

## Supporting Information

# Unveiling the Influence of Absorber Thickness on Efficient Sb<sub>2</sub>(S, Se)<sub>3</sub> Solar Cells Through Controlled Chemical Bath Deposition

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**Table S1.** Prepared materials for each layers of solar cells.

Each layers of solar cells	Prepared materials
CdS	Thiourea, NH <sub>3</sub> OH aqueous solution, and Cadmium Sulfate
Sb <sub>2</sub> (S,Se) <sub>3</sub>	C <sub>4</sub> H <sub>4</sub> KO <sub>7</sub> Sb·0.5H <sub>2</sub> O, Na <sub>2</sub> S <sub>2</sub> O <sub>3</sub> ·5H <sub>2</sub> O, and Selenourea (CH <sub>4</sub> N <sub>2</sub> Se)
Spiro-OMeTAD	Spiro-OMeTAD, Chlorobenzene, and 4-tert-butylpyridine lithium bis

**Supplementary note 1. Background of DLTS measurements**

The deep-level transient spectroscopy (DLTS) was used to analyze the deep defects in the Sb<sub>2</sub>(S,Se)<sub>3</sub> absorber layer of 2H and 4H solar cells. Fig. 6(b) shows the arrhenius plots obtained from defect peaks in DLTS signal. The active energy ( $E_A$ ,  $E_C-E_T$  or  $E_T-E_V$ ) and capture cross section ( $\sigma$ ) of electron and hole defects are calculated from the Arrhenius plots according to the following equations.

$$\ln(\tau_e \nu_{th,n} N_C) = \frac{E_C - E_T}{k_B T} - \ln(X_n \sigma_n) \quad (1)$$

$$\ln(\tau_e \nu_{th,p} N_V) = \frac{E_T - E_V}{k_B T} - \ln(X_p \sigma_p) \quad (2)$$

There,  $\tau_e$ ,  $N_C$ ,  $N_V$ ,  $E_C$ ,  $E_V$  and  $E_T$  are the emission time constant, conduction band state density, valence band state density, conduction band, valence band, and trap energy level, respectively.  $X_n$  and  $X_p$  are the entropy factor of hole and electron,  $\sigma_n$  and  $\sigma_p$  are the electron and hole defects capture cross-section, respectively.  $T$  and  $k_B$  are the temperature and Boltzmann constant,

respectively.  $v_{th,n}$  and  $v_{th,p}$  are the thermal velocities associated with electron and hole defects.

The  $v_{th,n}$  and  $N_C$  can be obtained by following equations.

$$v_{th,n} = \sqrt{\frac{3kT}{m_n^*}} \quad (3) \quad N_C = 2 \left( \frac{2\pi m_n^* kT}{h^2} \right)^{\frac{3}{2}}$$

(4)

Where  $m_n^*$  is the effective mass for electrons, with similar equations for  $v_{th,p}$  and  $N_V$ . The activation energy of electron ( $E_C-E_T$ ) and hole ( $E_T-E_C$ ) traps were obtained from the slopes of equations (2) and (3) through linear regression.  $\sigma_n$  and  $\sigma_p$  values can be extracted from the intersection with y-axis. Defect concentration ( $N_T$ ) can be obtained from following equations.

$$N_T = 2N_S \frac{\Delta C}{C_R} \quad (5)$$

$$N_S = \frac{2C^2}{q\epsilon A^2} (V + V_d) \quad (6)$$

Where  $N_T$  and  $N_S$  are the trap density and the shallow dopant concentration, respectively.  $C_R$  is the capacitance under reverse bias, and  $\Delta C$  is the amplitude of capacitance transient.  $V$  and  $V_d$  are the applied voltage and diffusion voltage, respectively.”