Effect of Mesoporous TiO_2 on Charge Dynamics of RbCsMAFA-Based Quadruple Cation Perovskite Solar Cells

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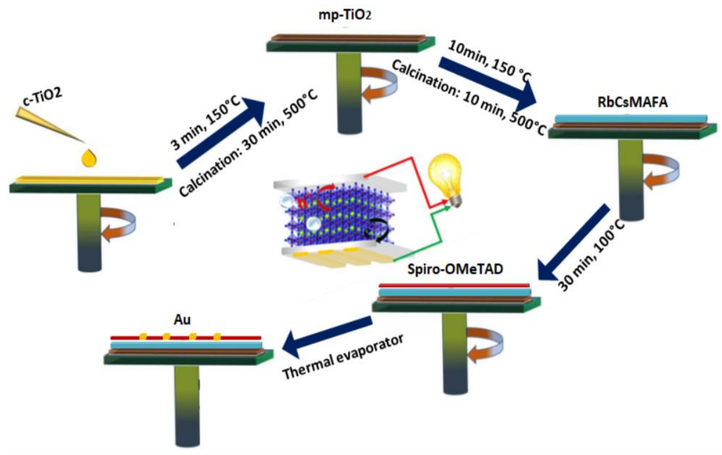
Introduction

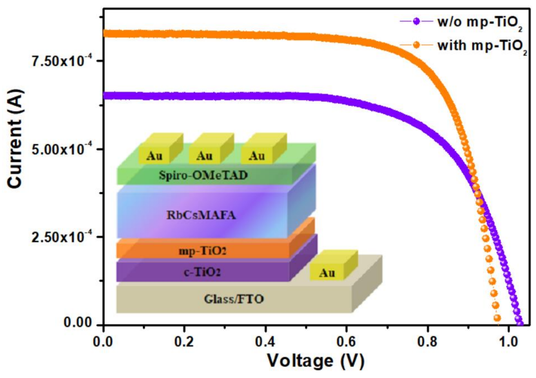
The electron transport layer of mesoporous TiO_2 (mp-TiO_2) plays a pivotal role in the performance and development of perovskite solar cells (PSCs). In order to understand the charge kinetics occurring in the bulk and at the selective interfaces, we studied quadruple cation RbCsMAFA-based PSCs deposited by spin-coating, with and without mp-TiO_2. The mp-TiO_2-free PSCs demonstrated a power conversion efficiency (PCE) of 12.10% with low short circuit current (J_{sc}) whereas a higher PCE of 16.12% with increment in J_{sc} was measured for the PSCs with mp-TiO_2. The interfacial charge kinetics of PSCs was investigated by bias-dependent electrochemical impedance spectroscopy (EIS). The PSCs fabricated with mp-TiO_2 showed a lower recombination and higher charge carrier lifetime. Further, by performing Mott-Schottky measurements, the built-in potential and doping density of immobile ions were evaluated.

KEYWORDS: mesoporous TiO_2, RbCsMAFA perovskite solar cells, impedance spectroscopy, charge recombination, Mott-Schottky.



Results

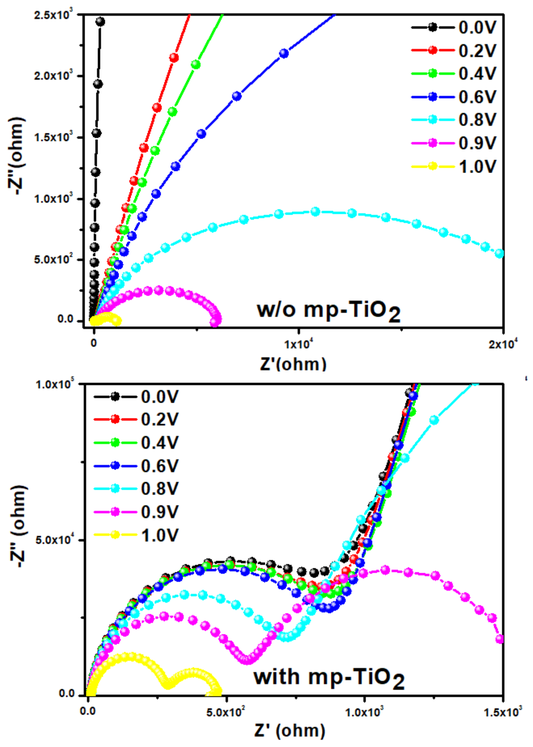
❖ I-V characteristics



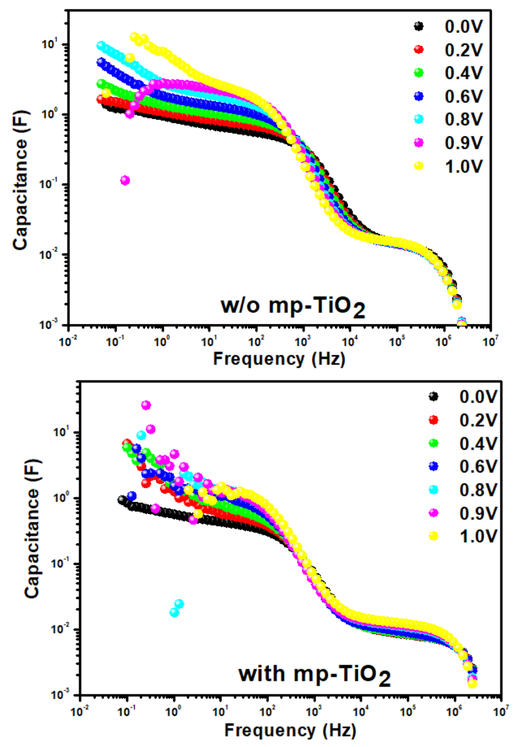
PSC	Scan direction	V_{oc} (V)	J_{sc} ($mAcm^{-2}$)	FF (%)	PCE (%)
Without mp-TiO2	*RS*	1.020	18.40	66	12.10
	FS	0.990	17.60	54	9.30
With mp-TiO2	*RS*	0.973	23.33	72	16.12
	FS	0.922	23.68	64	13.78

✓ The PCE of cells without and with mp-TiO_2 are 12.10% and 16.12% respectively, suggesting the decisive role of mp- TiO_2 on PSC performance.

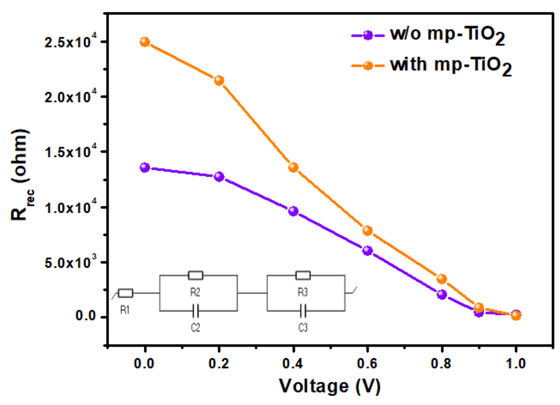
❖ Complex impedance plots



❖ Capacitance spectra



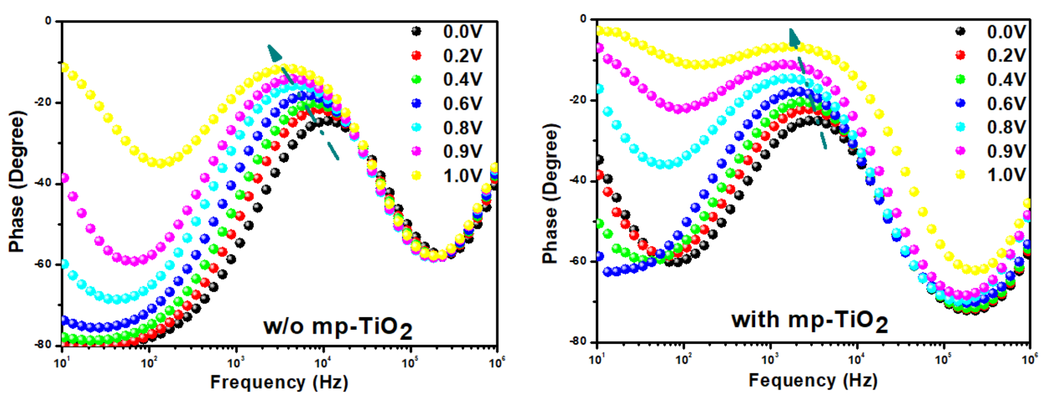
❖ Recombination resistance



✓ Incorporation of mp-TiO_2 decreases the charge recombination.

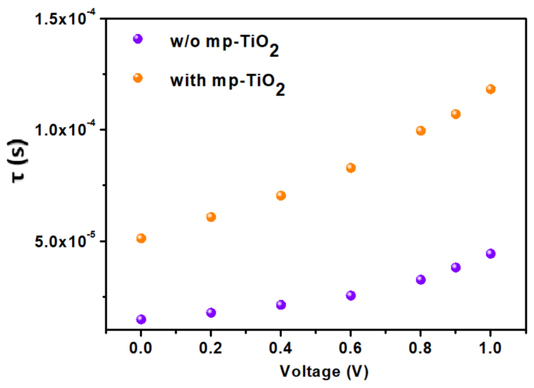
➢ This suggests that mp-TiO_2 is effective to suppress charge recombination and mitigating charge annihilation at the perovskite/ETL interface.

Bode plots



❖ Charge lifetime

$$\tau = \frac{1}{2\pi f_{max}}$$



✓ The PSCs based on mp-TiO_2 shows a longer charge lifetime compared with mp-TiO_2 free PSCs.

➢ The enhanced charge lifetime can be credited to the reduced charge recombination, resulting in rapid charge carrier transport and enhanced electron density at the mp-TiO_2/perovskite interface.

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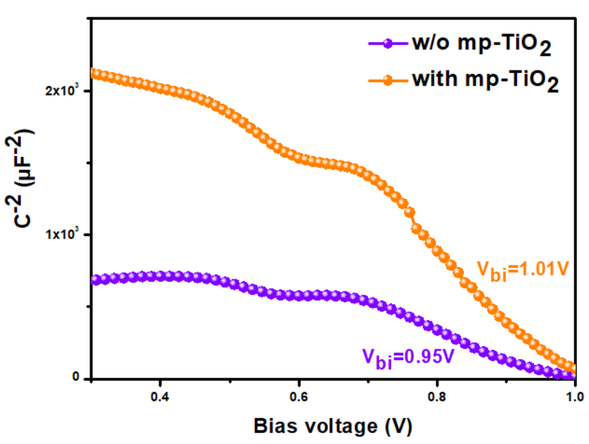
Mott-schottky measurements

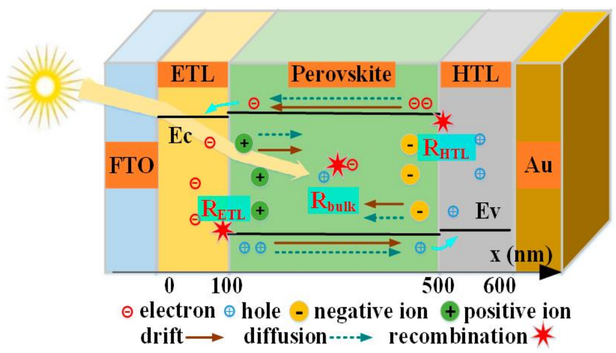


$$\frac{1}{C^2} = \frac{2(V_{bi} - V)}{\varepsilon_0 \varepsilon_r q N A^2}$$

$$W = \sqrt{\frac{2\varepsilon_0 \varepsilon_r V_{bi}}{qN}}$$

	Built-in potential V_{bi} (V)	Impurity doping density N (cm^{-3})	Depletion width W (nm)
w/o mp-TiO2	0.95	$1.11\ 10^{17}$	20.96
with mp-TiO2	1.01	$0.45\ 10^{17}$	33.95

➢ The enhanced depletion region assists in the proper charge separation and annihilates the recombination, and thus contributes to the increase in PCE.



Conclusions

❑ The obtained results provide a insight for the improvement of PV performance and charge dynamics in mp-TiO_2-based PSCs.

❑ The mp-TiO_2 effectively minimizes the detrimental charge recombination and boosts the photoinduced charge transfer dynamics at the perovskite interface.