Electronic Supplementary Material (ESI) for RSC Advances.


Supporting Information

# Reducing series resistance in $Cu_2ZnSn(S,Se)_4$ nanoparticle ink solar cells on flexible molybdenum foil substrates

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## S1. Fabrication of CZTS nanoparticle inks

In the synthesis, $Cu(acac)_2$, $Zn(acac)_2$, and $Sn(acac)_2Cl_2$ were used as cation precursors, and elemental sulphur was used as an anion precursor. Oleylamine (OLA) was used as surfactant and solvent to prevent aggregation and enable dispersion. Appropriate volumes of 0.75 mmol starting solutions were mixed to yield metal precursor molar ration of Cu/ (Zn+ Sn) = 0.79 and Zn/Sn= 1.27. The cation precursors were mixed with 10 mL OLA in a 100 mL three-neck flask. Both precursor solutions were initially heated to 65°C to fully dissolve. In parallel, the two flasks were degassed by evacuating for 5 min and then purged with nitrogen. 3 mL of 1M S in OLA was then injected into the cation precursor after heating up to 225°C and holding the temperature constant for 30 min under a nitrogen atmosphere. Following the reaction, the solution was washed in toluene and isopropanol (IPA) three times. The collected nanoparticles were then dispersed into 1-hexanthiol as the CZTS nanoparticle inks.

## S2. Calculation of texture coefficients

The texture coefficients $C_{hkl}$ and preferred orientation $\sigma$ of the samples were calculated by equations 1 and 2,

$$C_{h_ik_il_i} = \frac{I(h_ik_il_i)}{I_0(h_ik_il_i)}\left[\frac{1}{n}\sum_{i=1}^{n}\frac{I(h_ik_il_i)}{I_0(h_ik_il_i)}\right]^{-1} \tag{1}$$

$$\sigma = \sqrt{\sum\frac{1}{n}(C_{hkl}-1)^2} \tag{2}$$

where n is the number of reflections, $I(h_ik_il_i)$ is the intensity at $h_ik_il_i$reflection, $I_0(h_ik_il_i)$ is the intensity of corresponding reflection for an absolute random sample. $C_{hkl}$ reveals the relative change of crystal orientations, and $\sigma$ from the standard deviation of $C_{hkl}$ values indicates the random disperse degree of crystal orientation. The results are shown in Table S1.

**Table S1** Summary of peak texture coefficients and preferred orientation from XRD spectrum

| | hkl | CZTSSe/Foil | CZTSSe/Film/Foil | CZTSSe/Film/Glass |
|---|---|---|---|---|
| | 101 | 3.560 | 2.649 | 2.422 |
| | 110 | 0.000 | 0.896 | 0.963 |
| | 112 | 0.728 | 0.844 | 0.901 |
| | 103 | 0.987 | 1.081 | 1.029 |
| $C_{hkl}$ | 211 | 2.218 | 1.759 | 1.977 |
| | 204 | 0.563 | 0.534 | 0.576 |
| | 312 | 0.542 | 0.544 | 0.578 |
| | 400 | 0.403 | 0.247 | 0.117 |
| | 332 | 0.000 | 0.446 | 0.438 |
| $\sigma$ | | 1.10 | 0.72 | 0.70 |

## S3. Figures

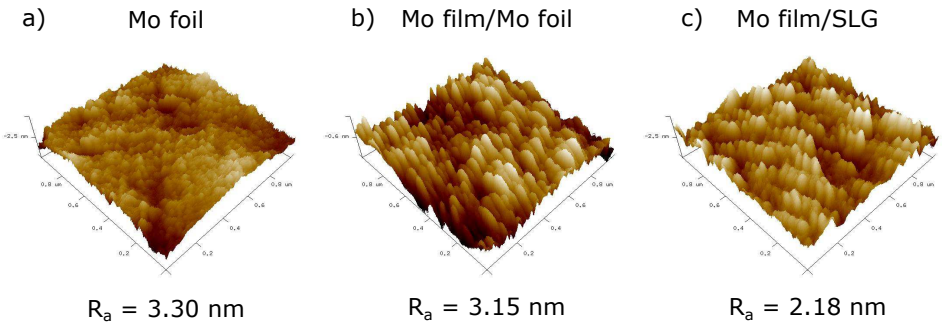


**Figure S1** Three dimensional AFM images of Mo foil substrate (a) with Ra of 3.3 nm, Mo foil coated with Mo film (b) with Ra of 3.15 nm, and SLG coated with Mo film (c) with Ra of 2.18 nm.

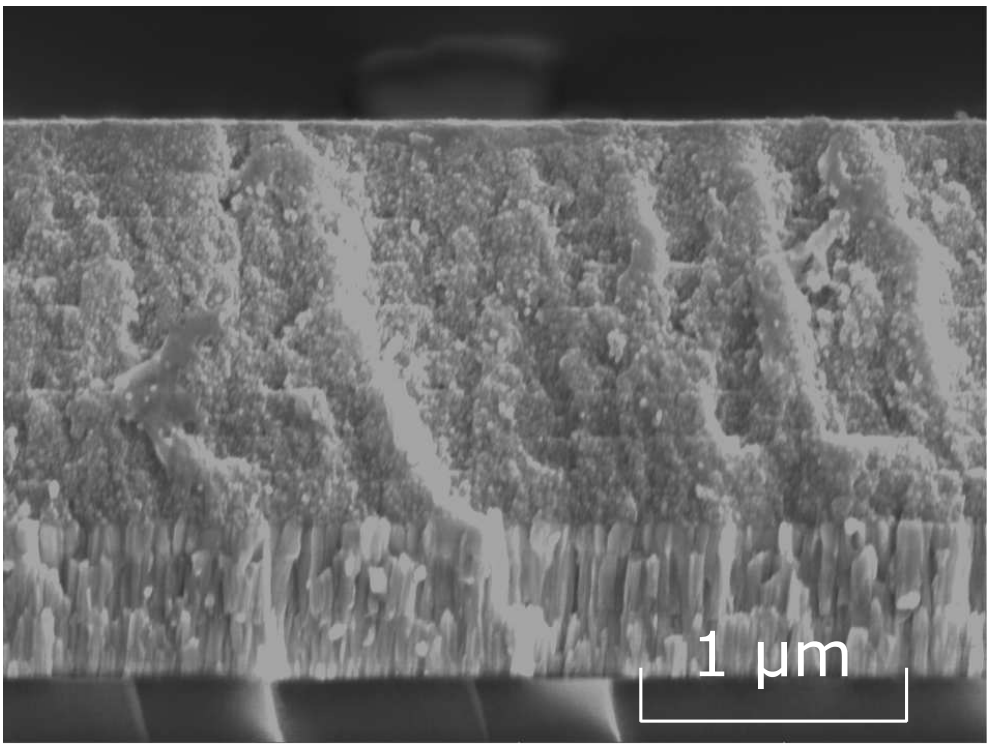


**Figure S2** Cross-sectional image of CZTS on SLG.

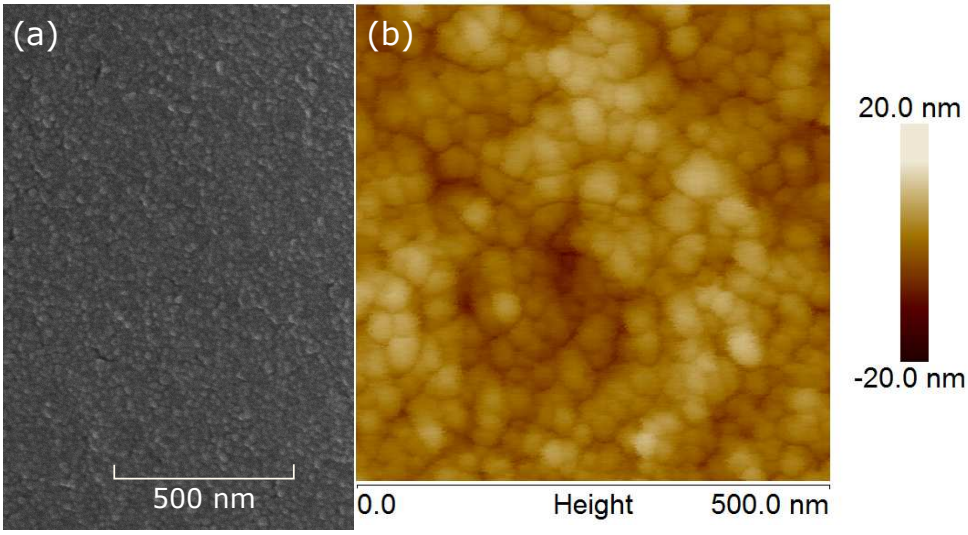


**Figure S3** CZTS film with an average particle size of 21±6 nm spin-coated from nanoparticle inks: (a) SEM image and (b) scanned with AFM.

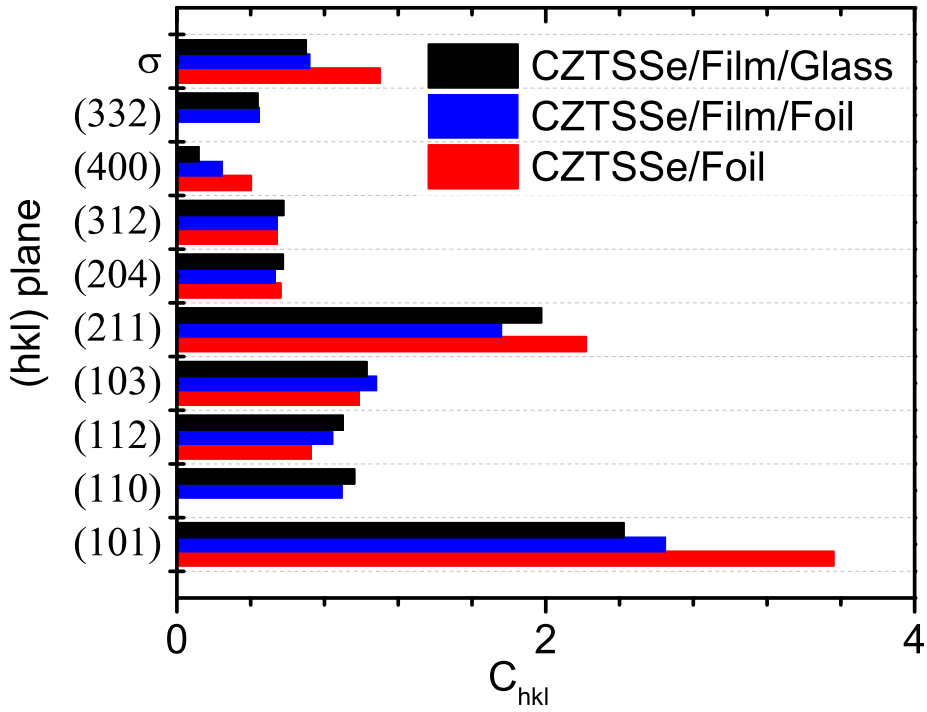


**Figure S4** The crystal texture data and the preferred orientation varies on different substrates.

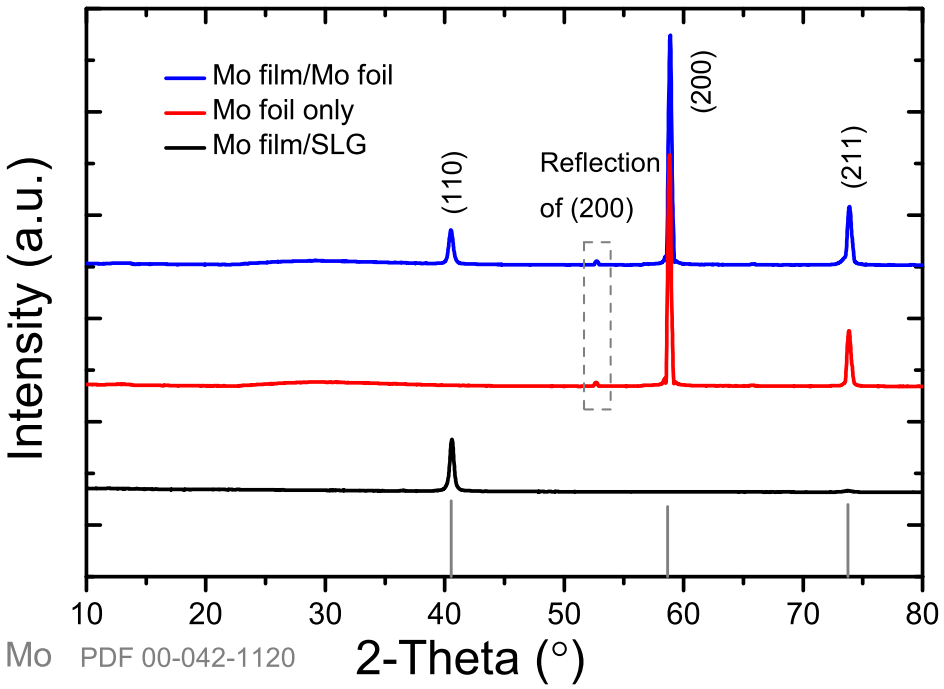


**Figure S5** XRD patterns of different substrates. The peaks in the dash square belong to reflection of peak (200).