Electrical equivalent circuit (EEC) based impedance spectroscopy analysis of HTM free perovskite solar cells

Faculty and PostDoc
Science and Engineering

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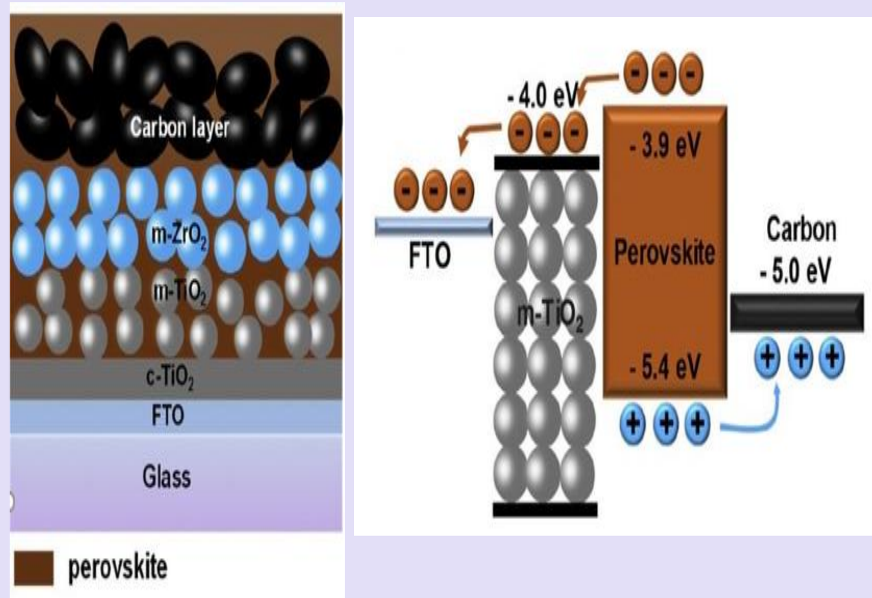
Abstract

Monolithic perovskite solar cells (mPSCs) are the multi-layered organic-inorganic hybrid cells that have been focused due to the affordable cost, ease of fabrication and noteworthy power conversion efficiency (PCE). In this research, we have carried out a systematic study to understand the physical phenomenon inside successive layers of the mpscs using the impedance spectroscopy (IS). This study was performed on the optimized mPSCs with power conversion efficiency over 13%, where $CH_3NH_3PbI_3$, perovskite has been used as light absorber. The internal electrical processes at the interfaces of the layers of mPSCs devices have been studied and correlated to produce electrical equivalent circuit of overall device.

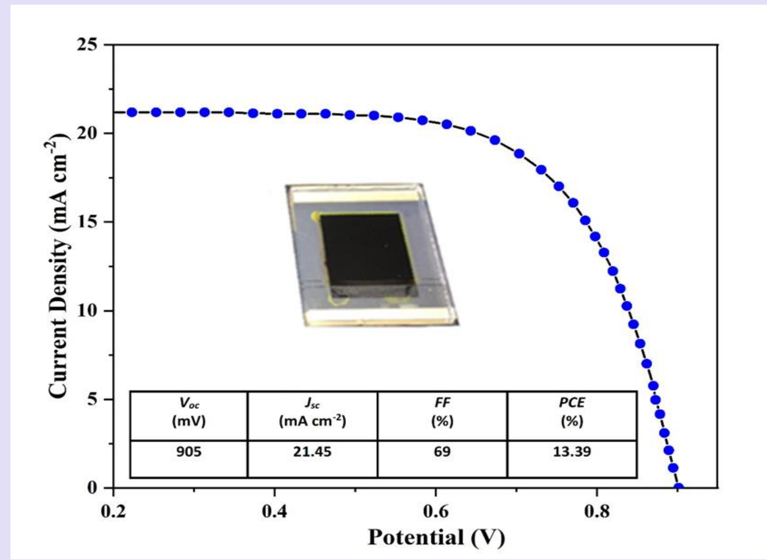
Experimental Setup



The mPSCs consist of four successive layers i.e. c-TiO_2, m-TiO_2, ZrO_2 and carbon as shown in Figure 1. The compact and mesoporous TiO_2 layers were deposited by using the dip coating technique. The ZrO_2 and carbon layers were deposited by using screen-printing technique.

Figure 1: Schematic representation and energy band diagram of carbon-based monolithic perovskite solar cells

The PCE of the optimized mPSCs was ~13.4%. Figure 2 shows J-V characteristics, measured under 100mW/cm^2 illumination using the Abet Sun light solar simulator. The impedance measurements were performed with Gamry-3000 potentiostat.



Fugure 2: J-V characteristics of the carbon based HTM-free perovskite solar cells.

Results & Discussion

FESEM and EDX Results

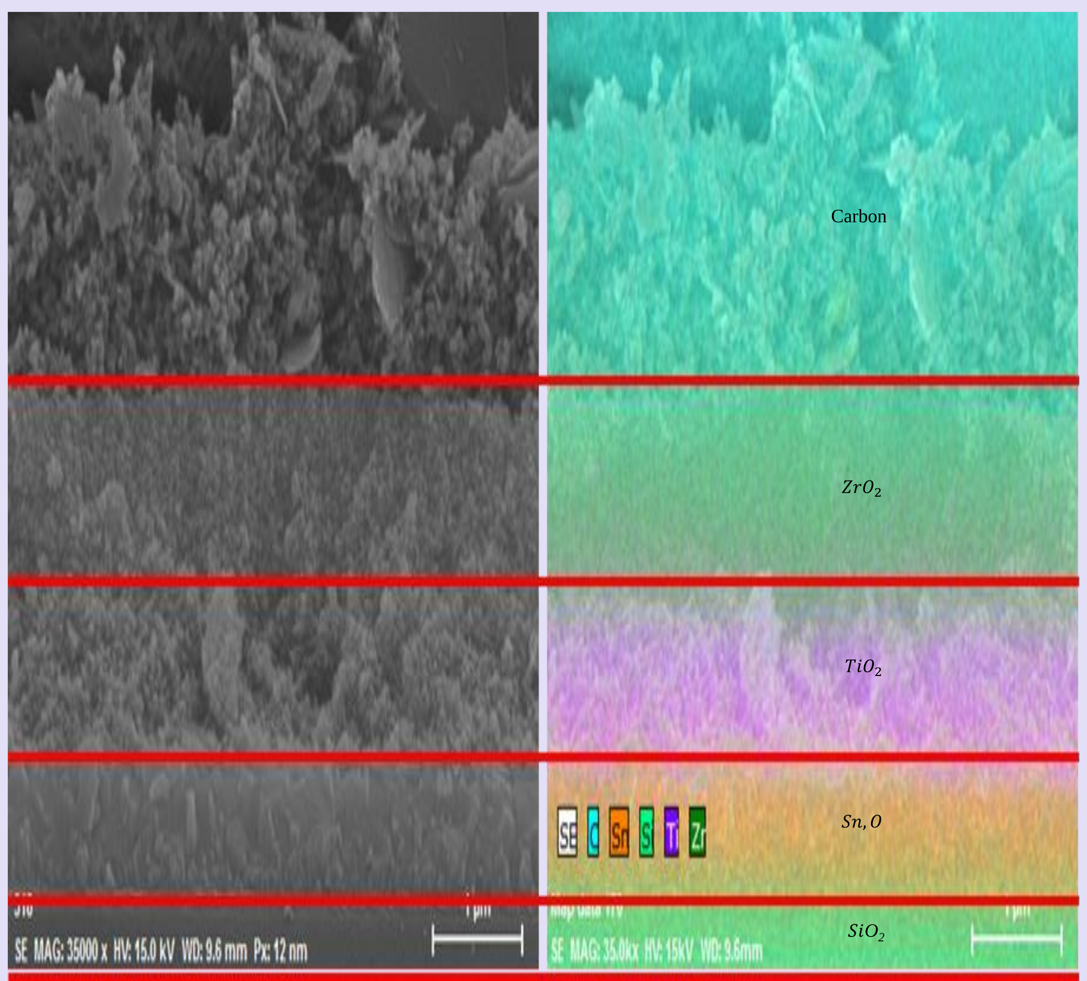


Figure. 3: FESEM and EDX analysis of the mPSCs samples. The mPSCs consist of four successive layers i.e. c-TiO_2, m-TiO_2, ZrO_2 and carbon on the glass substrates.

EIS Results (Nyquist Plots)

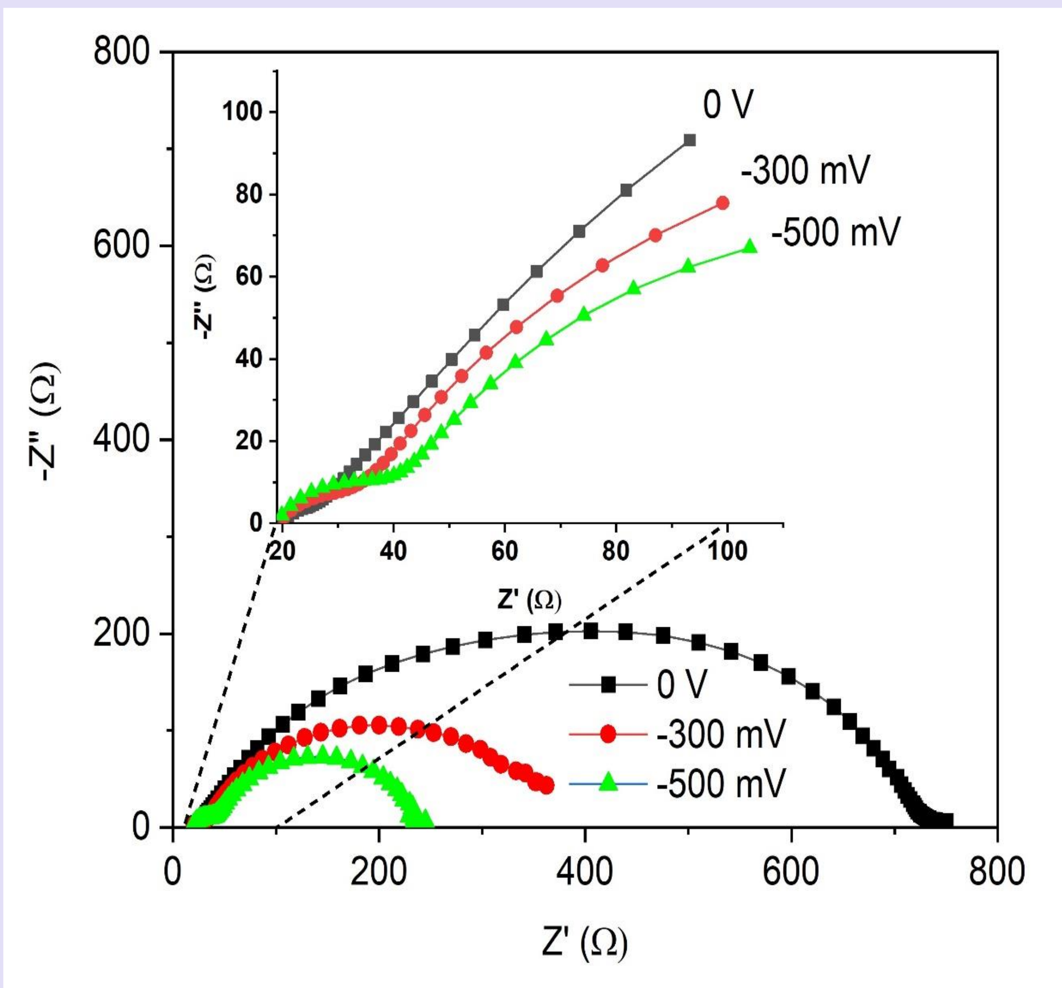


Figure 4: Nyquist plots of the mPSCs under different DC applied potential (0V, 300 mV and 500 mV) and 10 mV AC perturbation.

EIS Results (Nyquist Plots)

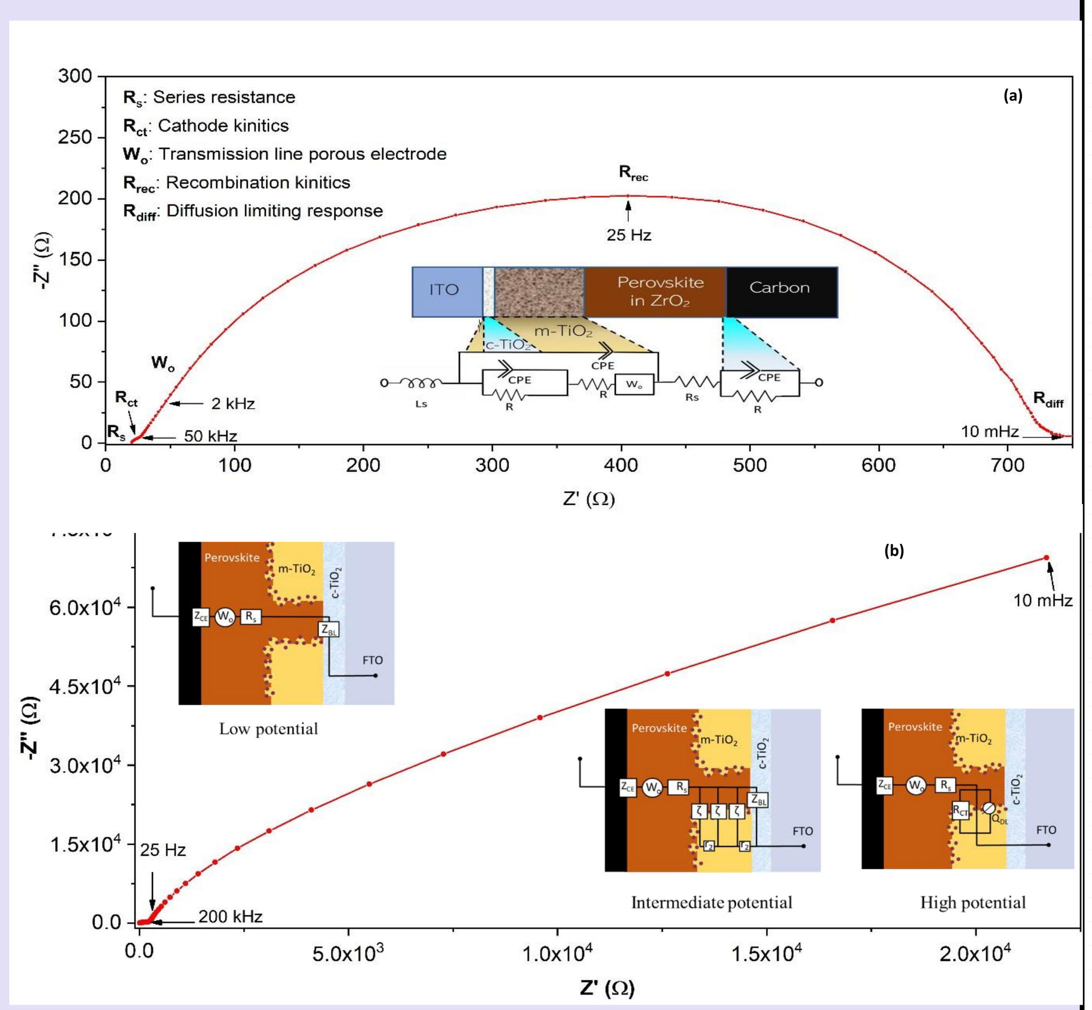


Figure 5: EIS of the mPSCs under the 0V DC applied potential and 10 mV AC perturbation. (a) with perovskite and (b) without perovskite.

Concluding Remarks

On the base of the EEC analysis, it can be concluded that the electron transport is directed over the mTiO_2 as evinced by the observation of the chemical capacitance (Cc) of the mTiO_2. The Cc is associated with the low frequency arc in the Nyquist plot and this time constant element describes the mTiO_2. The proposed EEC model allowed the recognition and chemical analysis of the individual elements impacting to the IS results. We have established a procedure and a suitable model that can be applied to fit the experimental IS data generated for the mPSCs.

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The findings made herein are solely the responsibility of the authors.