

Supporting Information for

Low-temperature Growing Anatase-TiO₂/SnO₂ Multi-dimensional Heterojunctions at MXene Conductive Network for High-efficient Perovskite Solar Cells

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Supplementary Figures

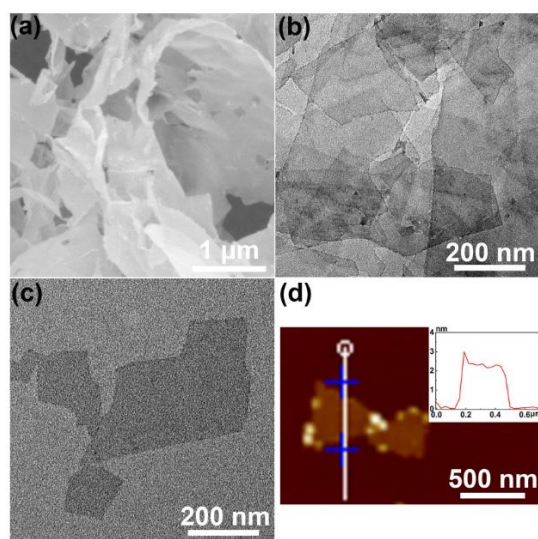


Fig. S1 (a) The SEM morphology, (b-c) TEM morphologies, and (d) AFM surface morphology of resulted MXene material with its height profile in inset

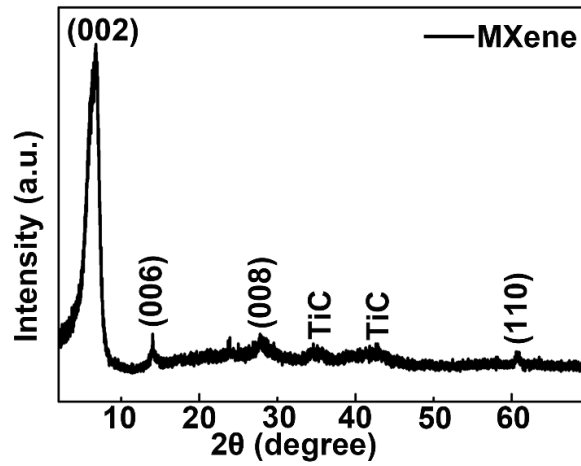


Fig. S2 XRD pattern of resulted MXene material

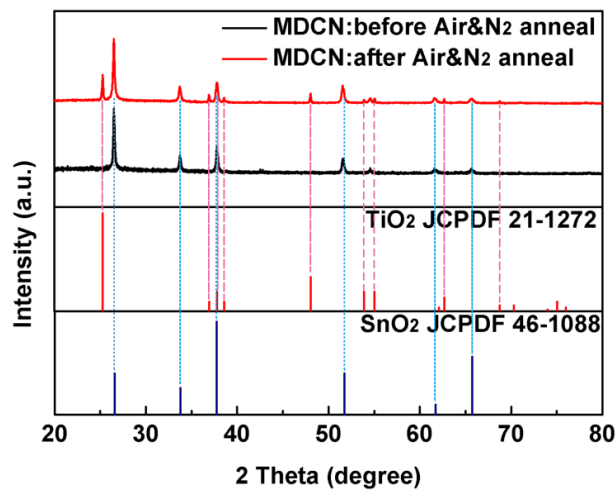


Fig. S3 XRD patterns of MDCN before and after controlled anneal method in Air&N₂ atmospheres

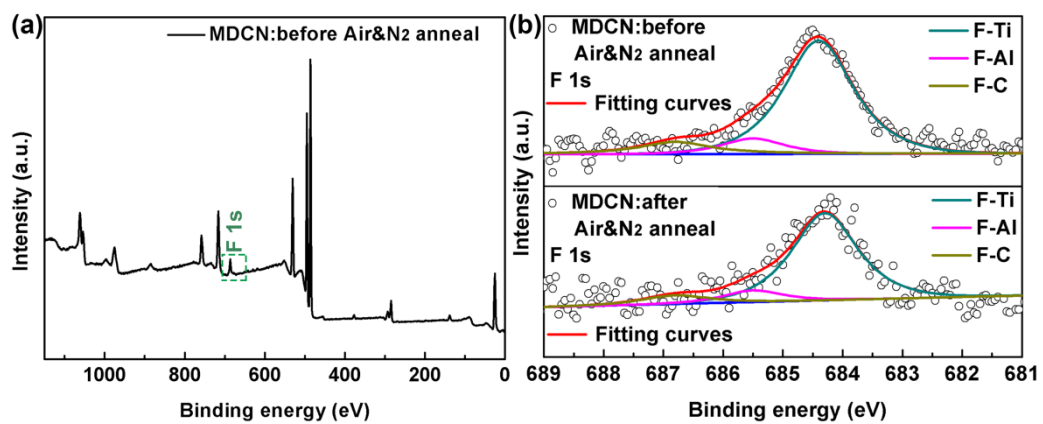


Fig. S4 **a** The survey spectra of MDCN before controlled anneal. **b** The extracted F 1s spectra of MDCN samples before and after controlled anneal

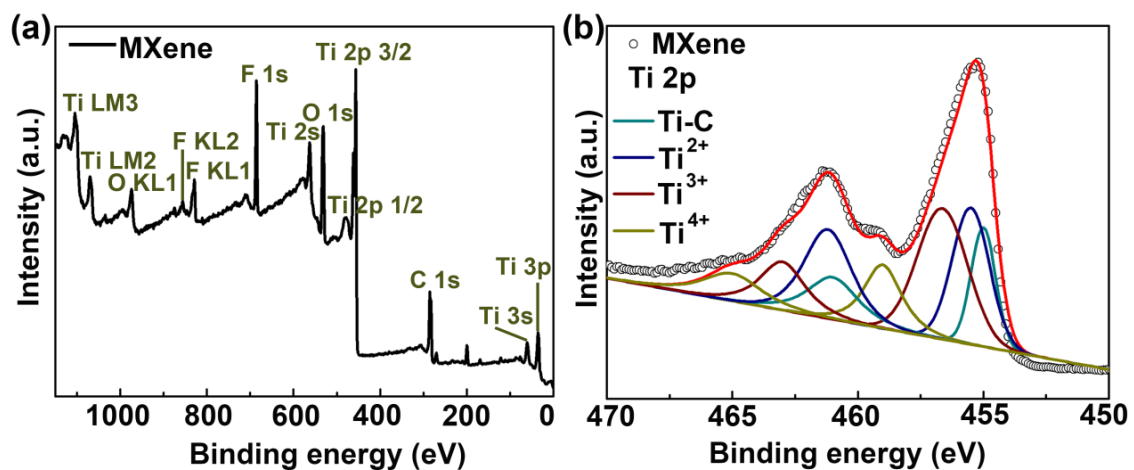


Fig. S5 Survey spectrum of **a** pure MXene **b** with its Ti 2p

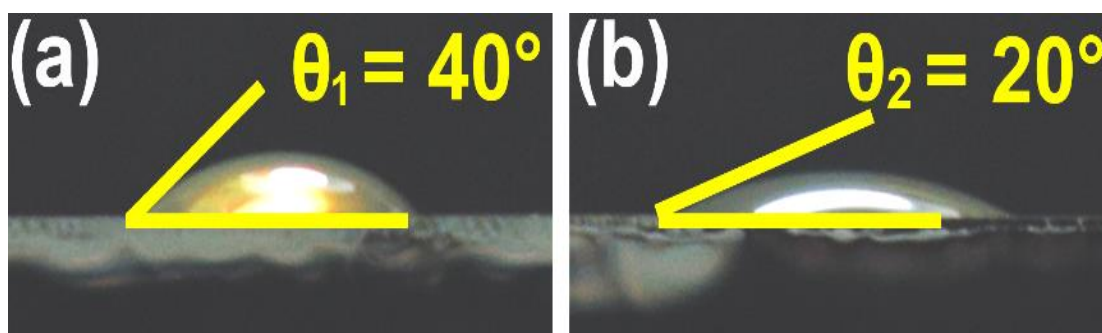


Fig. S6 Wetting angles of a water droplet on the **(a)** SnO₂ and **(b)** MDCN films

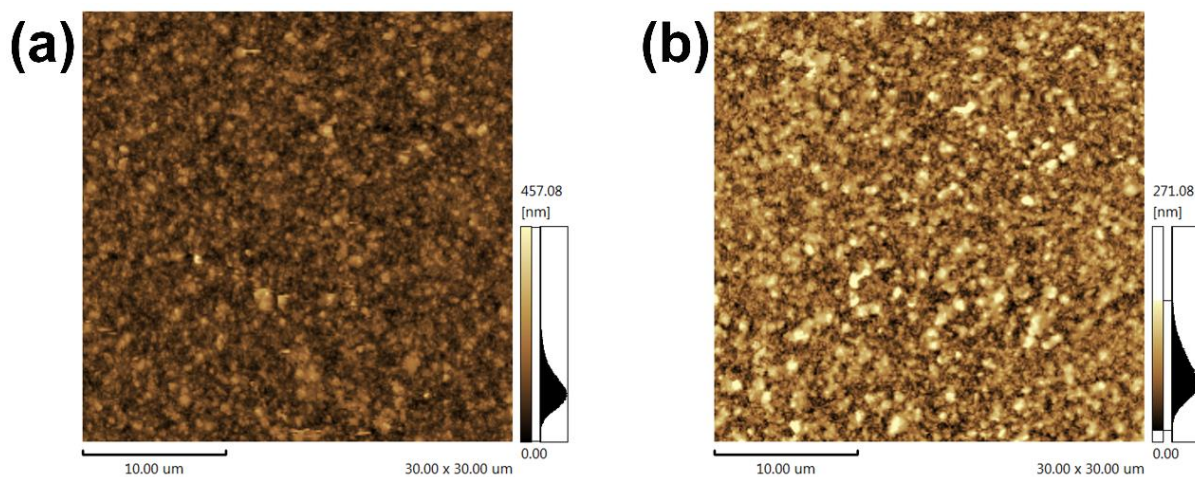


Fig. S7 AFM images of **(a)** SnO₂ and **(b)** MDCN surfaces

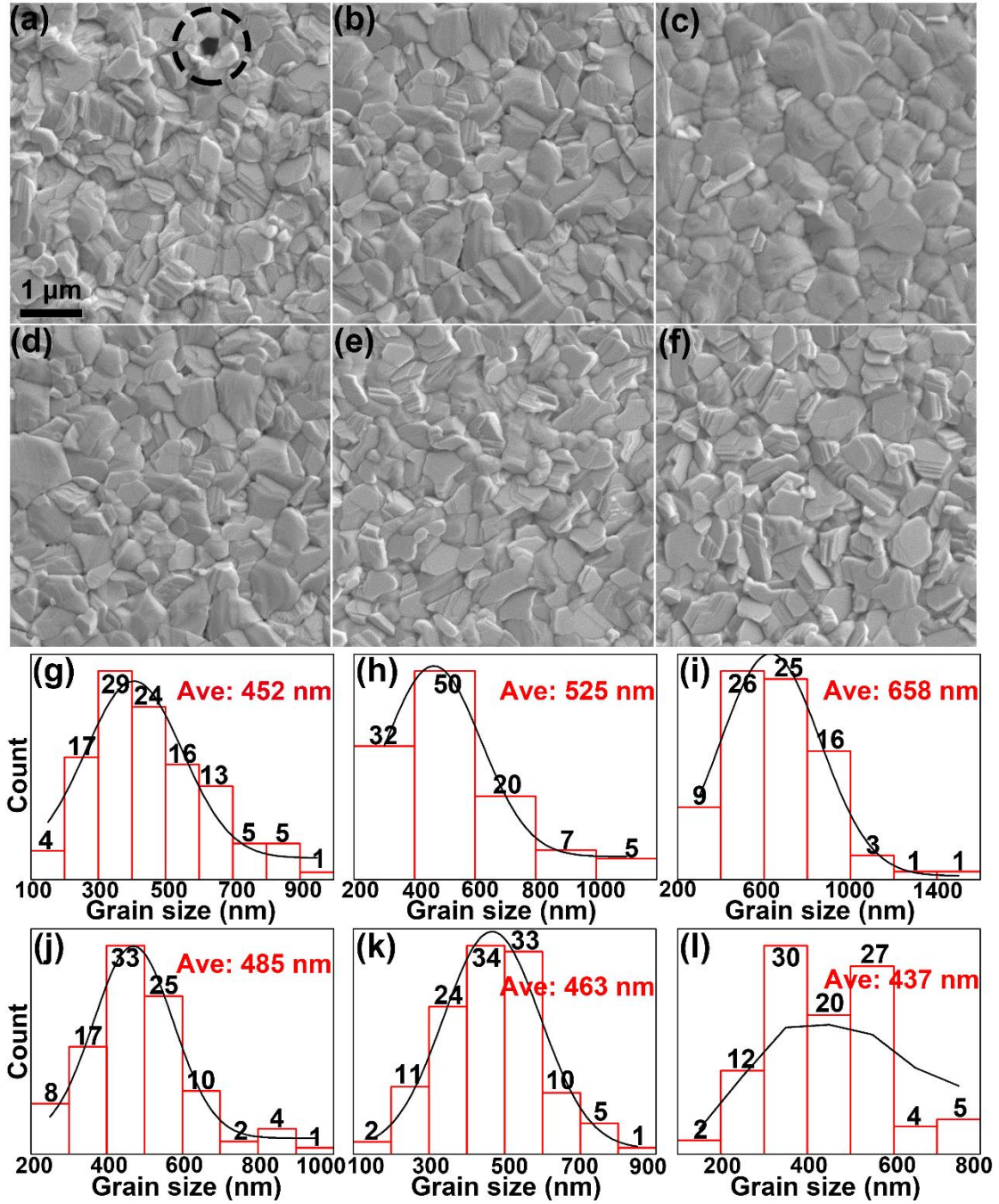


Fig. S8 Top-view SEM images of perovskite/ETL/FTO with different ETL: (a) SnO₂; (b) MDCN-0.01; (c) MDCN-0.02 (i.e., MDCN sample); (d) MDCN-0.03; (e) MDCN-0.05; (f) MDCN-0.1. (g-l) Statistic grain size distributions for perovskite film in (a-f)

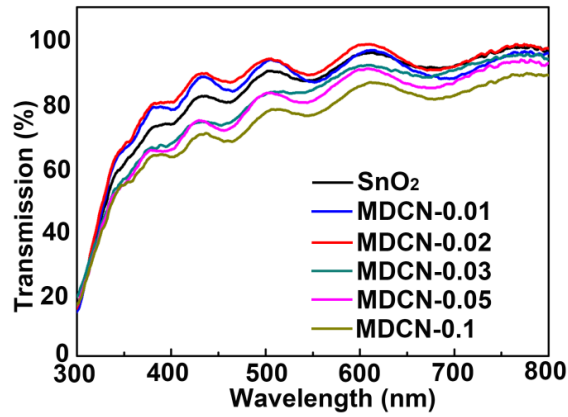


Fig. S9 Transmittance spectra of SnO₂, MDCN-0.01, MDCN-0.02, MDCN-0.03, MDCN-0.05, and MDCN-0.1 ETLs

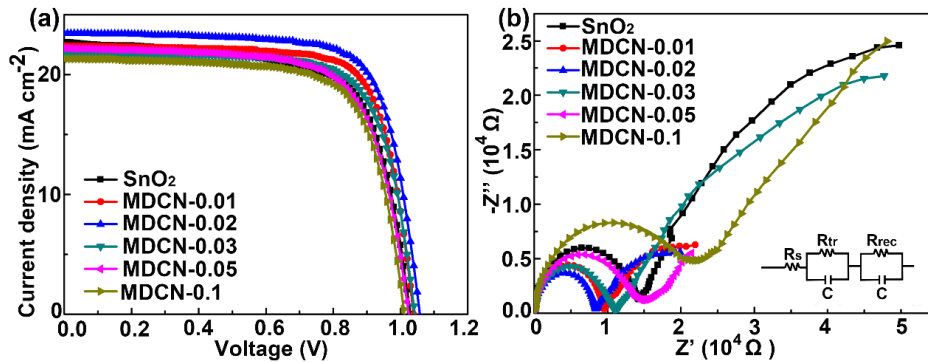


Fig. S10 (a) J-V curves and (b) Nyquist plots of EIS for PSCs using SnO₂, MDCN-0.01, MDCN-0.02, MDCN-0.03, MDCN-0.05, and MDCN-0.1 as ETLs. The equivalent circuit for (b) shown its inset.

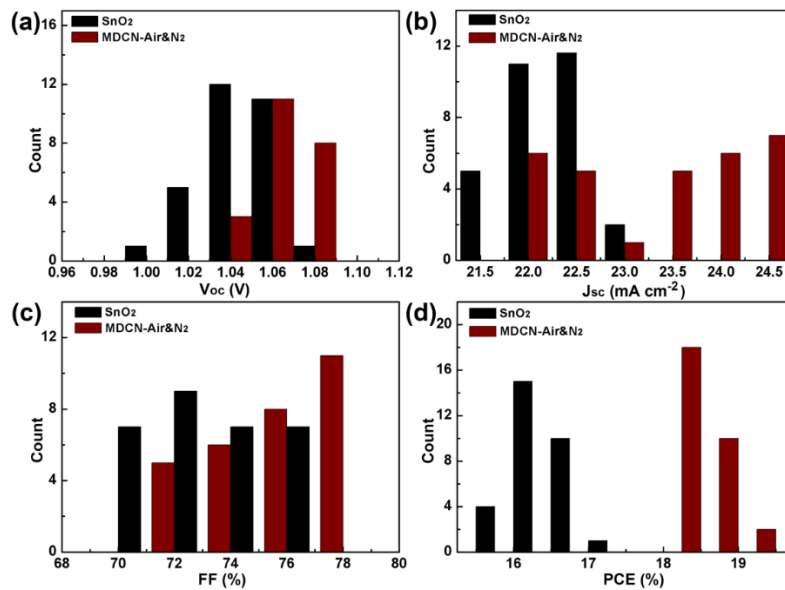


Fig. S11 Histogram of parameters of PSCs with SnO₂ and MDCN-Air&N₂ ETLs

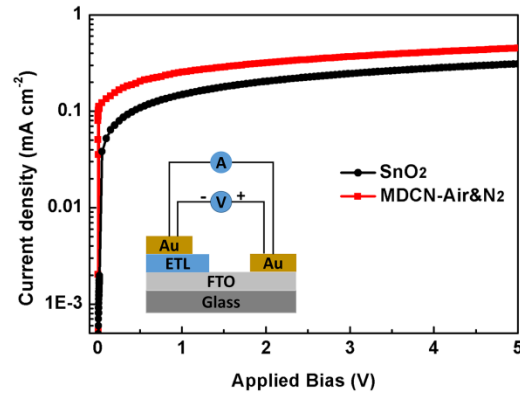


Fig. S12 The SCLC curve of SnO₂ and MDCN-Air&N₂ layers with the test devices sketch in inset

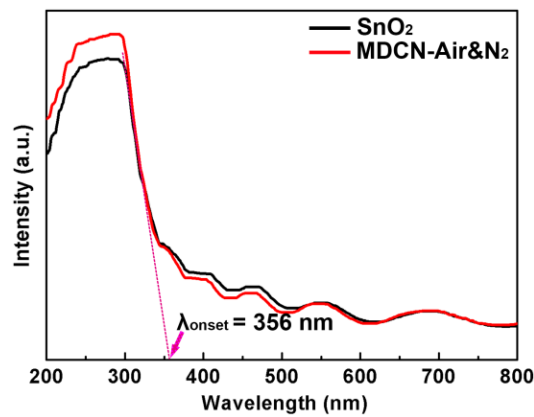


Fig. S13 Absorption onset value measure for SnO₂ and MDCN-Air&N₂ samples with UV-vis absorption spectra

Table S1 Atomic contents of different Ti-based bonds for pure MXene and MDCN

	Ti-C	Ti ²⁺	Ti ³⁺	Ti ⁴⁺
Pure MXene	18.76	33.91	31.67	15.65
MDCN	19.94	31.27	25.39	23.40

Table S2 Device performance of PSCs based on ETLs with different MXene contents (30 samples for each type of ETL)

ETL	V_{oc} (V)	J_{sc} (mA cm ⁻²)	FF (%)	PCE (%)
SnO ₂	1.03 ± 0.04	22.51 ± 1.56	70.55 ± 3.11	16.42 ± 0.41
MDCN-0.01	1.05 ± 0.05	22.73 ± 1.65	72.89 ± 3.50	17.38 ± 0.48
MDCN-0.02	1.07 ± 0.03	23.13 ± 1.39	74.62 ± 3.35	18.44 ± 0.70
MDCN-0.03	1.04 ± 0.05	21.92 ± 0.76	73.14 ± 2.88	16.74 ± 0.24
MDCN-0.05	1.03 ± 0.06	22.33 ± 1.79	69.51 ± 3.84	15.93 ± 0.82
MDCN-0.1	1.02 ± 0.04	21.76 ± 0.74	69.71 ± 3.04	15.54 ± 0.44