# Cryo-Hysteresis in Perovskite Solar Cells

Ivan Shmarov | BSc Hons Physics | 160017294 | i.shmarov2@ncl.ac.uk
Supervisor: Dr. Pablo Docampo

## Aims

- Design and prototype a set of instruments that allow convenient electrical measurements of solar cells at cryogenic temperatures
- Using the designed instruments, conduct measurements to witness the ionic migration and affirm its effect on open-circuit voltage of Perovskite solar cells by varying temperature

## Background

- Perovskites are materials with specific crystal structure
- From electrical point of view, Perovskites are mixed ionic/electronic semi-conductors
- They conduct electrons and holes as conventional semi-conductors (like Silicon)
- Also have ion vacancies within, that move and affect the current
- Perovskites are good photoabsorbers – they can be used as the material for solar cells

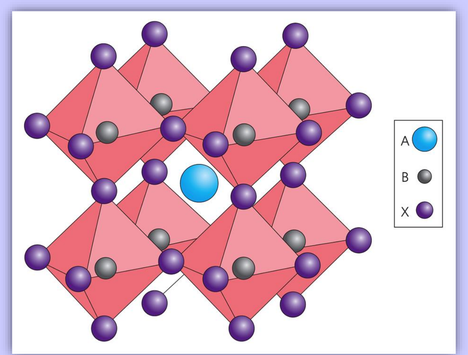


**FIG. 1** Generic Perovskite structure, formula $ABX_3$, A & B – anions, X – cations [1]

$Cs_5$ is one example of Perovskites with formula: $Cs_{0.05}\,[(FA)_{0.83}\,(MA)_{0.17}]_{0.95}\,Pb\,(I_{0.83}\,Br_{0.17})_3$ [2]

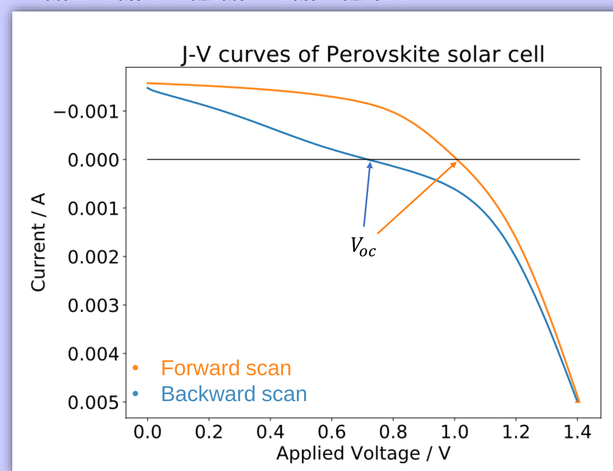


**FIG. 2** J-V Curve of $Cs_5$ Perovskite solar cell at room temperature under light intensity of 1 sun

Forward and Backward refer to the direction of scanning (Forward = from High Voltage to Low voltage, Backward – the other way around)

Point where J-V curve crosses the x-axis (when current is 0) is *open-circuit voltage*, $V_{oc}$

- Ions, being charged particles, bend the band structure of the device, i.e. affect the performance
- Ions migrate depending on the initial applied bias and direction of scanning
- This results into curves diverging, showing hysteresis
- Open-circuit voltage is one of the key parameters of Perovskite solar cells

## Instrument Setup

The idea behind this setup is to freeze ions at their position, i.e. stop their migration, and scan for open-circuit voltage

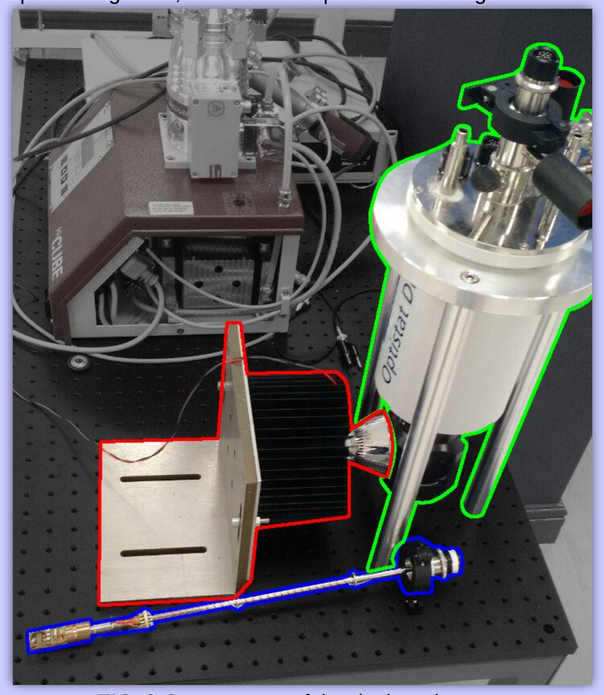


**FIG. 3** Components of the designed setup

- Cryostat exposes the sample to cryogenic temperatures, down to ≈ 77 K (-196 °C)
- High Power LED is used to imitate sun light intensity
- Sample Holder connected the sample to the measuring device (SourceMeter)
- All components were connected to a computer and controlled by self-made software with Python 3
- Setup instructions – scan J-V curve for both directions for every light intensity for every temperature resulting in huge amount of data

## Data Analysis

$Cs_5$ Perovskite solar cell were used to test the instrumental setup. Acquired J-V curves were processed and the data was condensed in the following figure:

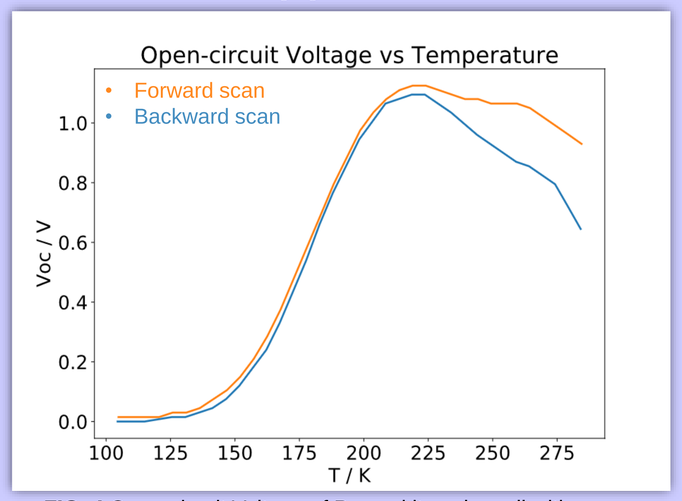


**FIG. 4** Open-circuit Voltage of Perovskite solar cell with respect to temperature under light intensity of 1 sun

- below 150 K: $V_{oc}$ is negligible – no photo-voltaic behaviour
- [150 K, 215 K]: $V_{oc}$ increases and is the same for both scan types – perovskite works like conventional solar cell, but ions are still frozen
- after 215 K: $V_{oc}$ for two scan types diverge – ions unfreeze and moves within the perovskite

## Conclusions

- The designed set of instruments is functional and allows to measure J-V curves under cryogenic temperatures and under different light intensities
- To test the setup, $Cs_5$ Perovskite solar cell was used and initial data set was extracted
- Processing of this data revealed that ions in $Cs_5$ Perovskite freeze at their position below 215 K

## Acknowledgments

- I would like to thank Susana Iglesias Porras, current PhD student of Newcastle University, for her big contribution to this project, for helping with the instrumental setup and preparing $Cs_5$ Perovskite solar cells
- I would like to thank Dr Pablo Docampo for his guidance and theoretical support in explanation and understanding of the project results
- I would also like to thank Newcastle University Physics office, in particular Andrea Dawson, for providing the Cryostat and the lab as a workplace for this project

## Reference

[1] Green, M. A., Ho-Baillie, A., Snaith, H. J. (2014) 'The emergence of perovskite solar cells', *Nature Photonics*, volume 8, pages 506–514
[2] Hu, Y., et al. (2017). 'Impact of Rubidium and Cesium Cations on the Moisture Stability of Multiple-Cation Mixed-Halide Perovskites', *ACS Energy Letters*, 2
[3] Snaith, H. J., et al. (2014) 'Anomalous Hysteresis in Perovskite Solar Cells', *The Journal of Physical Chemistry Letters*