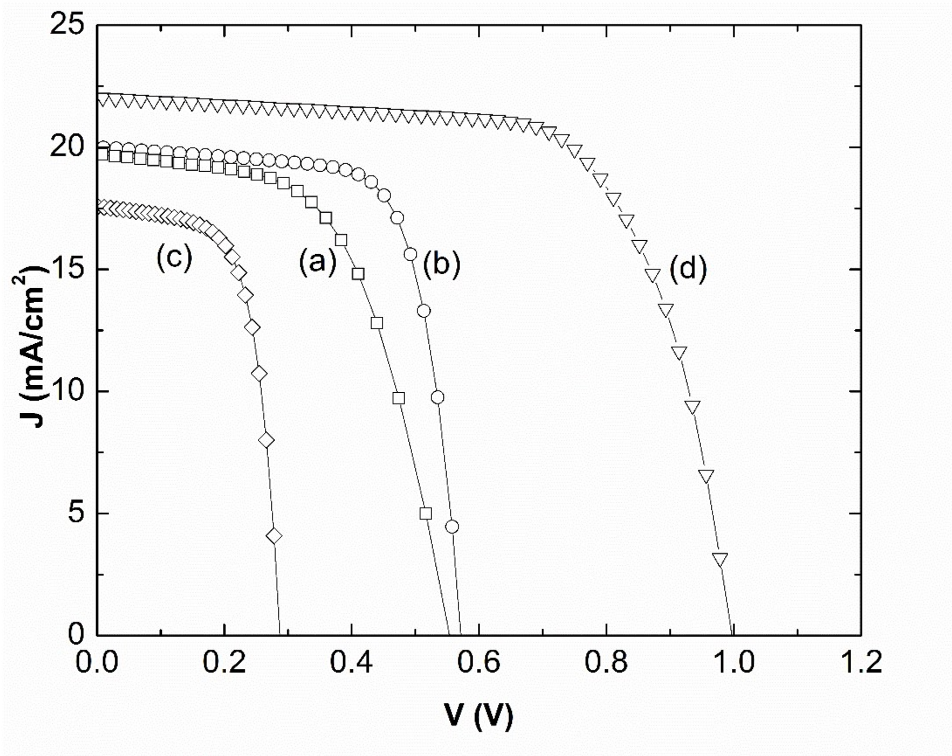

Figure S6: Calculated J(V) curves for different substrate/superstrate configurations: (a) substrate = $Cu_2ZnGe(S,Se)_4/MoSe_2/Mo$/glass, (b) same configuration as (a) but using optimized device simulation parameters (see Table S2), (c) superstrate = $Cu_2ZnGe(S,Se)_4$/TCO, and (d) superstrate = $Cu_2ZnGe(S,Se)_4/MoO_3$/TCO. For configurations (c) and (d) also optimized parameters were used in the device simulation.