Electronic Supplementary Material (ESI) for Journal of Materials Chemistry C.

Electronic Supplementary Information

Electron transport bilayer with cascade energy alignment based on Nb_2O_5-Ti_3C_2 MXene/TiO_2 for efficient perovskite solar cells

Hugo G. Lemos[a], Jessica H. H. Rossato[a], Roberto A. Ramos Jr.[a], João V. M. Lima[a], Lucas J. Affonço[a], Sergei Trofimov[b], Jose J. I. Michel[c], Silvia L. Fernandes[a], Boris Naydenov[b], and Carlos F. O. Graeff[a]**

[a] Department of Physics, School of Sciences, São Paulo State University (UNESP), Bauru, São Paulo, 17033-360, Brazil

[b] Department Spins in Energy Conversion and Quantum Information Science, Helmholtz-Zentrum Berlin

[c] Department of Electrical and Electronic Engineering, The University of Melbourne, VIC 3010, Australia

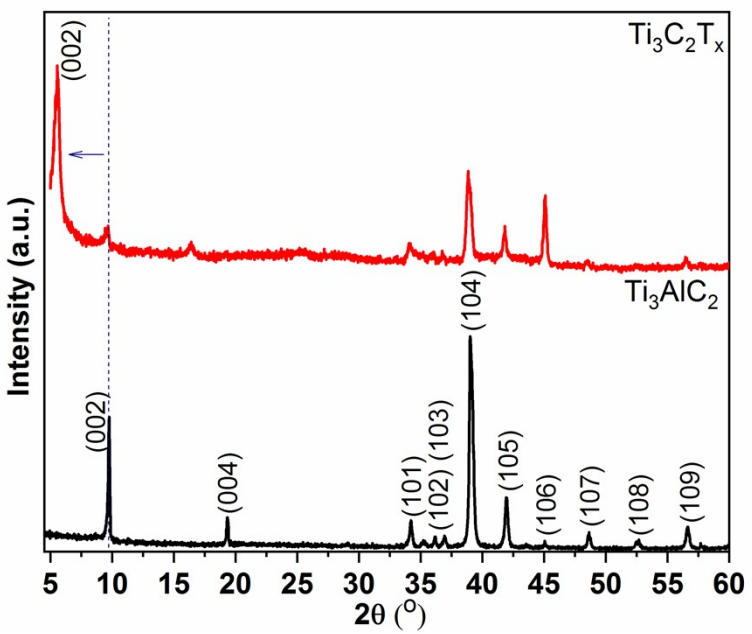

Figure S1. XRD patterns of Ti_3AlC_2 MAX phase and $Ti_3C_2T_x$ MXene.

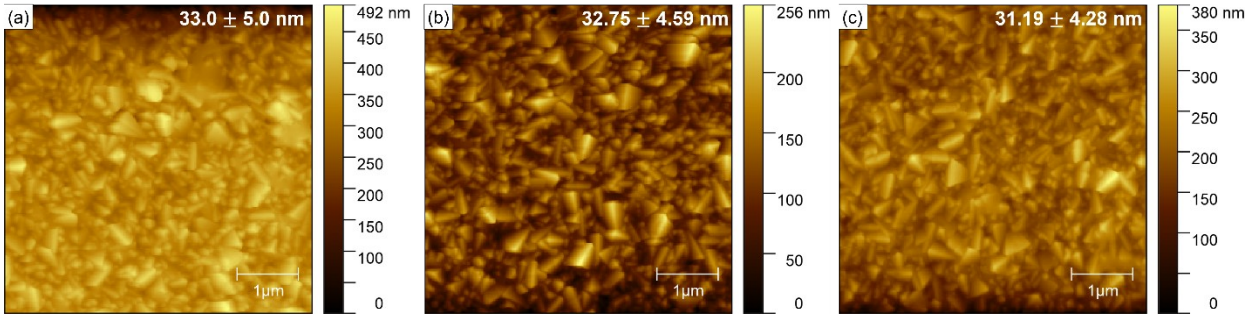

Figure S2. AFM images of Nb_2O_5 (a), Nb_2O_5-Ti_3C_2 (0.4 wt%) (b) and Nb_2O_5-Ti_3C_2 (0.8 wt%) (c) layers.

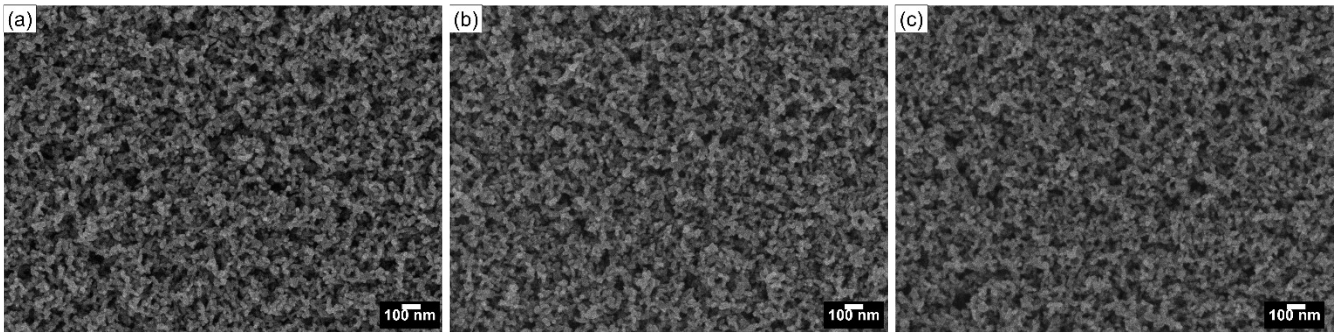

Figure S3. FE-SEM images of TiO_2 films on top of Nb_2O_5 (a), Nb_2O_5-Ti_3C_2 (0.4 wt%) (b) and Nb_2O_5-Ti_3C_2 (0.8 wt%) (c) layers.

.

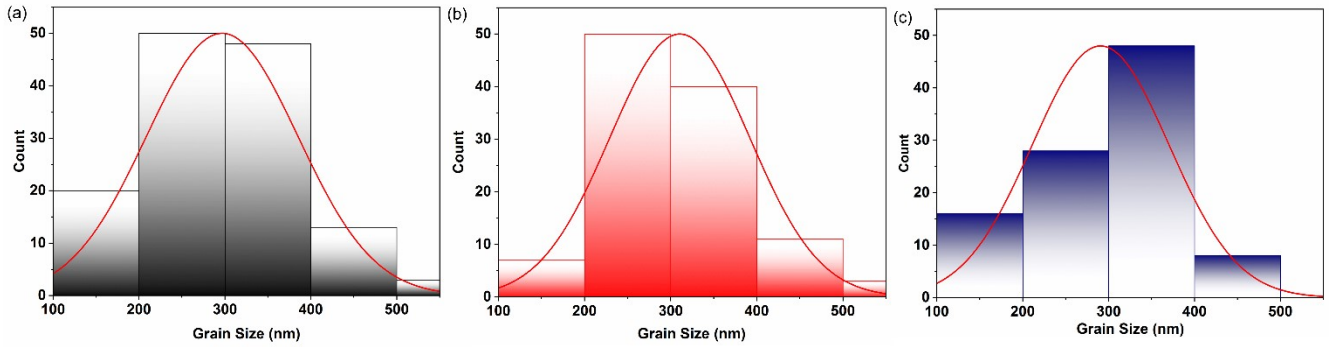

Figure S4. Grain size distribution measurements of perovskite films on top of ETLs based on Nb_2O_5 (a), Nb_2O_5-Ti_3C_2 (0.4 wt%) (b) and Nb_2O_5-Ti_3C_2 (0.8 wt%) (c) layers.

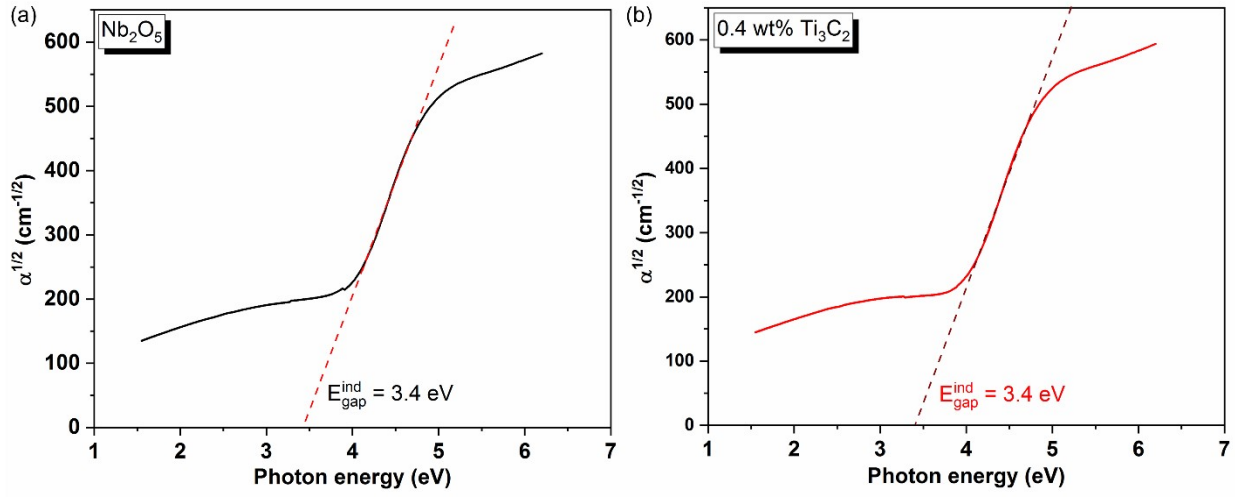

Figure S5. Tauc plots of Nb_2O_5 (a) and Nb_2O_5-Ti_3C_2 (0.4 wt%) (b).

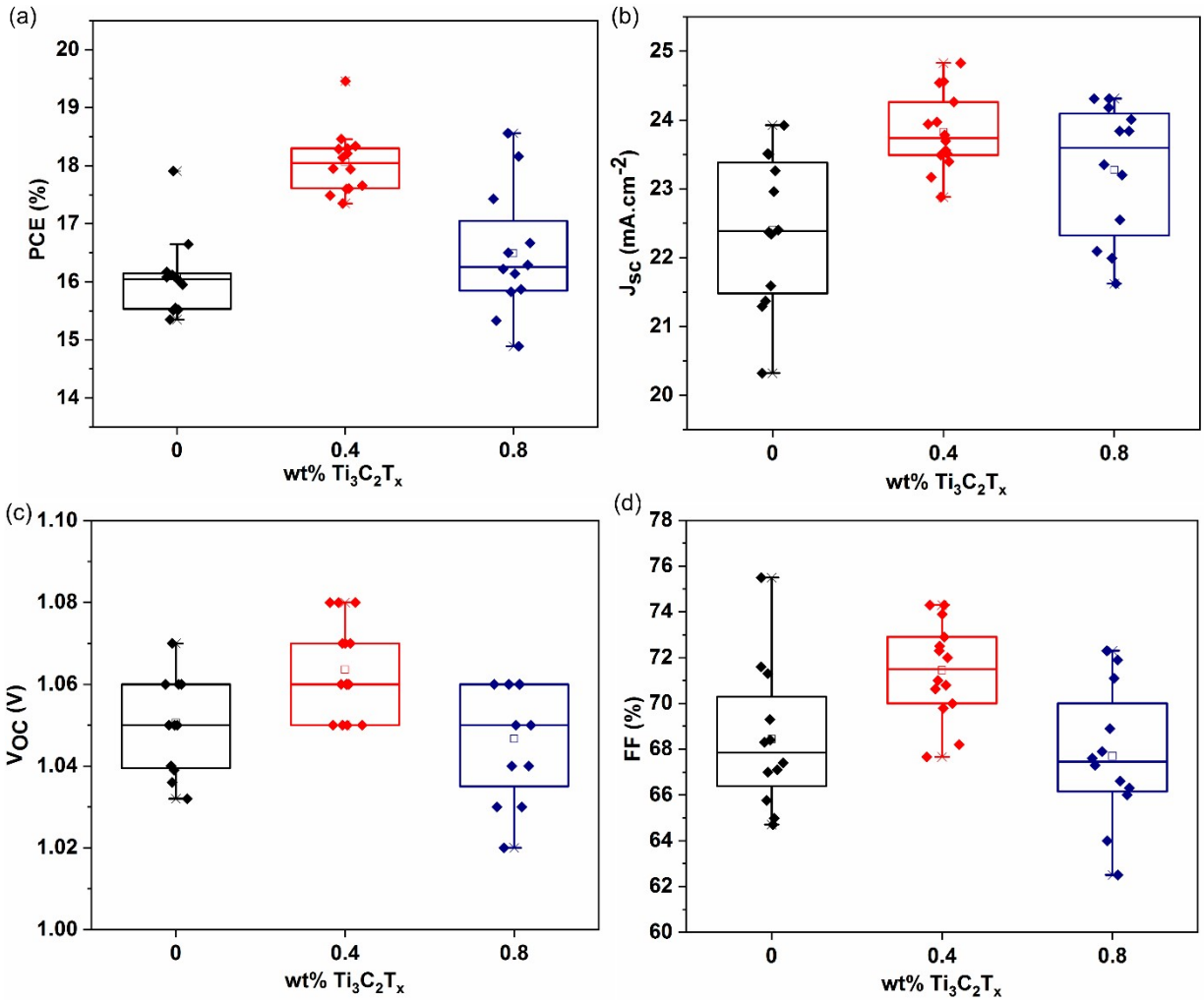

Figure S6. Box plots of photovoltaic parameters of PSCs: (a) PCE (%); (b) J_{sc} (mA.cm^{-2}); (c) V_{OC} (V) and (d) FF (%).

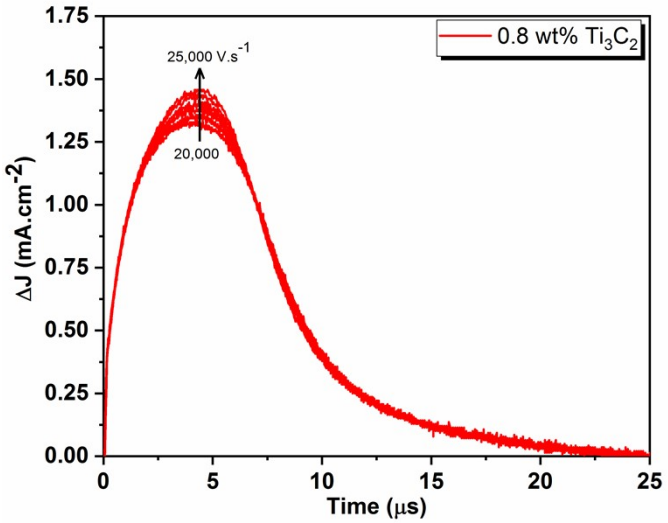

Figure S7. Photo-CELIV transient at varying voltage ramp rates.

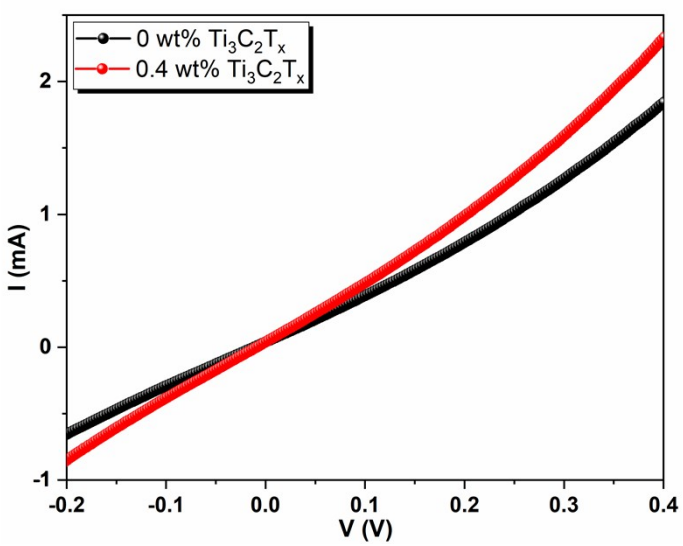

Figure S8. Current (I) vs. Voltage (V) curves of Nb_2O_5 with and without Ti_3C_2.

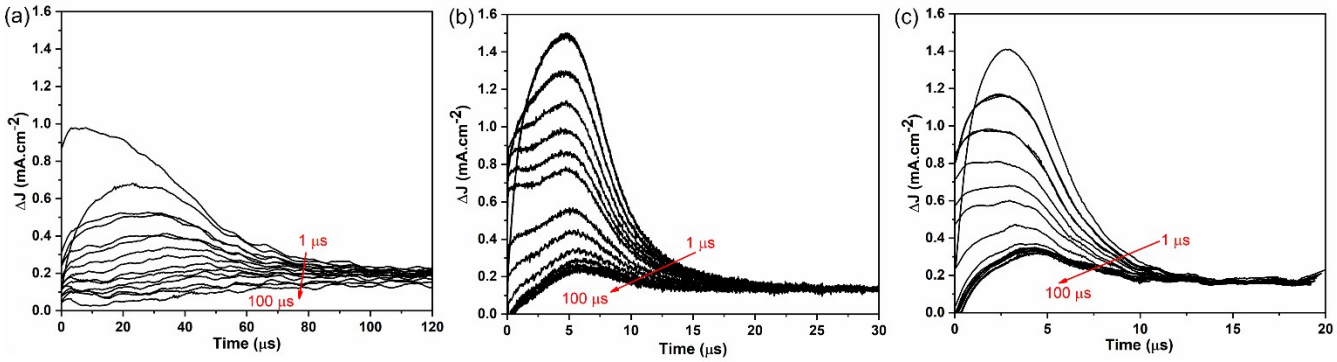

Figure S9. Photo-CELIV transient at varying delay time for Nb_2O_5 (a) and Nb_2O_5-Ti_3C_2 (0.4 wt%) (b) and Nb_2O_5-Ti_3C_2 (0.8 wt%).

Table S1. Calculated parameters for the fitted charge-carrier densities decay curves.

Device	n_1 (x10^{14} cm^{-3})	τ_1 (μs)	n_2 (x10^{14} cm^{-3})	τ_2 (μs)	R^2
Nb_2O_5	34.82 ± 2.25	0.42 ± 0.12	5.03 ± 0.04	8.44 ± 1.32	0.987
Ti_3C_2 (0.4 wt%)	14.68 ± 1.62	6.88 ± 0,23	-	-	0.998
Ti_3C_2 (0.8 wt%)	5.34 ± 1.52	4.86 ± 0,33	-	-	0.991