

Supporting information

Low-temperature curable TiO₂ sol for Separator, HTM free Carbon-based perovskite solar cells

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Device fabrication: Fluorine doped tin oxide (FTO) substrates were etched using Zinc metal dust and hydrochloric acid. The substrates were cut into 2 x 2cm and cleaned using various solvents such as soap solution, DI water, acetone and IPA, each 15min by ultrasonication. The substrates were blown dry using Nitrogen gas. 0.15M and 0.3M compact TiO₂ solution was spin coated at 4000rpm, 20s each. The substrates were sintered at 500°C for 30min. The ambient temperature curable TiO₂ sol was spin coated onto the compact TiO₂ layer at 1500rpm, 10s. Multiple layers were coated to attain the desired thickness. Perovskite precursor solution was prepared by adding 461mg PbI₂ and 159mg of MAI in 600mg of DMF and 79mg of DMSO. The solution was stirred at room temperature for 1h. The solution was filtered before spin coating. 70μL of precursor solution was spin coated on TiO₂ film at 4000rpm 25s, 400μL of Toluene was dropped at 15s during the spinning time. The films were subjected to two step annealing, 70°C for 1min followed by 100°C for 2min. The substrates were masked and carbon paste was doctor bladed. The films were subjected to annealing at 80°C for 30min. The devices were tested under AM 1.5 standard conditions.

Characterization techniques: Crystallographic studies were carried out using (Rigaku 9kW smartlab). Optical characteristics were analyzed using UV-Vis-NIR spectrophotometer (cary 5000 UV-Vis-IR Spectrophotometer) over the interval of 400-800nm. The surface morphology and cross section images were captured using (ZEISS GeminiSEM 500). Photoluminescence spectra of perovskite films were recorded using spectrofluorometer (450W ozone free Xe source, Horiba scientific, FL3C-21) from 650nm to 850nm with an excitation wavelength of 540nm. The devices were characterized under AM 1.5 standard conditions using a AAA solar simulator (oriel instruments) at ambient conditions.

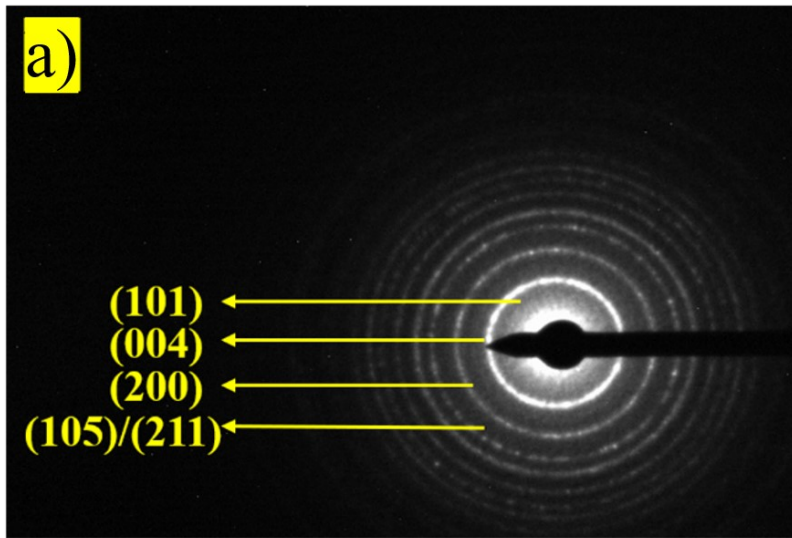


Figure S1. (a) SAED pattern of TiO₂

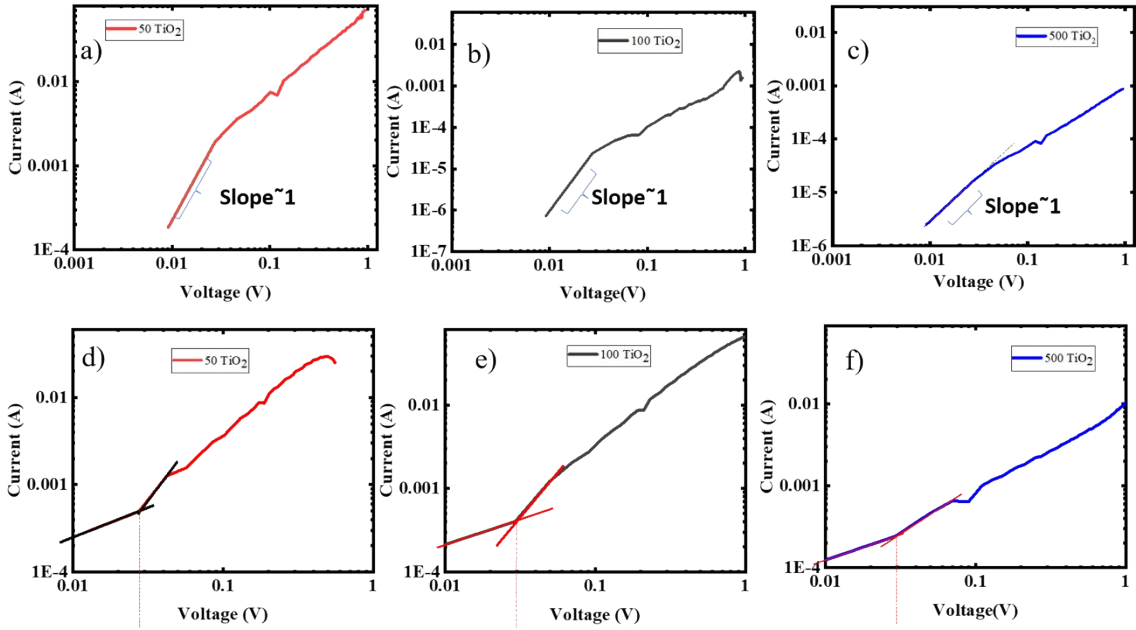


Figure.S2. Direct current conductivity measurement of (a) 50 TiO₂ (b) 100 TiO₂ and (c)500 TiO₂. Trap state density measurement of (d) 50 TiO₂ (e) 100 TiO₂ and (f)500 TiO₂.

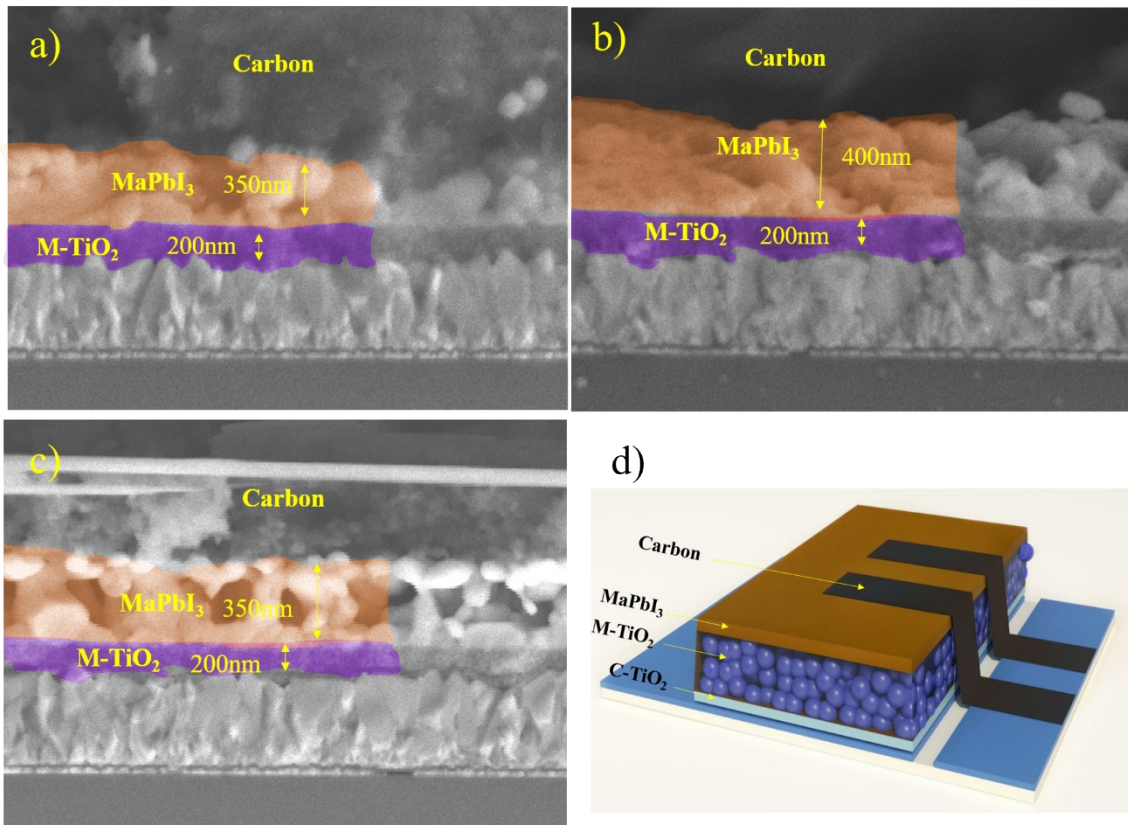


Figure.S3. CPSC device cross-sectional images with (a-c) 50TiO₂, 100TiO₂ and 500TiO₂ as ETL. (d) schematic illustration of CPSCs

Figure S3 shows the cross section of the devices, the TiO₂ thickness were measured to be 200nm thick, MaPbI₃ thickness varying between 350-400nm and 20μm thick carbon layer. The cross-section images clearly indicate the pores present in the perovskite layer in 500 TiO₂, which can contribute to the high resistance in the cell when compared to the other devices.

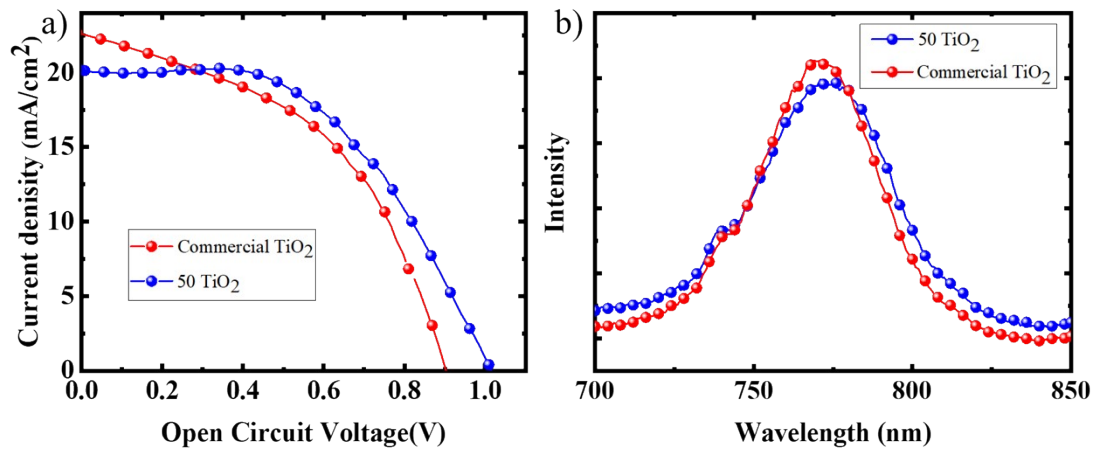


Figure.S4. (a)IV characteristics of CPSCs with Commercial TiO₂ and 50 TiO₂ and (b)PL spectra

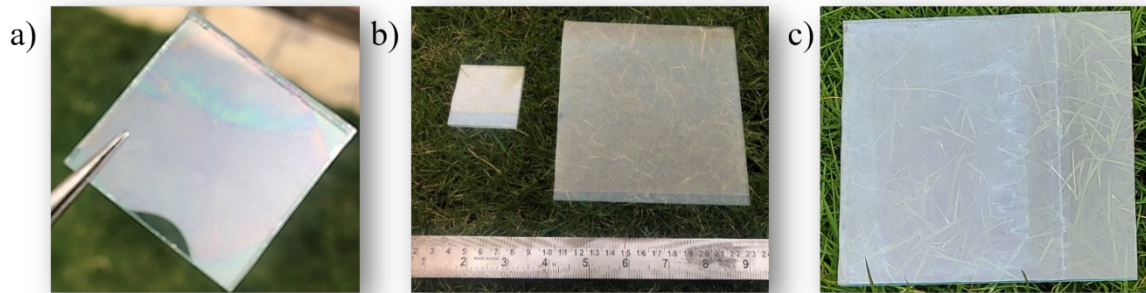


Figure.S5. TiO₂ films deposited by (a) spin coating (b) spray coating and (c) dip coating

Device id	V _{OC} (V)	J _{SC} (mA/cm ²)	F.F(%)	η (%)
50 TiO ₂	1.01	20.1	50.7	10.8
Commercial TiO ₂	0.90	22.5	46.7	9.9

Table.S1. Solar cell parameters of CPSCs with 50 TiO₂ and commercial TiO₂.

Comparison of low and high temperature processable CPSC device fabrication

