NANO · MICRO
small

# Supporting Information

for *Small*, DOI 10.1002/smll.202302581

Sodium Incorporation for Performance Improvement of Solution-Processed Submicron $CuIn(S,Se)_2$ Thin Film Solar Cells

*Yao Gao, Guanchao Yin* and Martina Schmid**

Supporting Information

# Sodium incorporation for performance improvement of solution-processed submicron $CuIn(S,Se)_2$ thin film solar cells

Yao Gao, Guanchao Yin*, Martina Schmid*

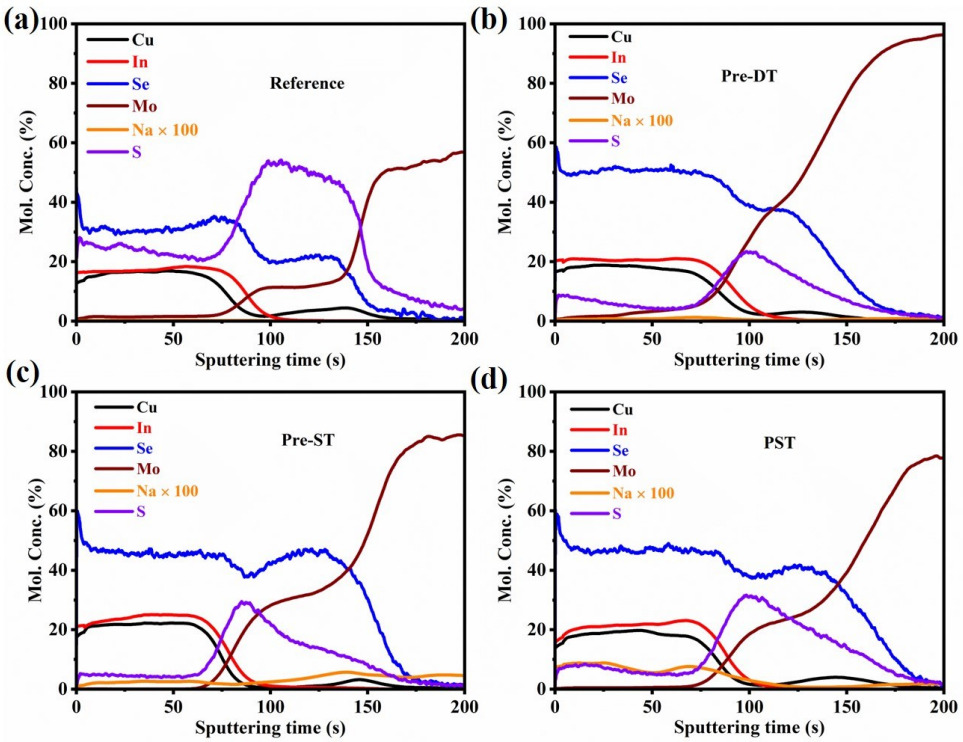


Figure S1 Composition depth profiles of CISSe absorbers without/with Na incorporation measured by GDOES. (a) Reference CISSe, (b) Pre-DT CISSe, (c) Pre-ST CISSe, and (d) PST CISSe. All these measurements are carried out after removing the CdS/i-ZnO/AZO top layers by 10% HCl etching.

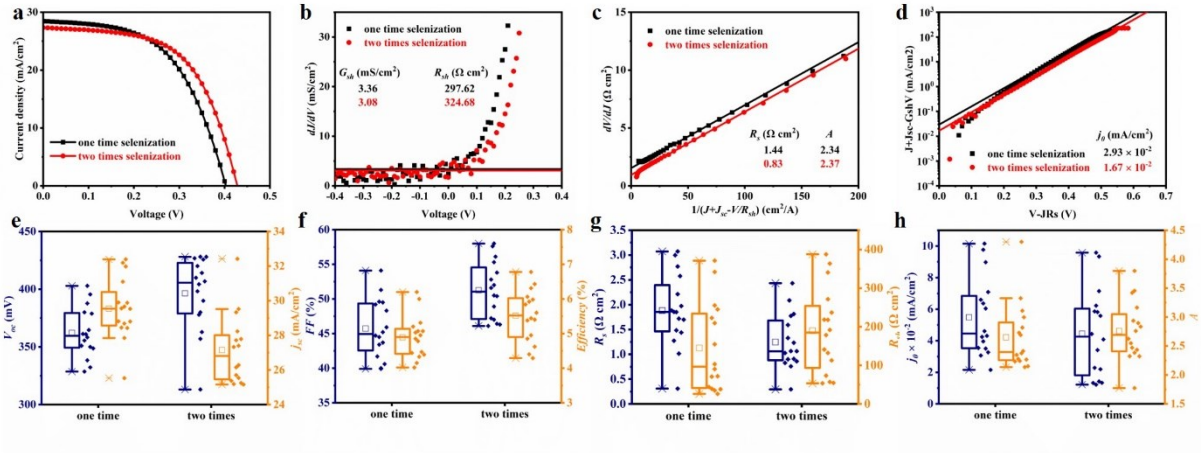


Figure S2 (a) *J-V* curves, (b) shunt resistance ($R_{sh}$), (c) series resistance ($R_s$) and ideality factor ($A$), and (d) reverse saturation current density ($j_0$) of best CISSe solar cells with one time or two times selenization. Statistical distributions of (e) $V_{oc}$ and $j_{sc}$, (f) *FF* and Efficiency, (g) $R_s$ and $R_{sh}$, (h) $j_0$ and $A$ derived from 16 devices for CISSe solar cells with one time or two times selenization.

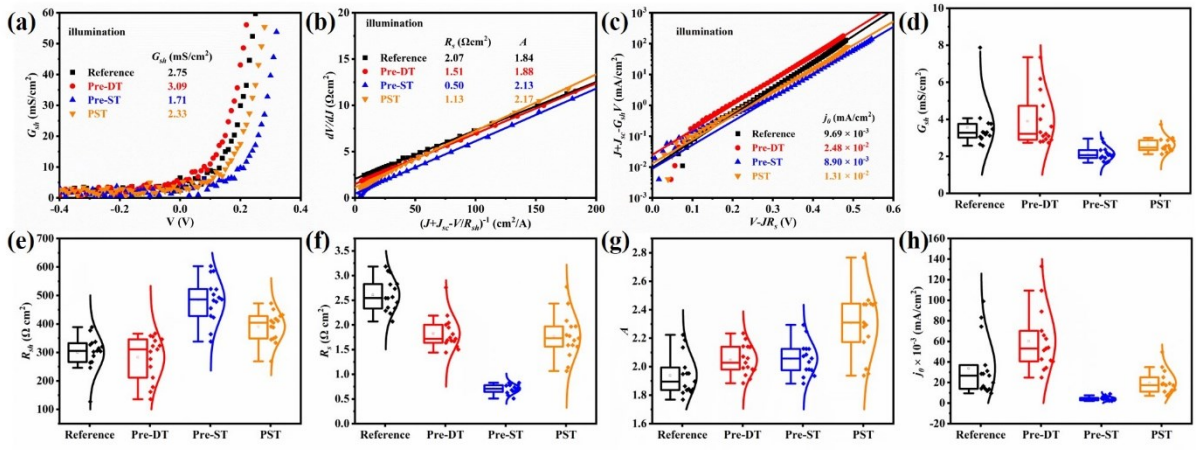


Figure S3 Plots of (a) $G_{sh}$ *vs.* $V$, (b) d$V$/d$J$ *vs.* $1/(J+J_{sc}-V/R_{sh})$ for derivation of $R_s$ and $A$, and (c) semi-logarithmic plot of $J+J_{sc}-G_{sh}V$ *vs.* $V-JR_s$ to determine $j_0$. Statistical distribution of (d) $G_{sh}$, (e) $R_{sh}$, (f) $R_s$, (g) $A$, and (h) $j_0$.

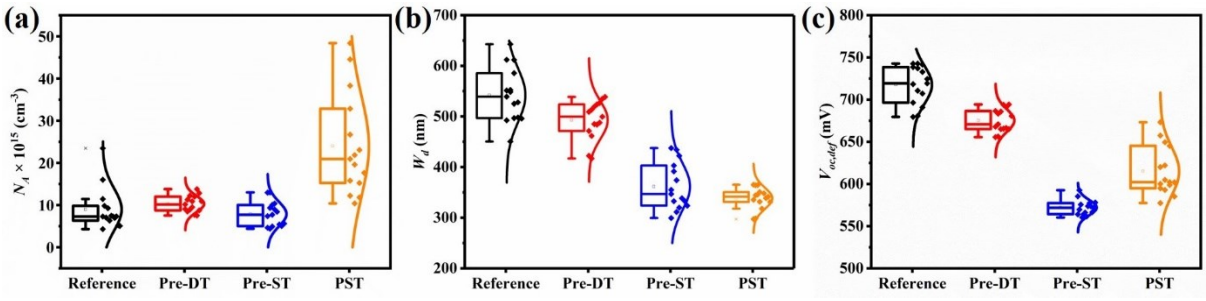


Figure S4 Statistical distribution of (a) $N_A$, (b) $W_d$, and (c) $V_{oc,def}$ derived from measurements of 15 CISSe sub-cells.

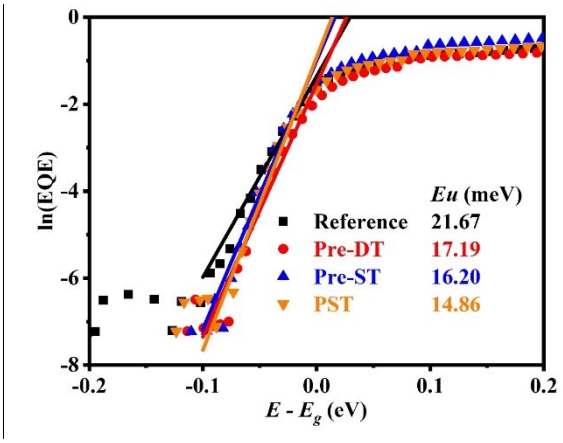


Figure S5 ln(EQE) vs ($E$ - $E_g$) of CISSe solar cells in the long-wavelength edge of EQE for the calculation of $E_U$ of CISSe absorbers with various Na incorporation strategies.

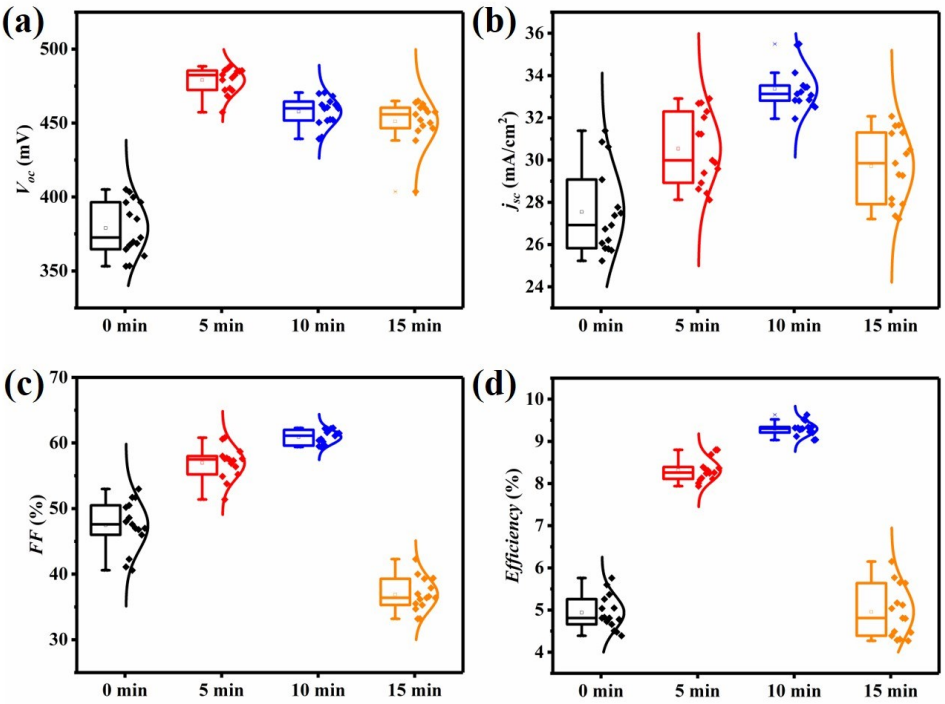


Figure S6 Statistical distribution of (a) $V_{oc}$, (b) $j_{sc}$, (c) $FF$, and (d) efficiency derived from 15 CISSe devices with 1 M NaCl aqueous-ethanol solution Pre-ST for various times.

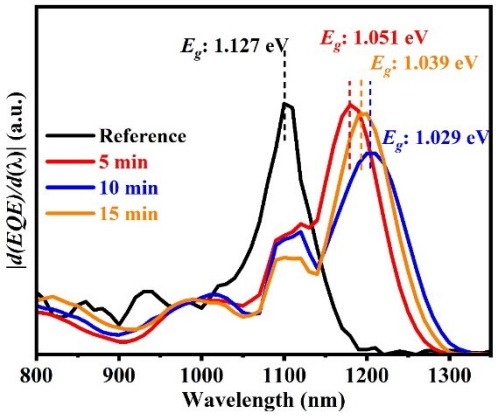


Figure S7 Band gaps of CISSe devices with 1 M NaCl aqueous-ethanol solution Pre-ST for various times.

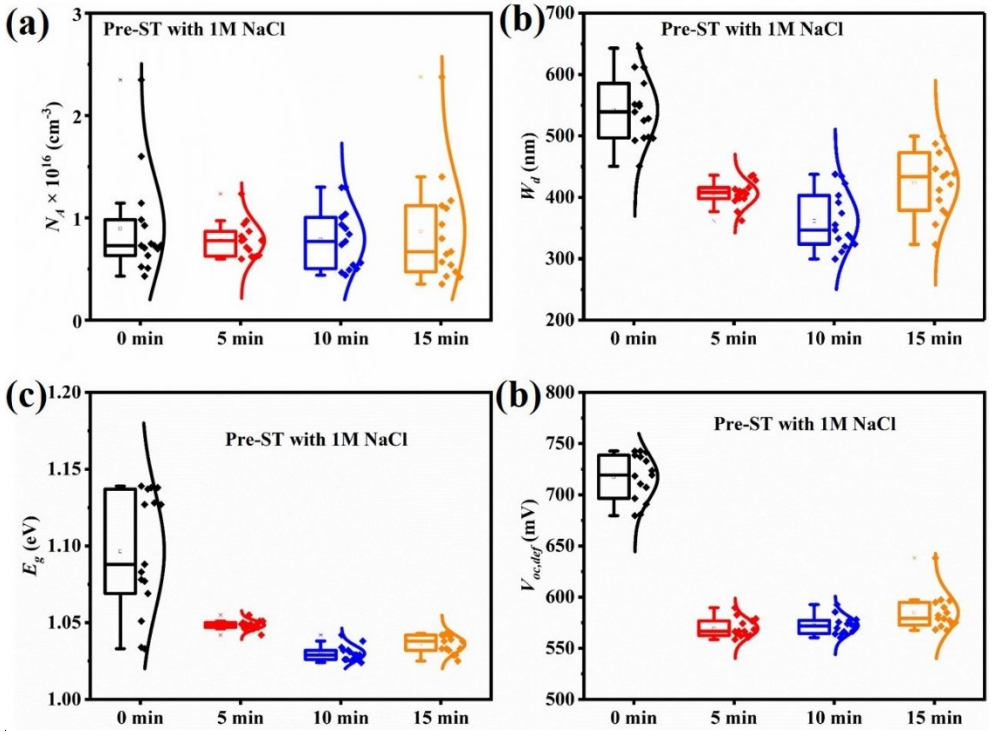


Figure S8 Statistical distribution of (a) $N_A$, (b) $W_d$, (c) $E_g$, and (d) $V_{oc,def}$ derived from 15 CISSe devices with 1 M NaCl aqueous-ethanol solution Pre-ST for various times.

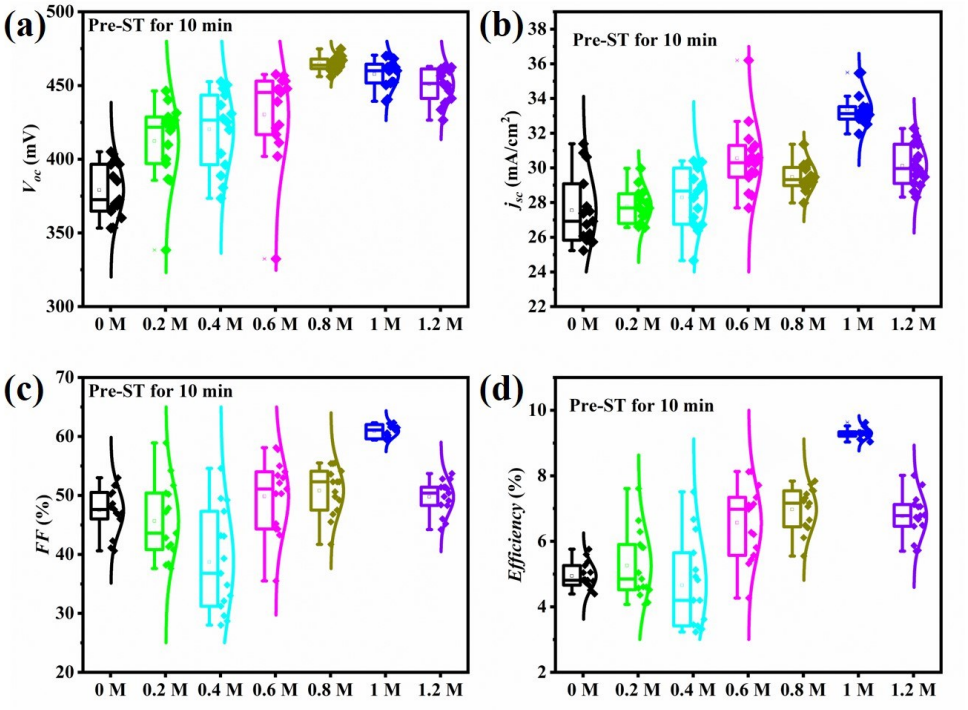


Figure S9 Statistical distribution of (a) $V_{oc}$, (b) $j_{sc}$, (c) $FF$, and (d) efficiency derived from 15 CISSe devices with Pre-ST for 10 min in various concentrations of NaCl aqueous-ethanol solution.

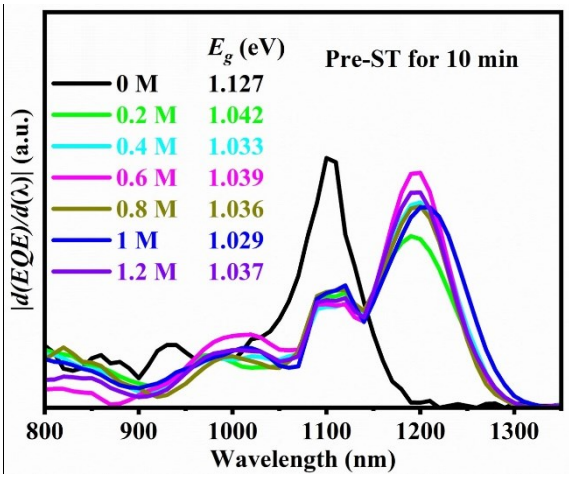


Figure S10 Band gaps of CISSe devices with Pre-ST for 10 min in various concentrations of NaCl aqueous-ethanol solution.

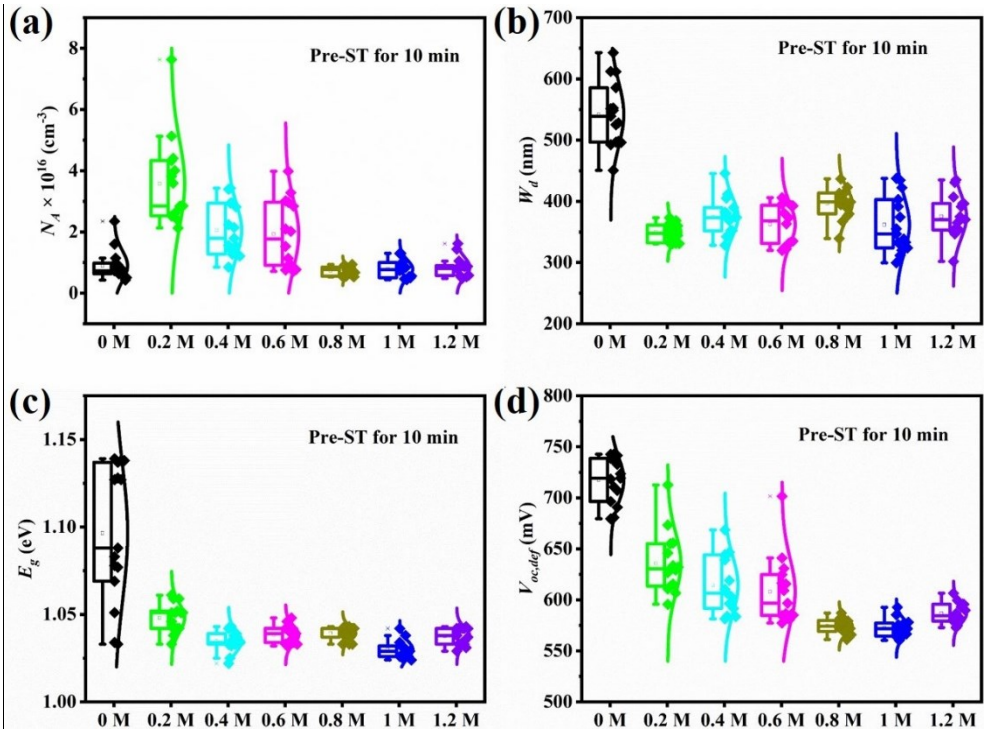


Figure S11 Statistical distribution of (a) $N_A$, (b) $W_d$, (c) $E_g$, and (d) $V_{oc,def}$ derived from 15 CISSe devices with Pre-ST for 10 min in various concentrations of NaCl aqueous-ethanol solution.