

**9.63% efficient flexible  $\text{Cu}_2\text{ZnSn}(\text{S},\text{Se})_4$  solar cells via scalable doctor-blading in ambient condition**

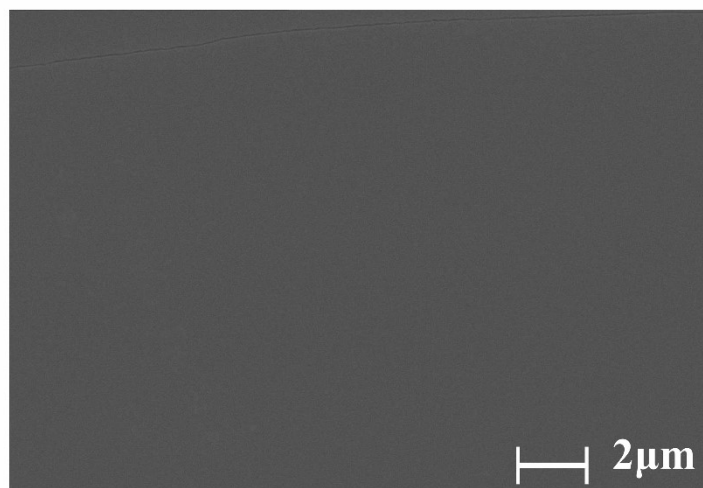
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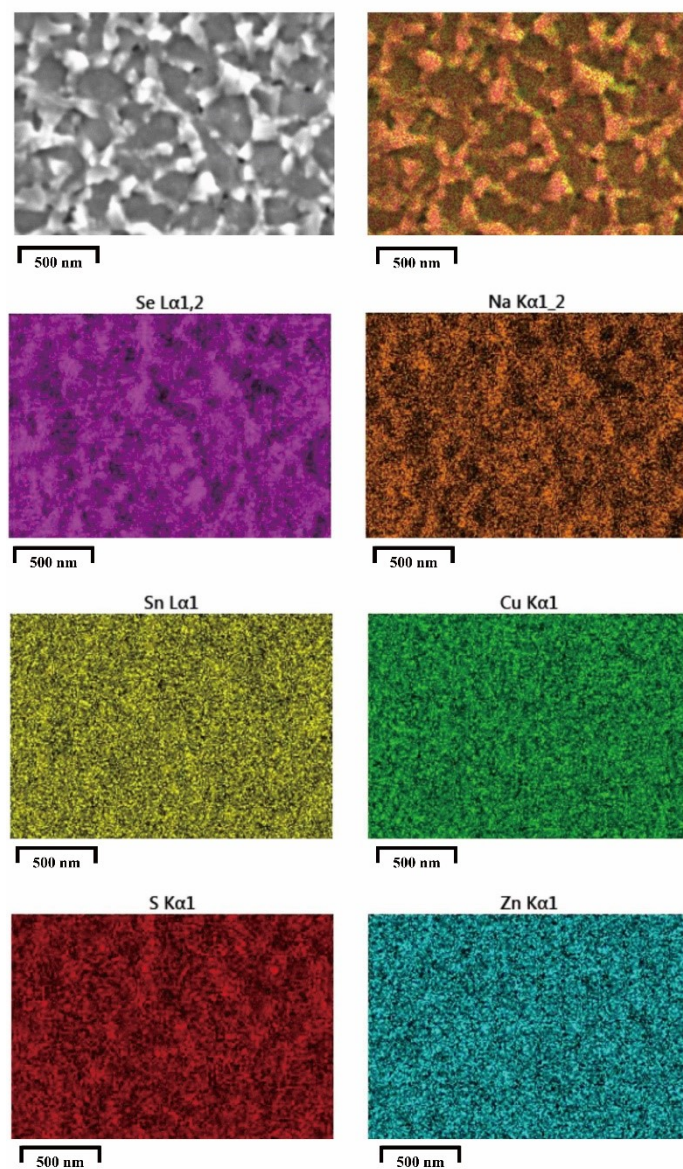
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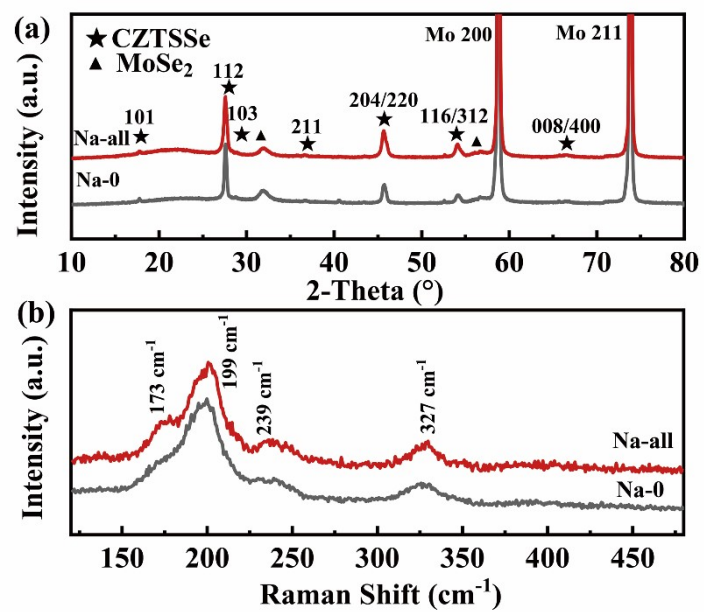
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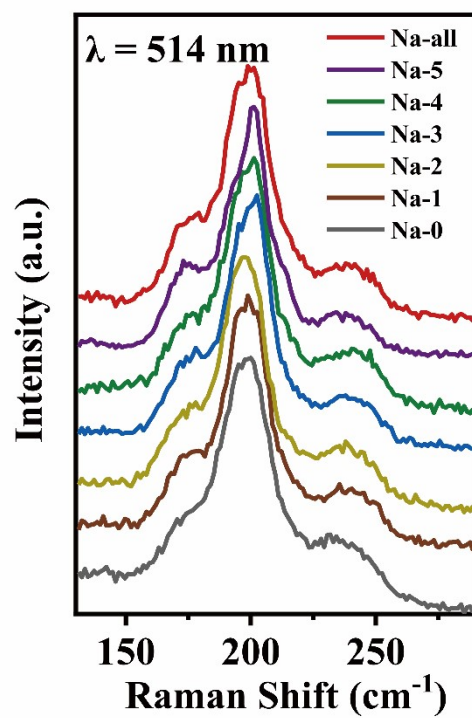
**Figure S1.** The top-view SEM micrograph of the Na-0 CZTS precursor film.



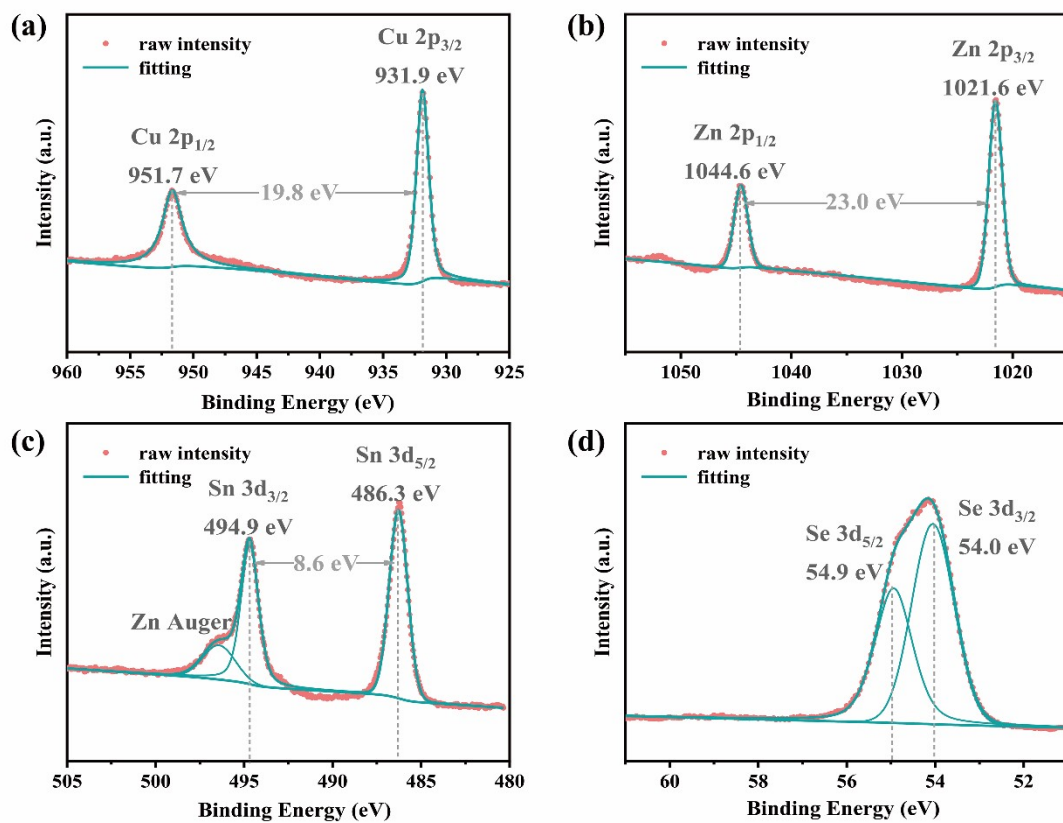
**Figure S2.** The EDX elemental mapping of the Na-all sample.



**Figure S3.** (a) XRD patterns and (b) Raman spectra of Na-0 and Na-all CZTSSe thin films on the Mo foil.



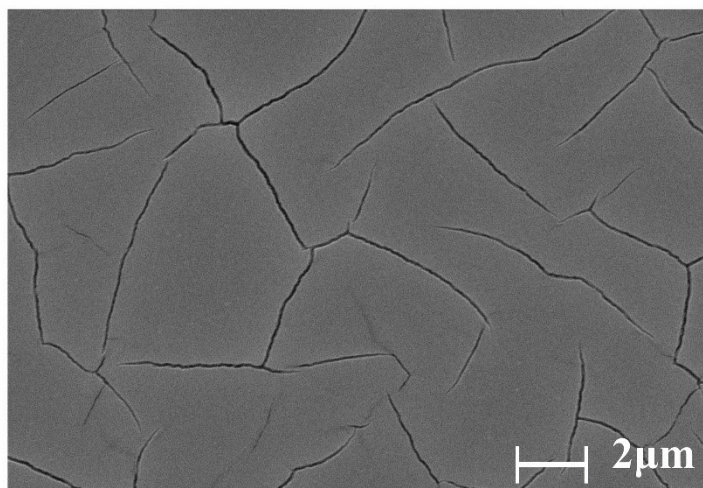
**Figure S4.** Raman spectra of Na-0 ~ Na-all at 130 ~ 290  $\text{cm}^{-1}$ , measured with an excitation wavelength of 514 nm.



**Figure S5.** XPS spectra of (a) Cu 2p, (b) Zn 2p, (c) Sn 3d, and (d) Se 3d in the Na-4CZTSSe.

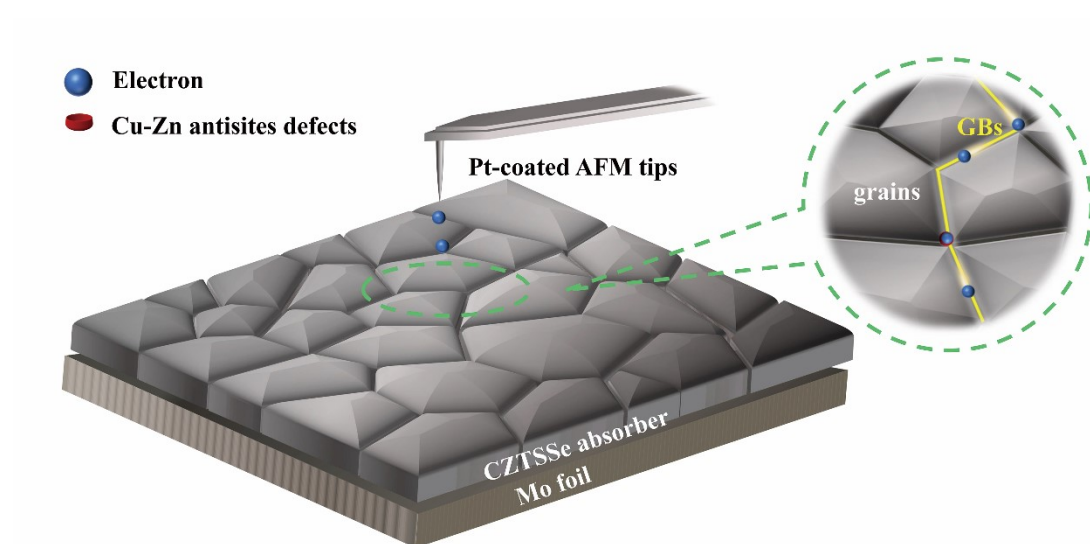
**Table S1.** FWHM of the (112) plane and the corresponding crystallite size estimated from the Scherrer equation for Na-0 ~ Na-5 samples.

Sample	FWHM	Size (nm)
Na-0	0.310	26.12
Na-1	0.283	28.60
Na-2	0.295	27.43
Na-3	0.288	28.11
Na-4	0.242	33.44
Na-5	0.297	27.24



**Figure S6.** The top-view SEM micrograph of the Na-5 CZTS precursor film.





**Figure S7** A schematic figure shows that the injected electrons from AFM tip transport along GBs, and the enlarged view illustrates that the Cu-Zn antisites defects at GBs reduce the mobility of electrons by trapping them, which leads to a lower current.