Supplementary Information

Oxygen vacancy modulation of nanolayer TiO_x to improve hole-selective passivating contacts for crystalline silicon solar cells

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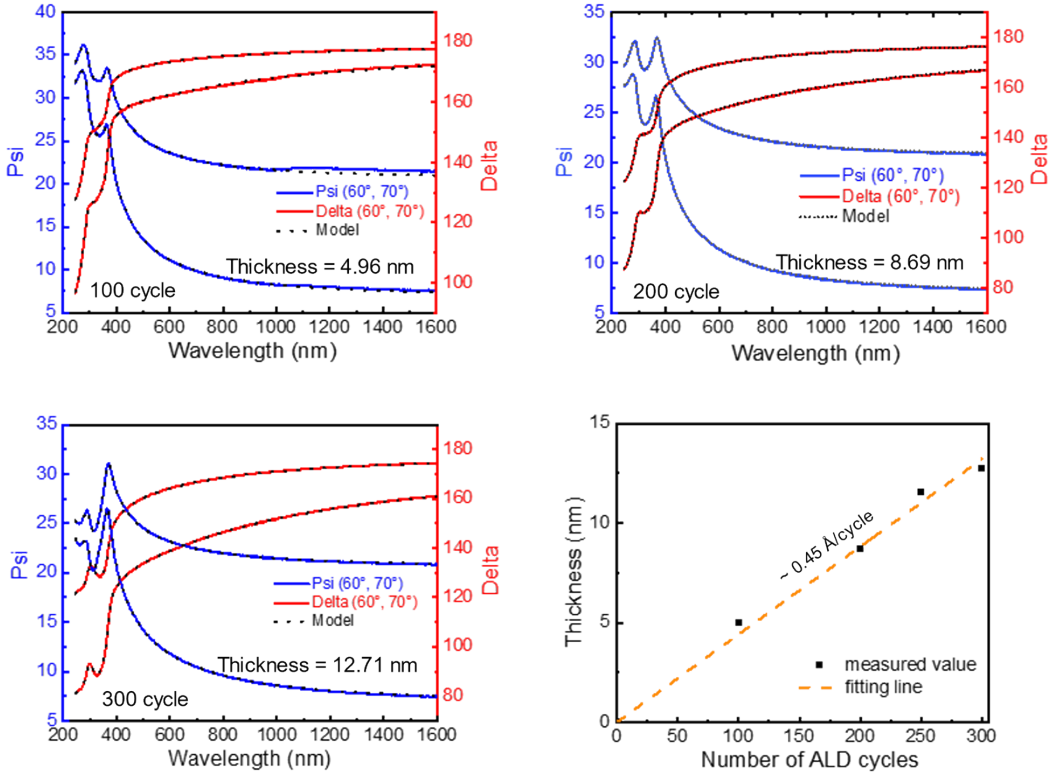

Fig. S1. The spectroscopic ellipsometry of TiO_x film with different ALD cycles and the extracted TiO_x thickness as a function of the number of ALD cycles.

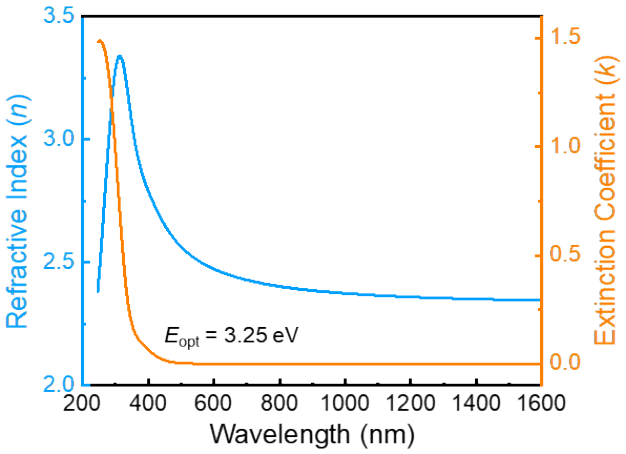

Fig. S2. Refractive index (n) and extinction coefficient (k) of the TiO_x film.

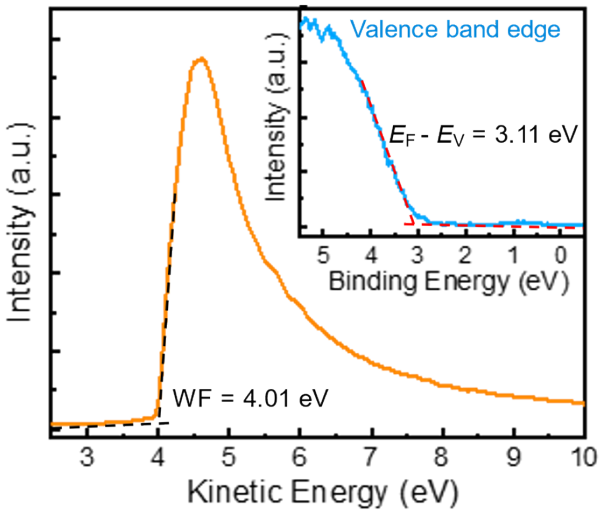

Fig. S3. Secondary electron cut-off and valence band spectra of as-deposited 15-nm TiO_x film.

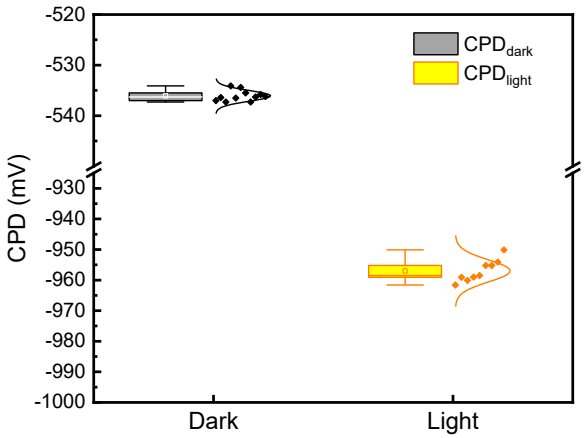

Fig. S4. Contact potential difference (CPD) measured in the dark and under illumination of Al_2O_3 film.

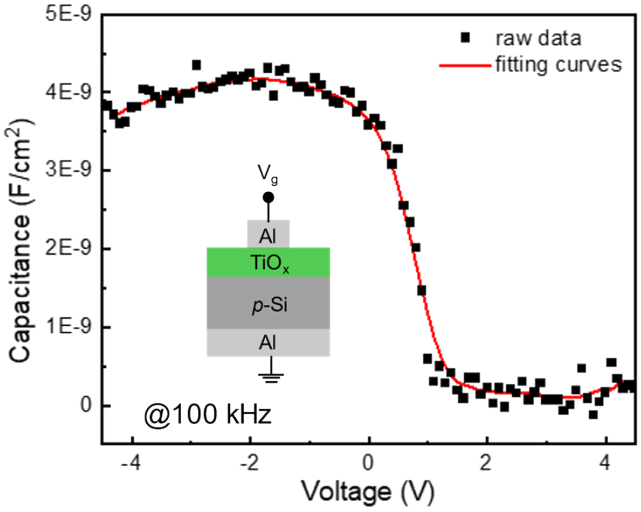

Fig. S5. The *C-V* measurement of the TiO_x film.

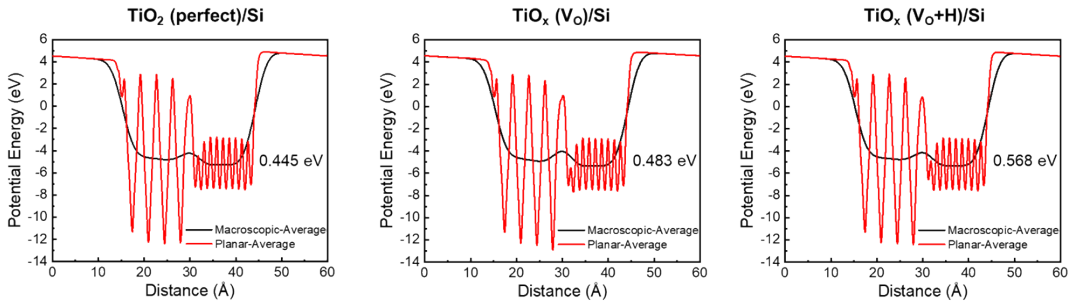

Fig. S6. The simulated macroscopic average and planar average of potential energy for the Si/TiO_2 (perfect), Si/TiO_x (V_O), and Si/TiO_x (V_O+H) structures, respectively.

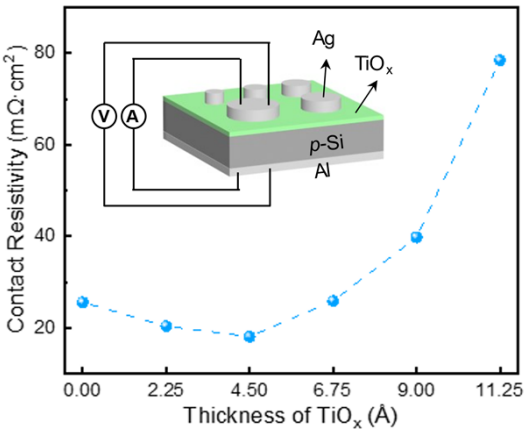

Fig. S7. Contact resistivity of *p*-Si samples with different TiO_x thicknesses.

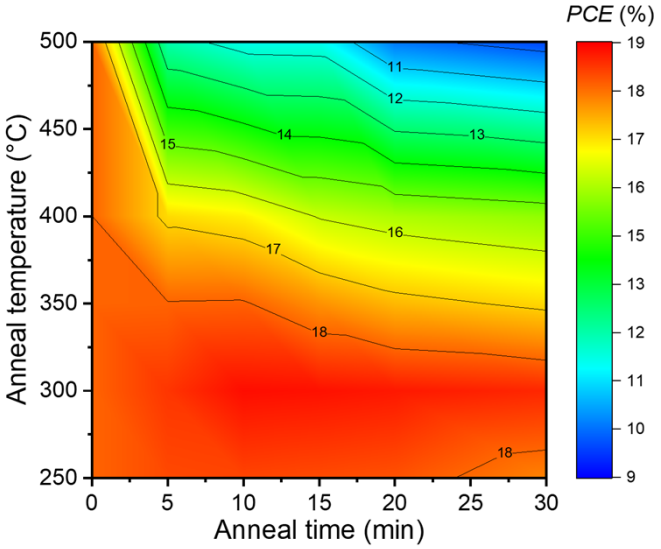

Fig. S8. *PCE* of solar cells as a function of forming gas annealing time and temperature.

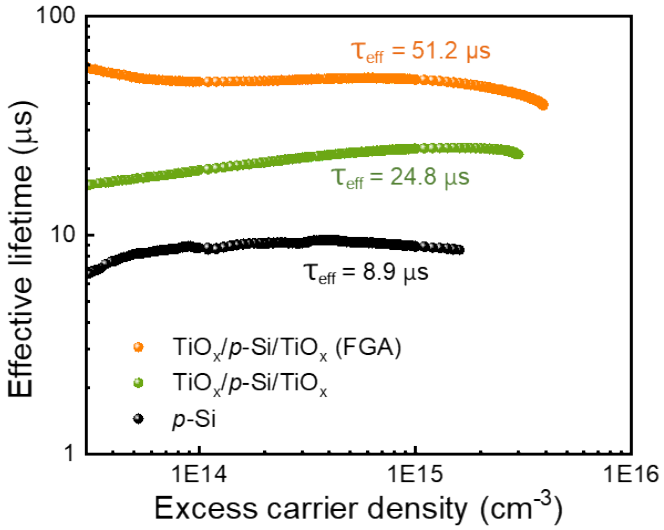

Fig. S9. Effective lifetime of the *p*-Si, TiO_x/*p*-Si/TiO_x, and TiO_x/*p*-Si/TiO_x with FGA, where the τ_{eff} is indicated for excess carrier density of 1×10^{15} cm^{-3}.

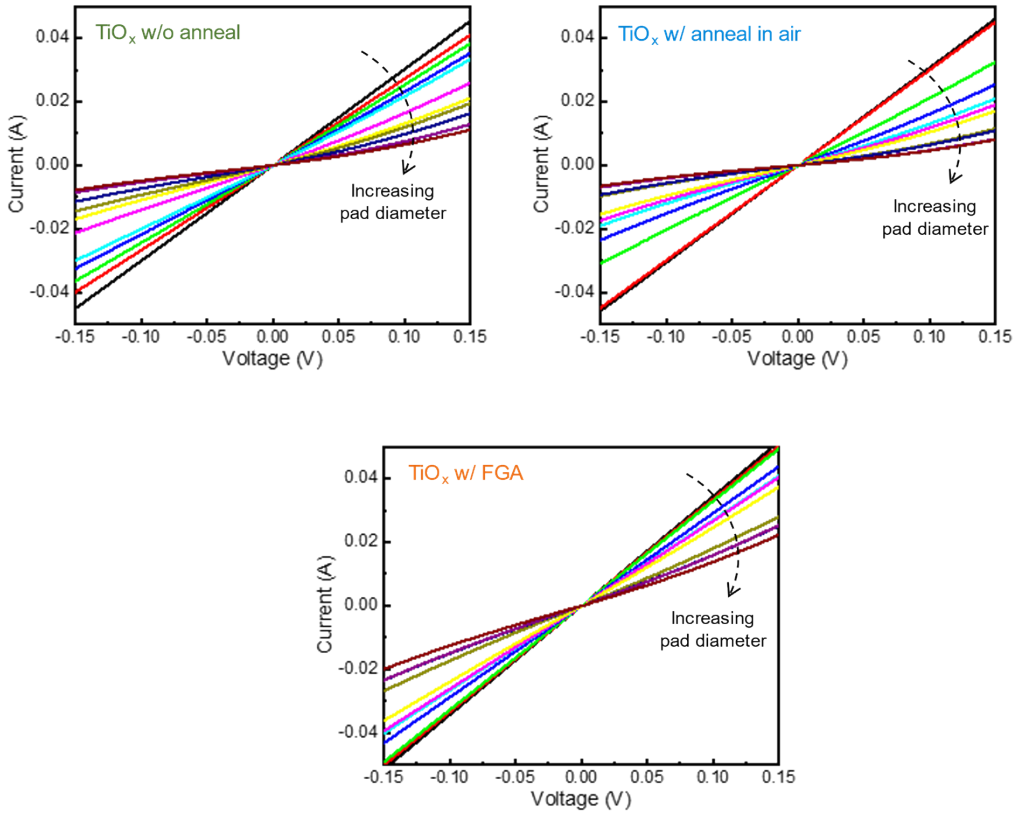

Fig. S10. The photograph of devices with different electrode pads and dark *I-V* curves of different contacts.

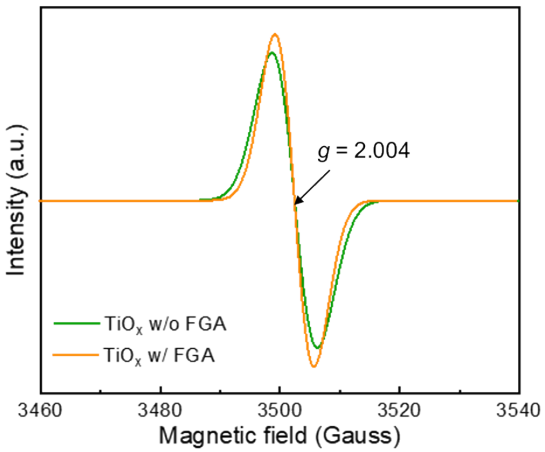

Fig. S11. Electron paramagnetic resonance (EPR) of the ultrathin TiO_x film with and without FGA treatment.

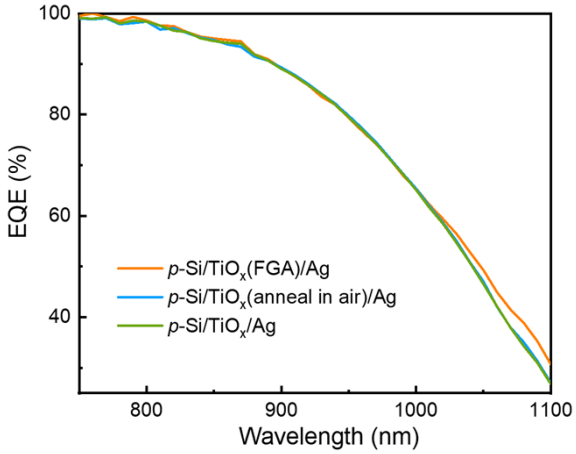

Fig. S12. EQE curves of solar cells with different TiO_x-based rear contacts.

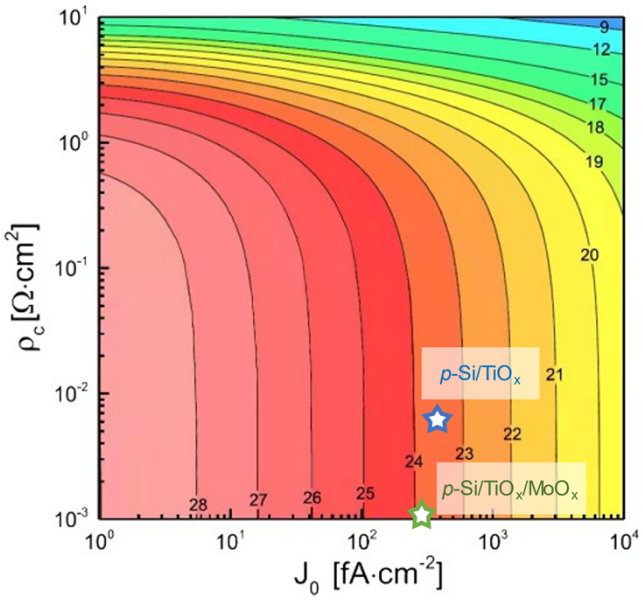

Fig. S13. Contour plot of *c*-Si solar cells featuring a full-area contact with the highest obtainable *PCE* in dependence of J_0 and ρ_c calculated from Quokka simulations. This figure has been adapted from reference [1]. The blue and green stars represent the J_0 and ρ_c values reported for *p*-Si/TiO_x and *p*-Si/TiO_x/MoO_x contacts in this work.

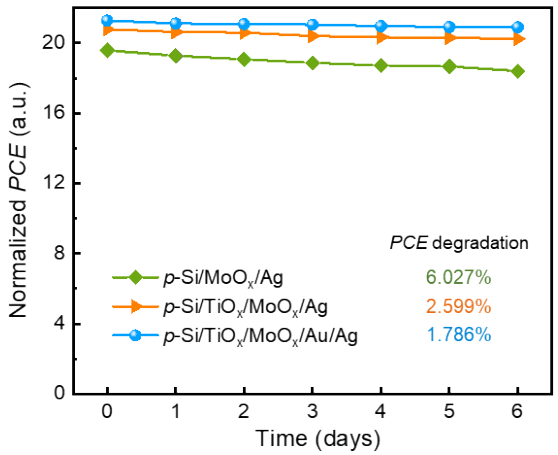

Fig. S14. Absolute *PCE*s of solar cells with different MoO_x-based HSCs as a function of storage time.

Reference

[1] Macco B, Black LE, Melskens J, et al. Atomic-layer deposited Nb2O5 as transparent passivating electron contact for c-Si solar cells. Sol. Energy Mater. Sol. Cells. 2018, 184, 98-104. doi: 10. 1016/j.solmat.2018.04.037