Eliminating Irregular Hysteresis behavior in Perovskite solar cells

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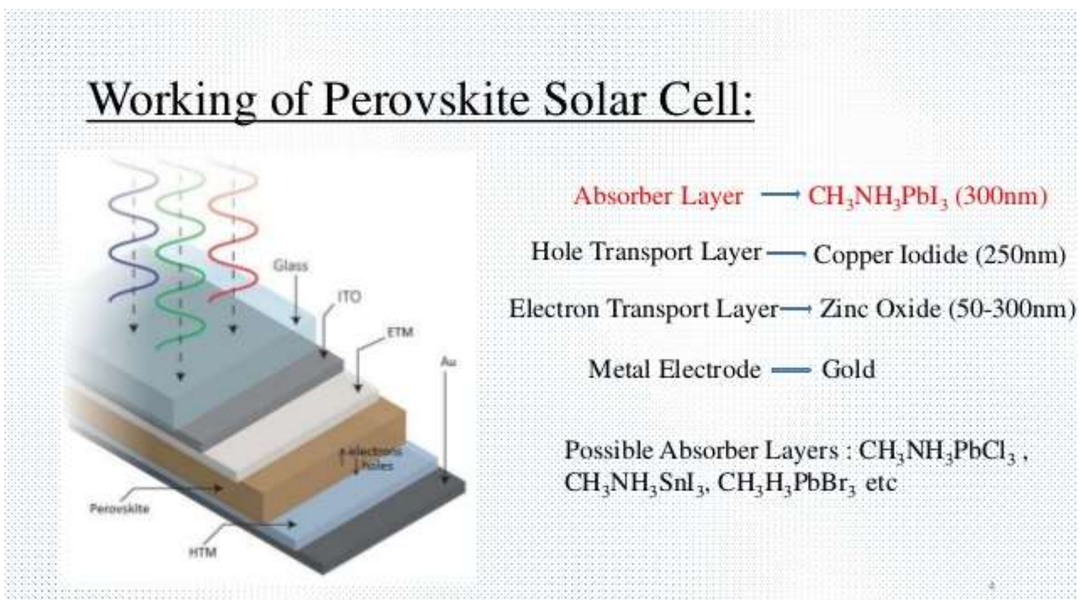
Introduction about my research

- My research motivation arises from complexity of production of silicon solar cells. Perovskites cells has an advantage over silicon cells because of its simplicity wet chemistry techniques for manufacturing.
- Power conversion efficiency of solar cell is determined by characteristics 'IV' behavior. Perovskites solar cells shows irregular hysteresis behavior thus it is not preferred over silicon solar cells.
- Objective of this research is to eliminating irregular hysteresis behavior by changing the degree of hysteresis as it depends on voltage setting time and low frequency capacitance.

Perovskite solar cells

- Perovskites solar cells have a great advantage over silicon because of its simplicity of manufacturing using wet chemical techniques.
- Methylammonium & formamidinium lead trihalides are created using vapor deposition techniques, which is simple to use.
- Lead halide and methylammonium halide can be dissolved in a solvent and spin created onto a substrate. As a result 'Crystallized Perovskite Material' is formed having strong ionic interaction with the material.



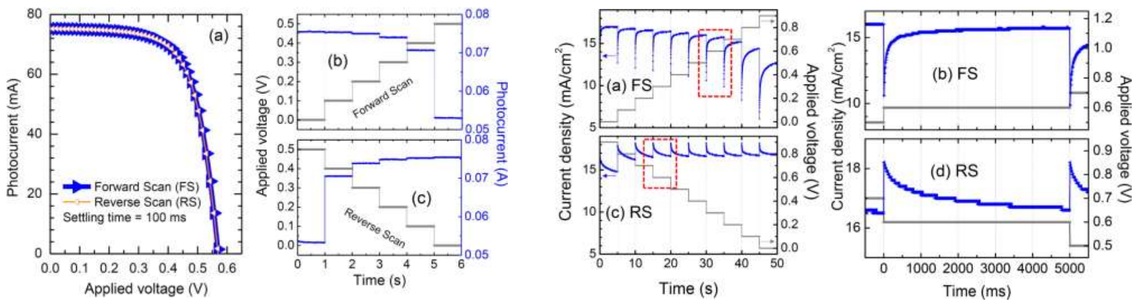
- Substrate is bathed in diethyl ether at 150°C applicable for production of multi junction cells. Long term in dry environment.
- Record efficiency of 20.1% as certified value by NREL (13-14% of silicon solar cells)

Forward Scan and Reverse Scan

- For perovskite solar cells hysteresis behavior depends on scanning such a scan direction, scan speed, light speed, light soaking and biasing. Therefore, determining behavior is tough.
- Working principle is based on IS (Impedance Spectroscopy) and Anomalous behavior is due to mixed halide perovskites. CH3NH3PbI3 is in crystal size and TiO2 is in Mesoporous state.
- Sensitized cell (CH3NH3PbI3) exhibits more than 2 orders of magnitude higher capacitance than dyed sensitized one.
- Size is inversely proportional to concentration of CH3NH3I. (Using two step spin coating method).
- A strong time dependent photocurrent in 500ms at both FS(Forward scan) and RS(Reverse scan) is responsible for 'IV' hysteresis.

$$Ic = C(dV/dt) + V(dC/dt)$$

Here Ic can be +ve(FS) or –ve(RS)



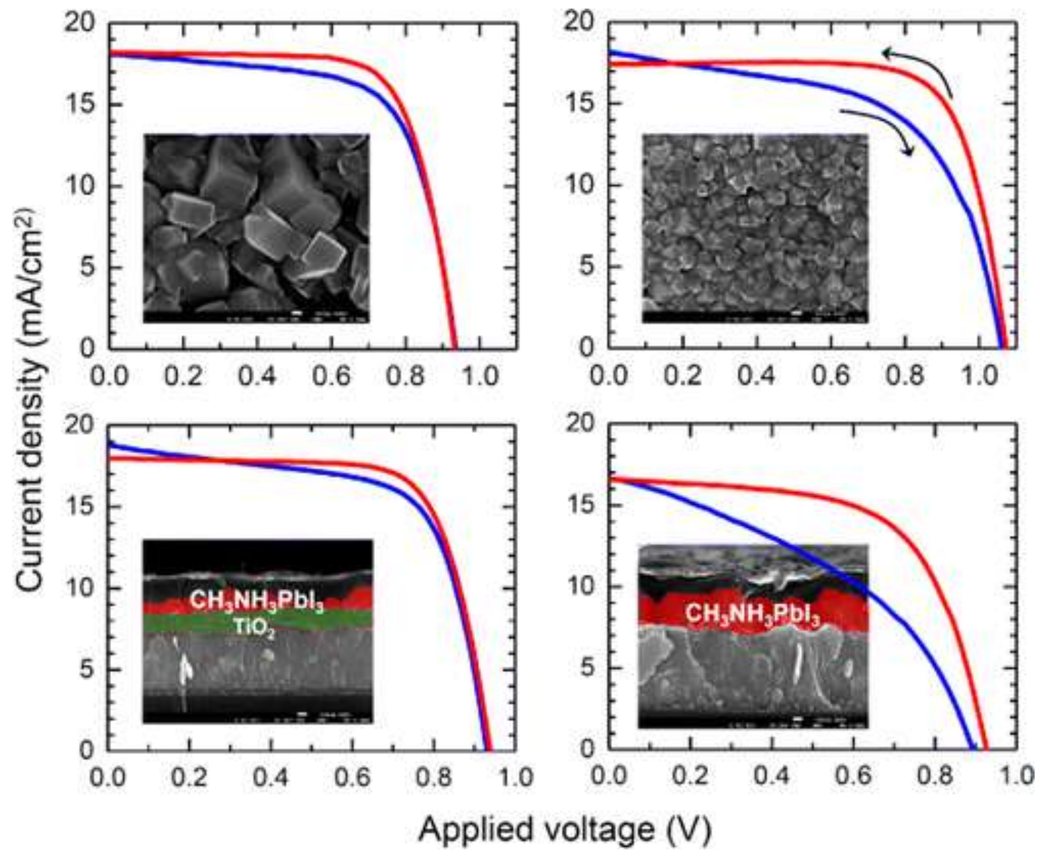
- Compared with the planar structure without mp-TiO2 layer, no significant difference in I-V curves between FS and RS is observed for mesostructured device with mp-TiO2.
- Crystal size decreases from 440nm to 130nm because photocurrent is over or under.

Behavior of Hysteresis

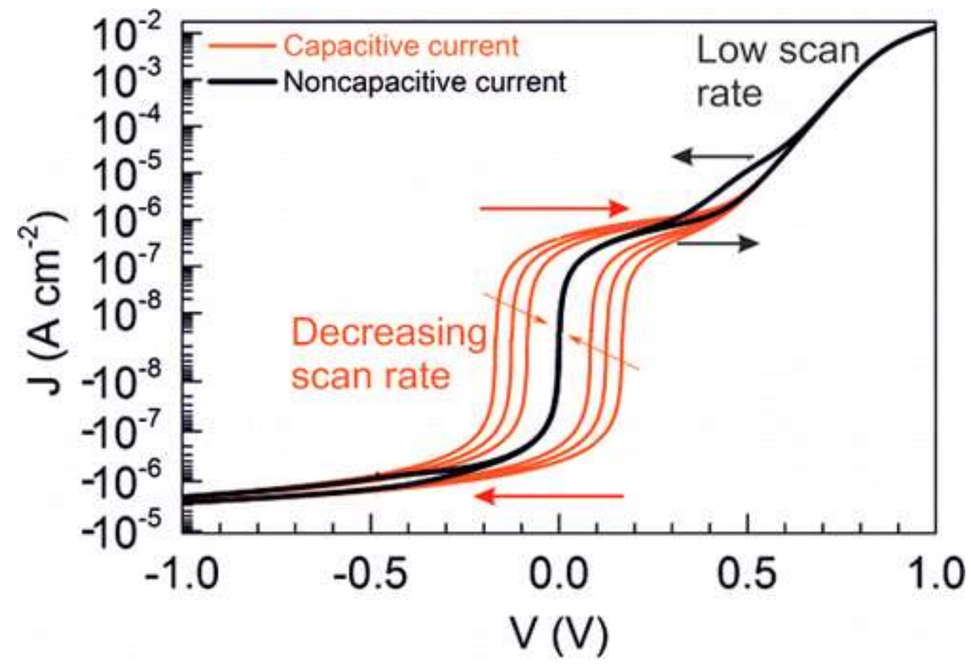
- Capacitive characteristics in solar cells affects the period to reach the steady-state condition, which leads to the I–V hysteresis.
- As crystal size decreases from 440 to 130 nm the time dependent current response becomes clearly intensified, especially at FS, which is responsible for the further aggravation in I–V hysteresis.
- Because the prominent feature in the IV hysteresis appears near open circuit, a modified hysteresis index is taken into consideration :

$$\text{Hysteresis Index} = [Jrs(0.8Voc) - Jfs(0.8Voc)]/Jrs(0.8Voc)$$

*Here Jrs and Jfs are photocurrent density at 60% of Voc.



- As we can see that graph drastically goes down after 0.8V if TiO2 is also present and gradually goes down if its not.
- When TiO2 is absent, current density of FS goes down faster than that of BS which ultimately tells us that presence of TiO2 matters and J value should be taken 60% instead of 80% of Voc.



Advantages and Future Applications

Since, now we have eliminated irregular behavior of hysteresis, we can focus on various advantages and future applications.

- One of advantage of Perovskite solar cells over silicon solar cells is that it is made up of common metals and industrial chemicals instead of expensive raw materials.
- Perovskite based materials could be used to print photovoltaic electronics directly onto glass or other materials which would be cheaper than most of the complex metals for producing thin film solar cells.
- Perovskite cells are heavy and rigid and works most efficiently when positioned flat in large reducing the heavy set panel cost.
- Hybrid cell of silicon solar cells and perovskite solar cells are possible by combining their efficiency.
- World's highest solar cell conversion efficiency is achieved with concentrator triple junction compound solar cell (44.4%) whereas students have generated maximum of 25.5% of efficiency using perovskite solar cells (17% was max.).

"There has never been this technology that grows in efficiency number so quickly." – Van De Lagemaat