

## Supporting Information

### In-situ Synthesis of Two-dimensional Leaf-like $\text{Cu}_2\text{ZnSnS}_4$ Plate Arrays as Pt-free Counter Electrode for Efficient Dye-Sensitized Solar Cells

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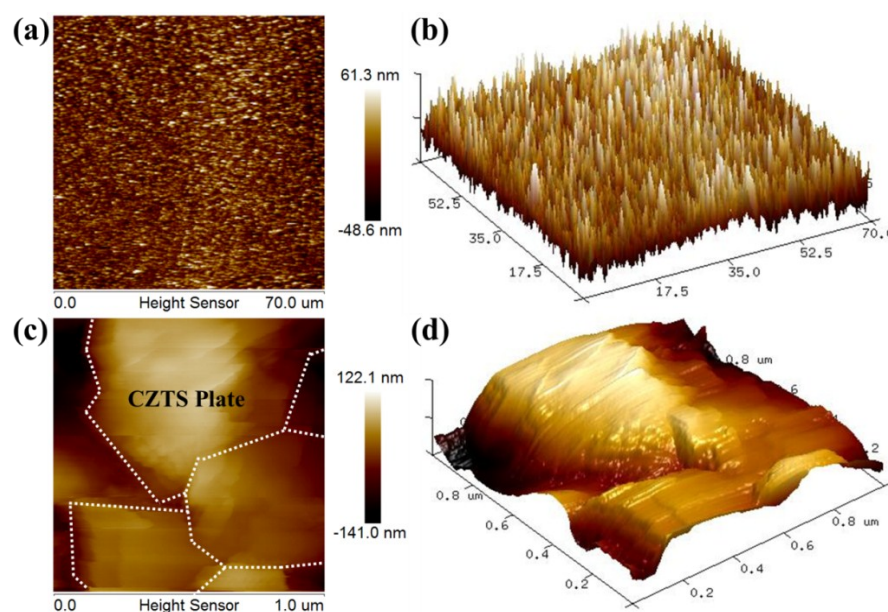
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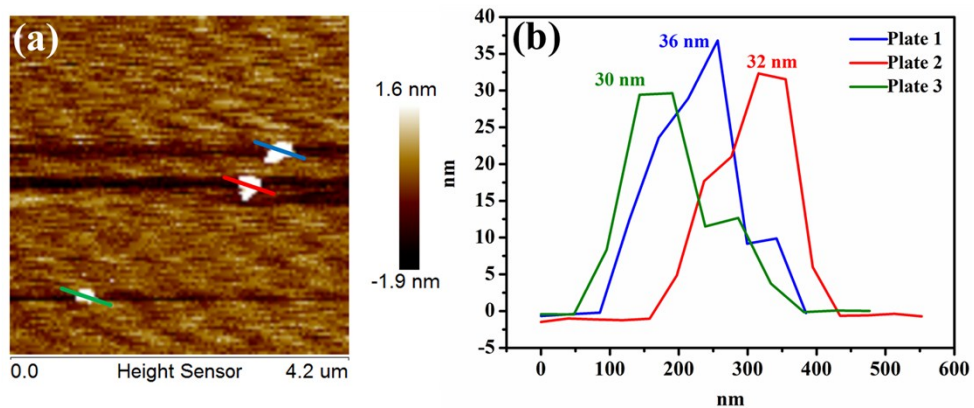
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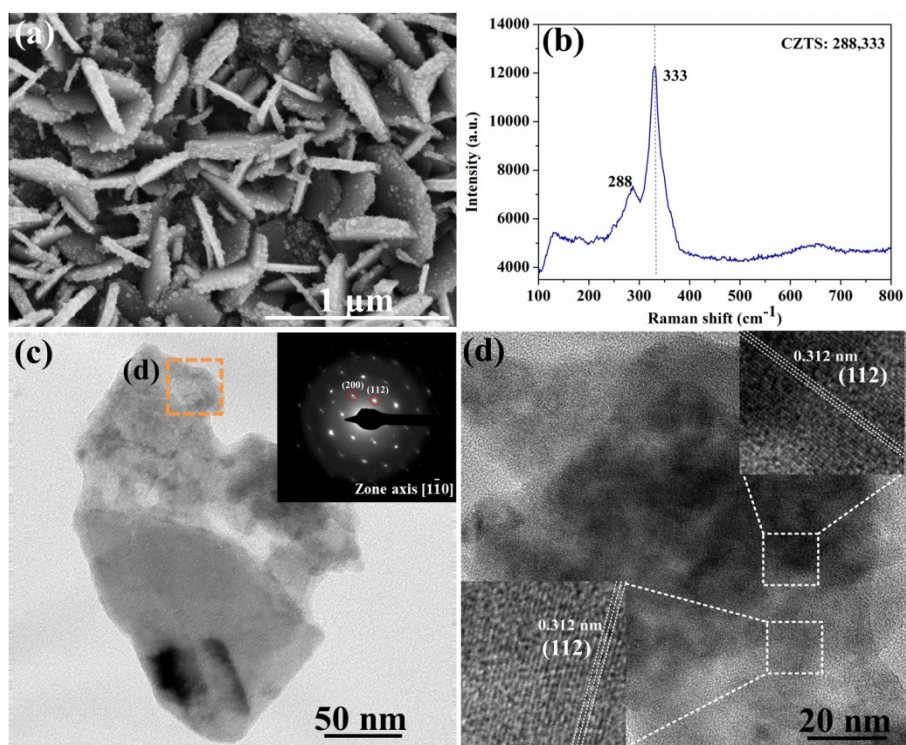
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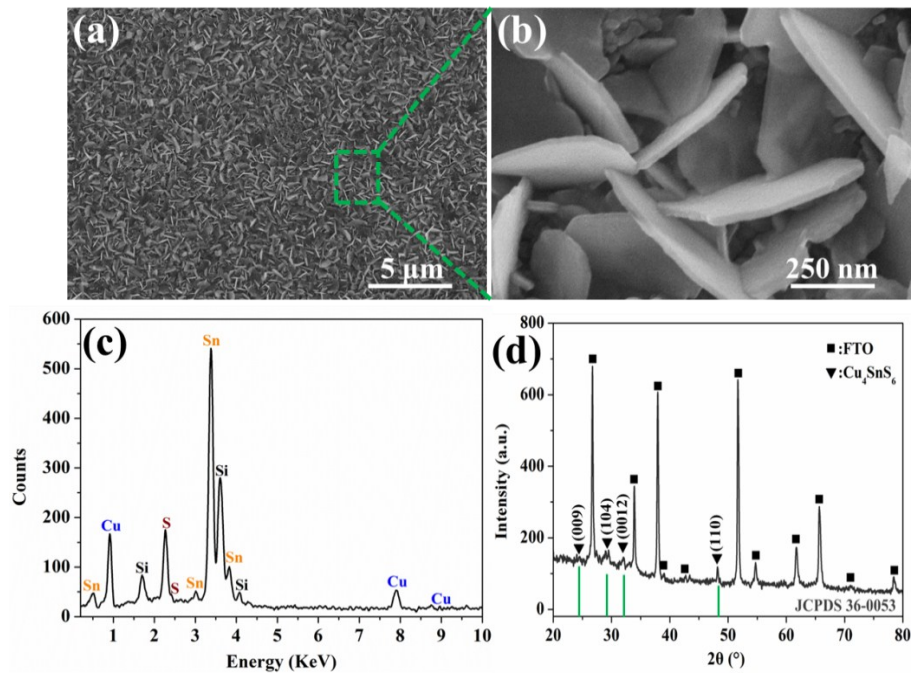
**Figure S1.** 2D and 3D AFM images of (a,b) CZT particles film and (c,d) leaf-like CZTS plate arrays.



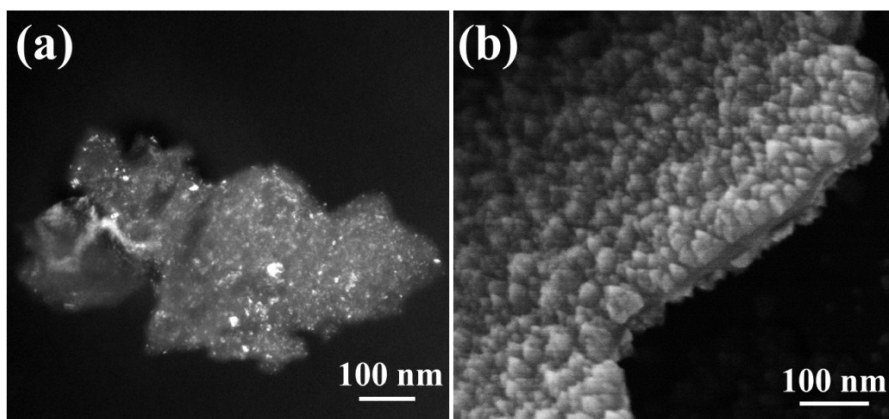
**Figure S2.** (a) 2D AFM image of CZTS plate and the corresponding plate (b) thickness distribution. The CZTS plate was described from the FTO substrate and then under ultrasonic dispersion in ethanol. The CZTS dispersion was subsequently deposited on mica sheet for AFM observation.



**Figure S3.** (a) FE-SEM images and (b) Raman spectra of CZTS nanodisk arrays on FTO substrate. (c) TEM images of the CZTS nanodisk. (d) HR-TEM image of a single nanodisk scraped from the films of CZTS arrays. The insert shows the corresponding SAED pattern of CZTS nanodisk.



**Figure S4.** (a,b) FE-SEM images, (c) EDS spectra, and (d) XRD pattern of  $\text{Cu}_4\text{SnS}_6$  sheet arrays on FTO substrate. The higher intensity of Sn element in EDS spectra is ascribed from the SnO on glass substrate surface.



**Figure S5.** (a) Dark-field TEM images of the CZTS plate grown on the FTO substrate by solvothermal treatment for 3h. (b) Magnified FE-SEM image of a single CZTS plate with the rough pointed cone covering on the surface.

**Table S1.** Comparison with the photoelectrochemical performance of DSSCs using various counter electrode (CE).

CE	$V_{OC}$ (V)	$J_{SC}$ (mA/cm <sup>2</sup> )	FF (%)	PCE (%)
Aligned CZTS nanoplates on FTO <sup>[1]</sup>	0.68 (Pt: 0.69)	10.27 (Pt: 8.72)	0.55 (Pt: 0.54)	3.65 (Pt: 3.33)
CZTS nanofibers on FTO <sup>[2]</sup>	0.57 (Pt: 0.62)	8.42 (Pt: 4.66)	0.65 (Pt: 0.57)	3.90 (Pt: 1.72)
CZTS graphene composite on FTO <sup>[3]</sup>	0.71 (Pt: 0.70)	16.77 (Pt: 16.79)	0.65 (Pt: 0.56)	7.81 (Pt: 6.66)
CZTS ultrathin film on FTO <sup>[4]</sup>	0.65 (Pt: 0.65)	14.54 (Pt: 11.99)	0.59 (Pt: 0.69)	5.63 (Pt: 5.44)
Porous CZTS thin film on FTO <sup>[5]</sup>	0.59 (Pt: 0.69)	3.03 (Pt: 2.47)	0.68 (Pt: 0.67)	1.23 (Pt: 1.15)
200-300 nm Cu <sub>2</sub> ZnSnSe <sub>4</sub> nanoparticles on FTO <sup>[6]</sup>	0.78 (Pt: 0.70)	10.39 (Pt: 12.23)	0.47 (Pt: 0.47)	3.85 (Pt: 4.03)
CZTS film on FTO with big grain size <sup>[7]</sup>	0.74 (Pt: 0.73)	17.20 (Pt: 18.30)	0.62 (Pt: 0.63)	7.94 (Pt: 8.55)
Hierarchical CZTS structures on FTO <sup>[8]</sup>	0.74 (Pt: 0.71)	14.26 (Pt: 14.30)	0.66 (Pt: 0.68)	6.98 (Pt: 6.91)
CZTS nanoflakes on FTO substrate <sup>[9]</sup>	0.65 (Pt: 0.62)	18.63 (Pt: 18.18)	0.53 (Pt: 0.74)	6.40 (Pt: 8.30)
2D leaf-like CZTS PLAr on FTO substrate	0.76 (Pt: 0.75)	16.32 (Pt: 12.90)	0.57 (Pt: 0.61)	7.09 (Pt: 6.01)

## References

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