Indium Arsenide Quantum Dots for Intermediate Band Solar Cell Applications

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UNDER SUPERVISION OF DR. IAN SELLERS

IN CONJUNCTION WITH YANG CHENG, HADI AFSHARI, HELP FROM VINCENT WHITESIDE AND COLLIN BROWN

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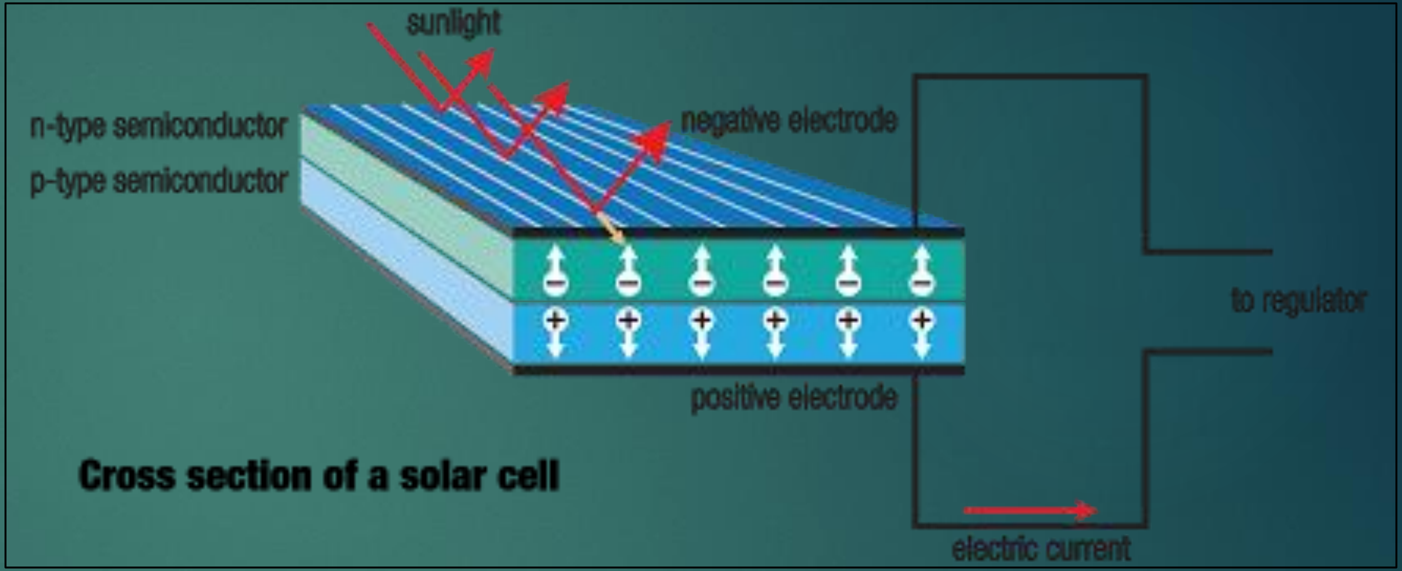
What is a Solar Cell

- An electronic device that converts sunlight into electricity
- Created by a p-n Junction
- This p-n junction is essentially what you would call a diode

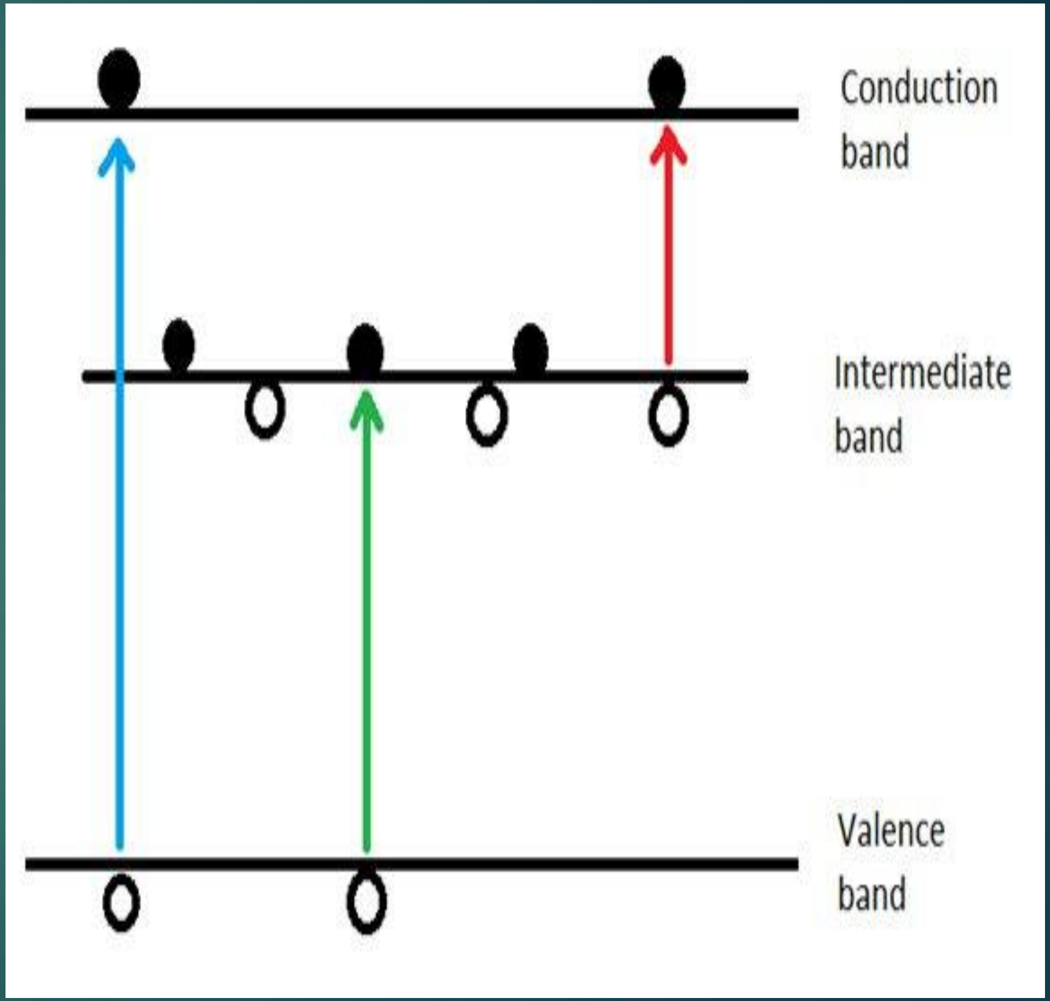


Solar Cell Efficiencies

- Examples of a single p-n junction solar cell would be Silicon (more typical) and Gallium Arsenide
- Shockley-Queisser limit is the maximum theoretical efficiency for a single p-n junction.
- Silicon based solar cells have reached an efficiency of 22%
- Gallium Arsenide Solar cells have reached 29%!

How do we improve upon this 30%?

- Most Loss is transmission
- That energy is needed to excite a carrier across the bandgap.
- Utilizing an Intermediate Band
- Difficult to achieve
- Has not been demonstrated, people are working on the idea.



Indium Arsenide Quantum Dots

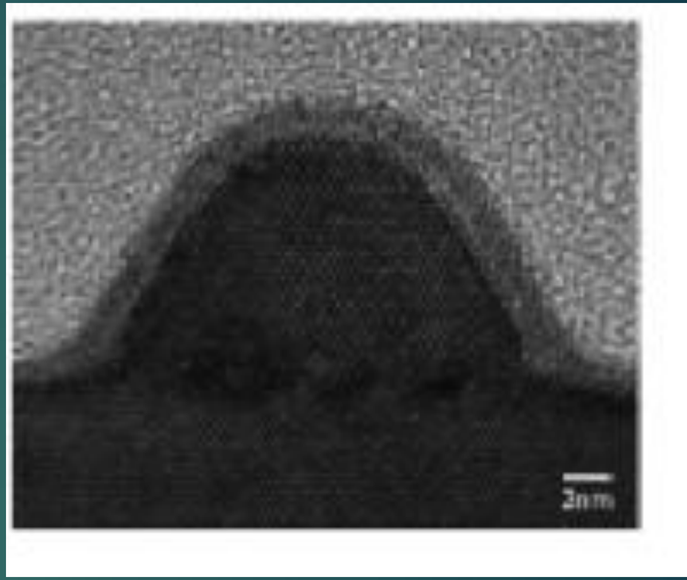
- Self assembled Indium Arsenide Quantum dots are

  grown

- Quantum Dots are nanoscale semiconducting particles

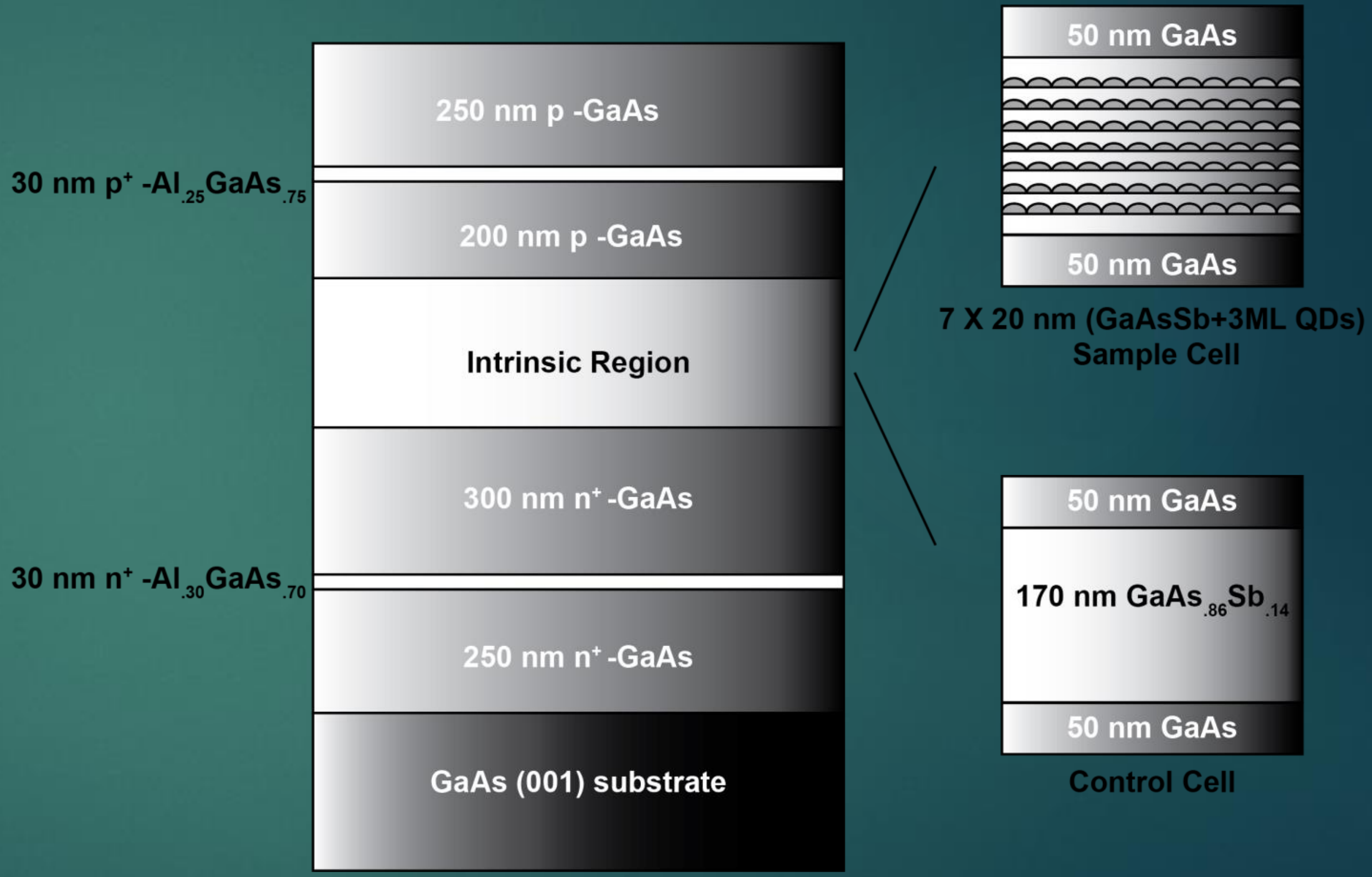
- These Quantum Dots Introduce discrete energy levels

- They can create Intermediate Band



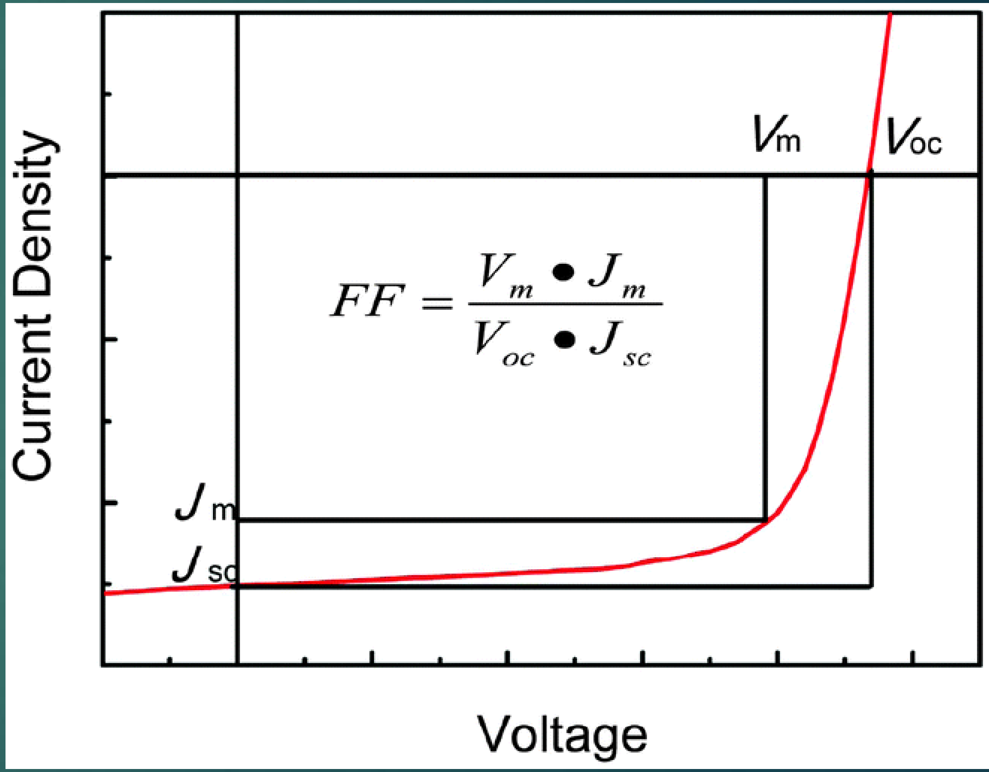
Schematics of the Solar Cells

- Worked with many different cell samples
- Samples have an intrinsic region containing GaAsSb between two 50nm GaAs layers
- 7 Quantum Dot Layer is similar, with the addition of 7 layers of Indium Arsenide QD within the GaAsSb matrix



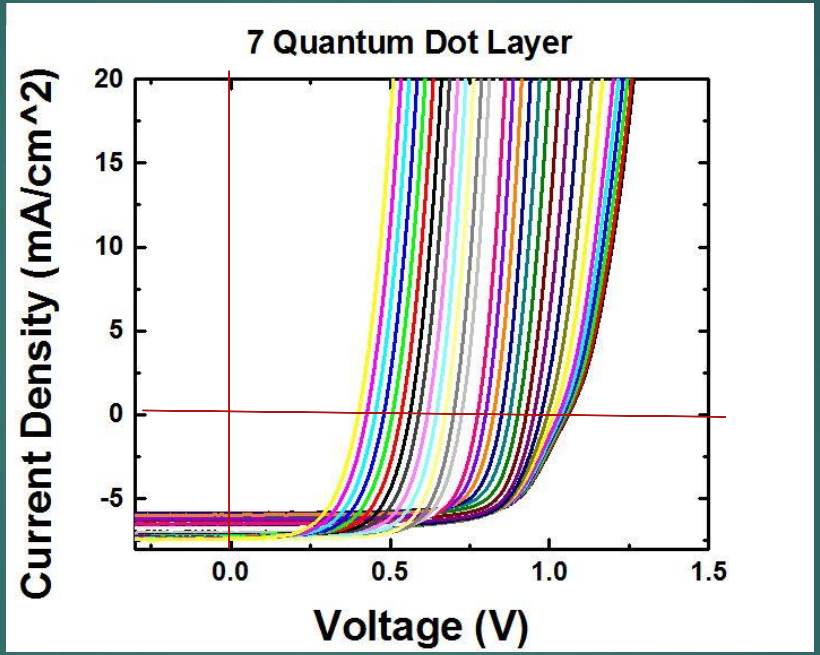
My Research Participation

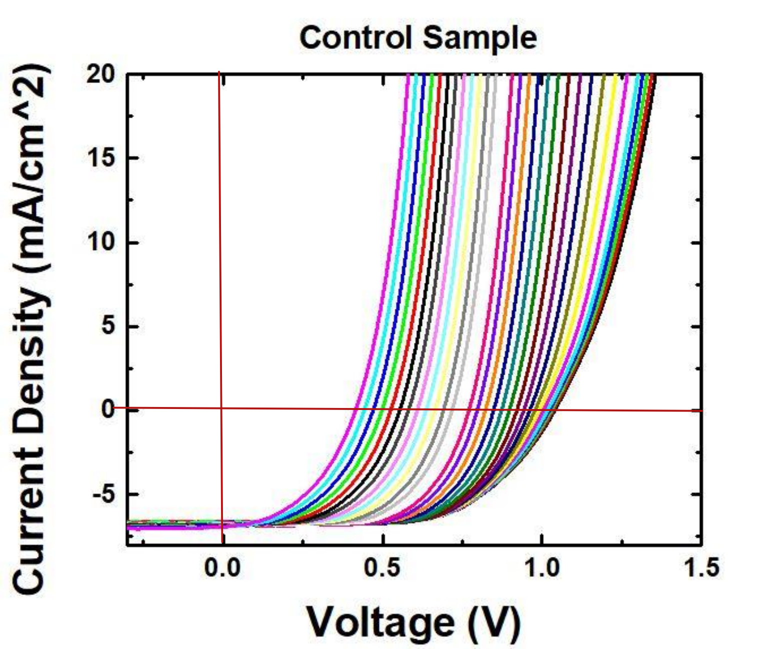
- Extract information about the transport properties of different cell samples.
- Properties include: Open Circuit Voltage, Short Circuit Current Density, Current Density Max and Voltage Max at the Maximum Power Point.
- Observe External Quantum Efficiency of Temperature Dependent and Bias Dependent Measurements.

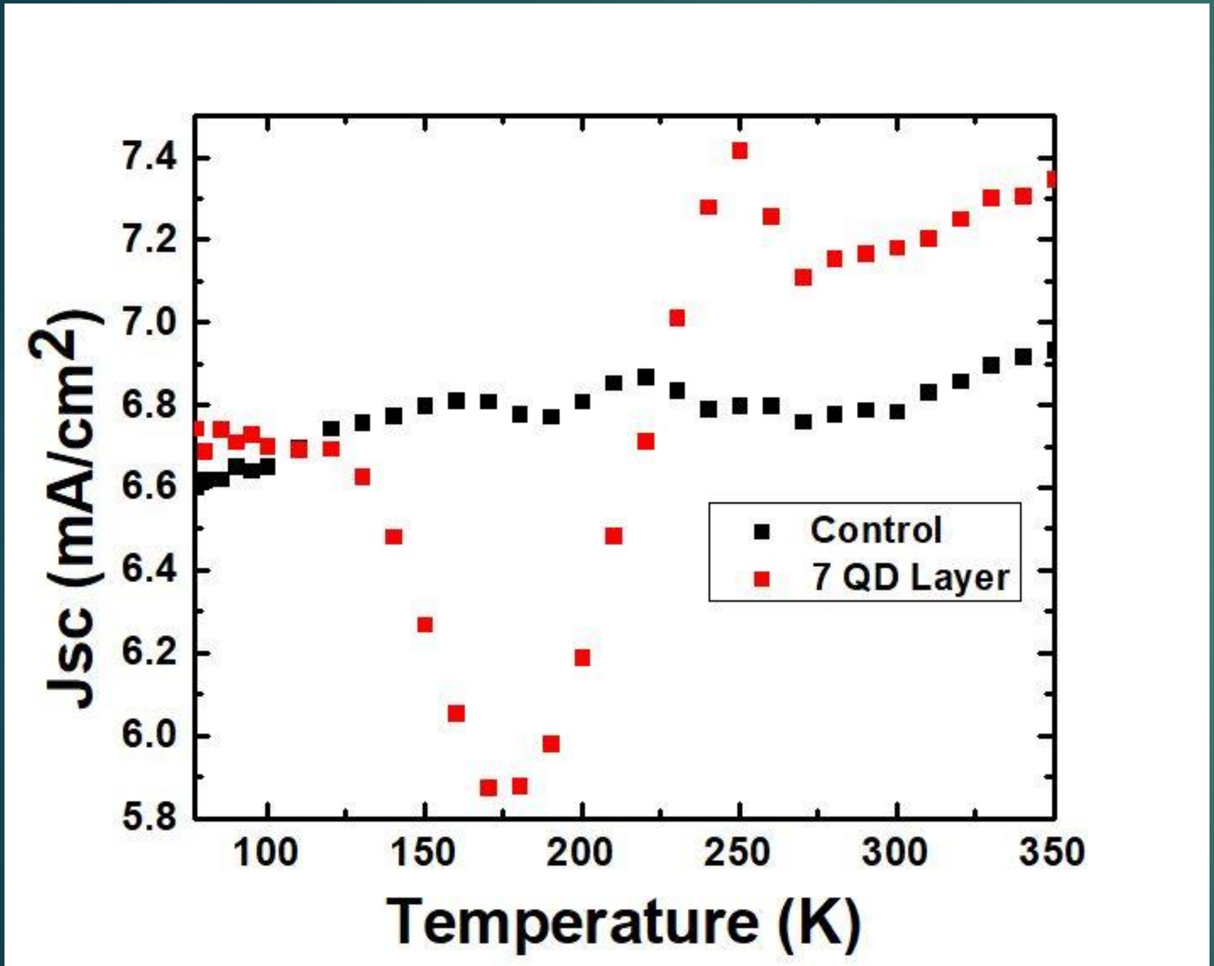


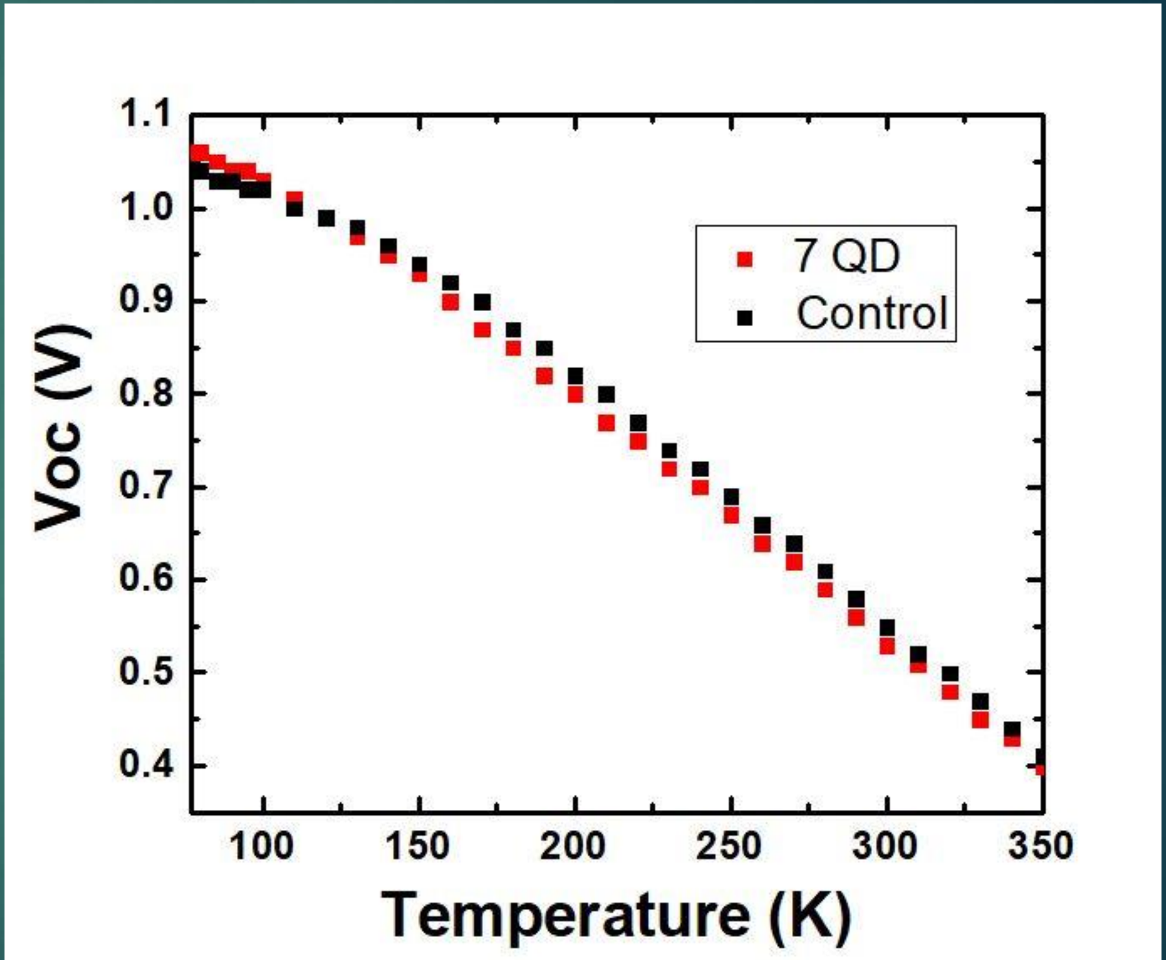
Current Density-Voltage Measurements

- These Parameters can be extracted by taking JV measurements (Voc, Jsc, Vmax, Jmax)
- At Low temperatures carriers are trapped in the dots.



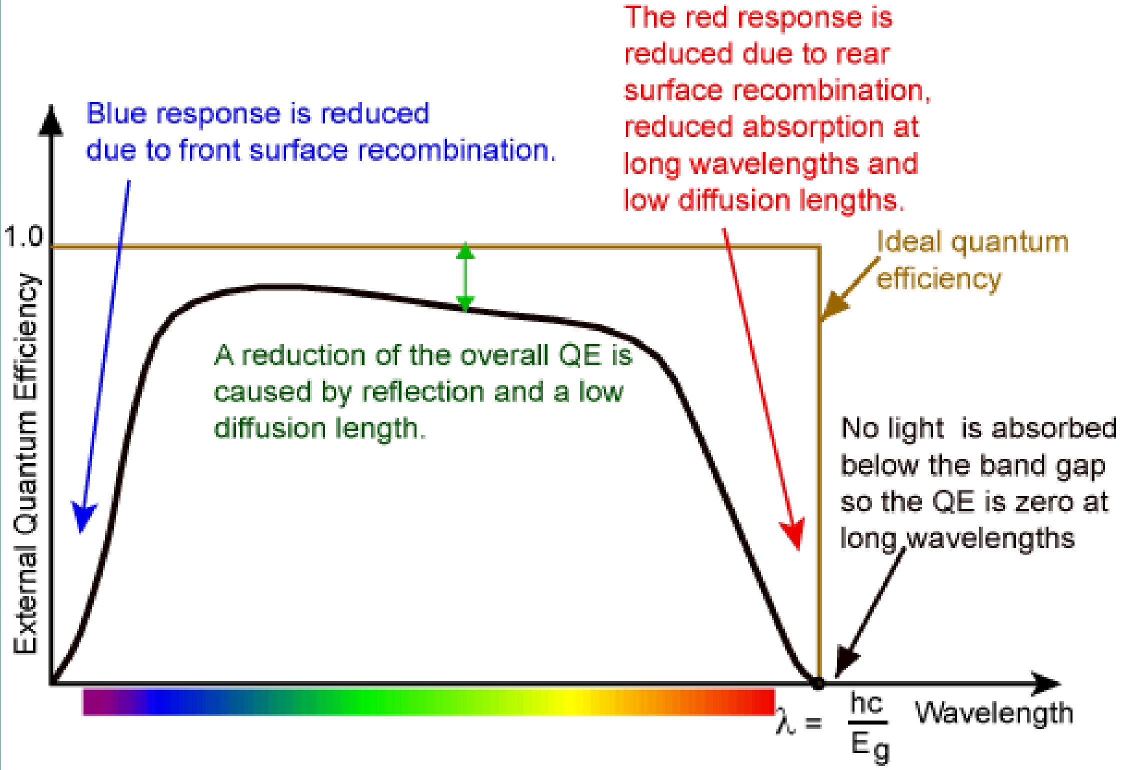


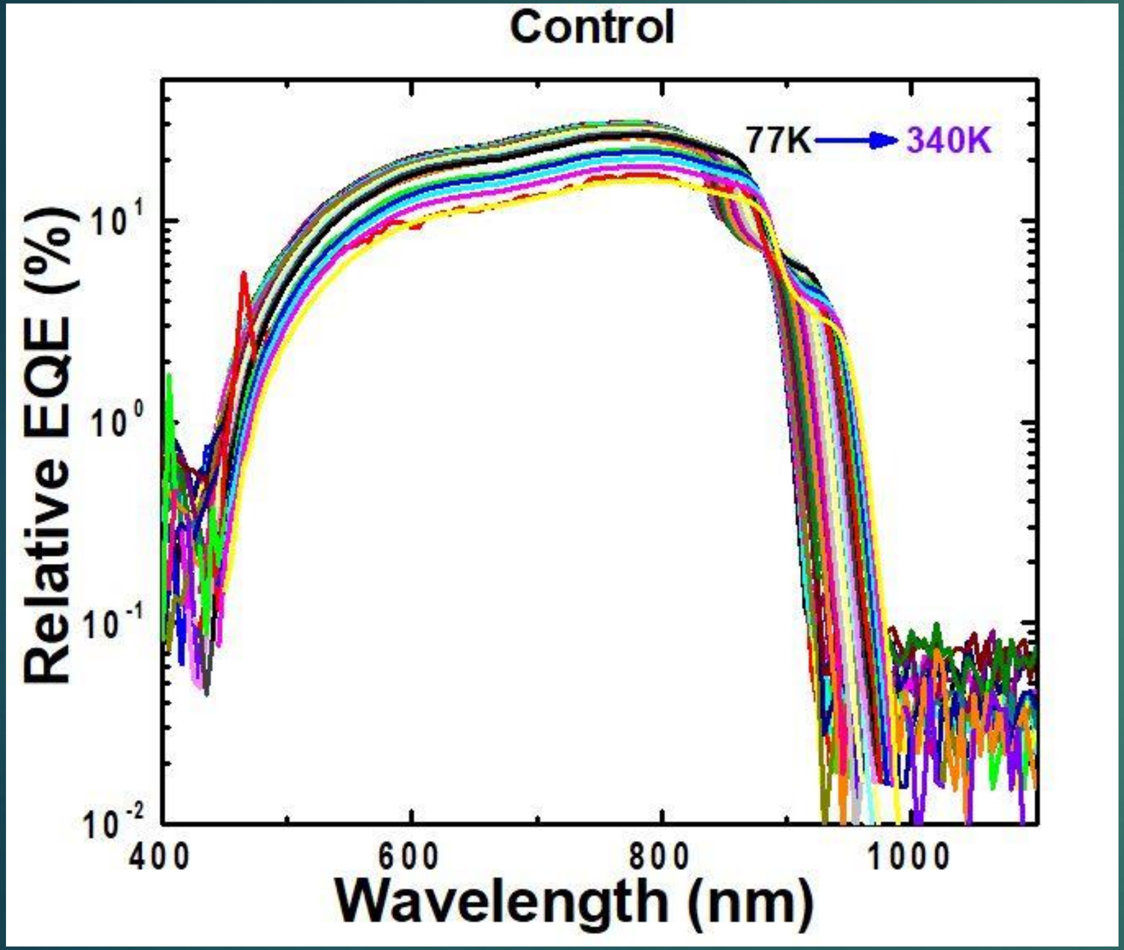

Jsc (mA/cm2)
7.4
7.2
7.0
6.8
6.6
6.4
6.2
6.0
5.8
100
150
200
250
300
350
Temperature (K)
Control
7 QD Layer

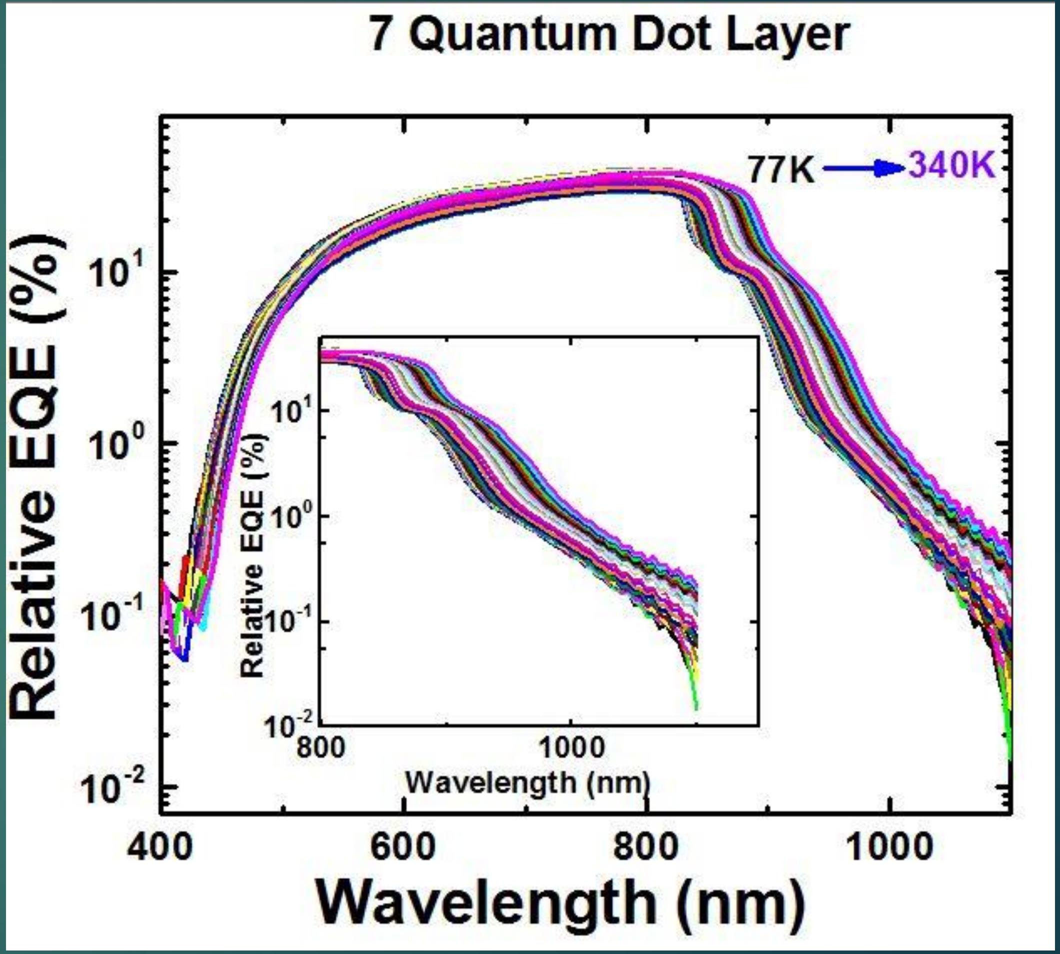

Voc (V)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
100
150
200
250
300
350
Temperature (K)
7 QD
Control

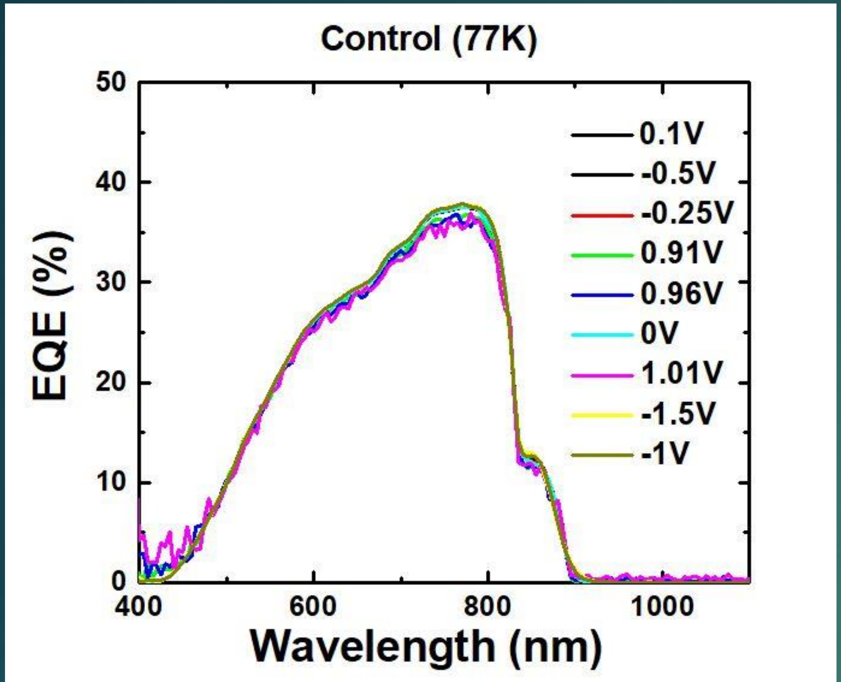
External Quantum Efficiency

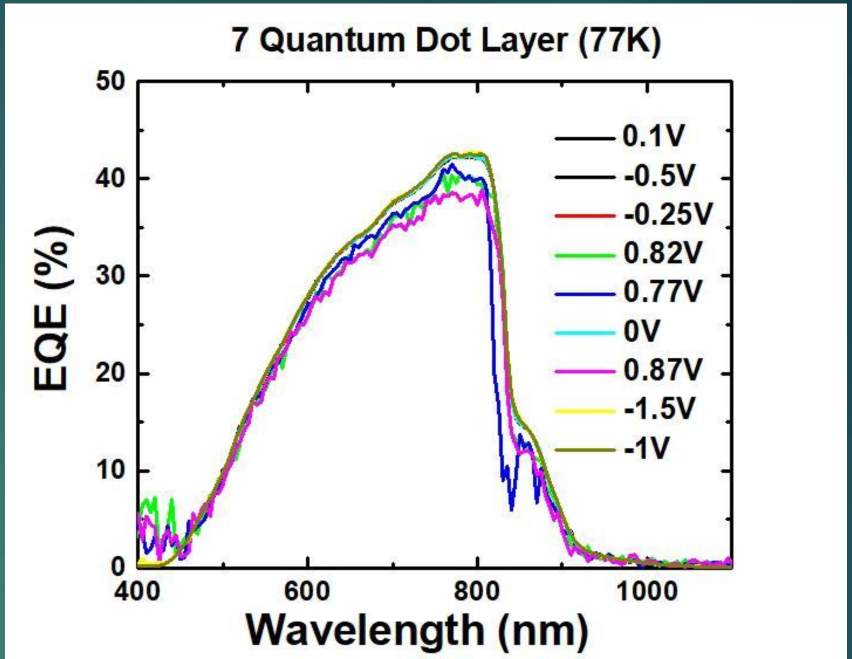
- Ratio of the number of charge carriers collected by the solar cell to the number of incident photons of a given energy
- Temperature Dependent and bias Dependent EQE measurements taken from 300-1100 nm
- Using a Quartz Halogen Lamp

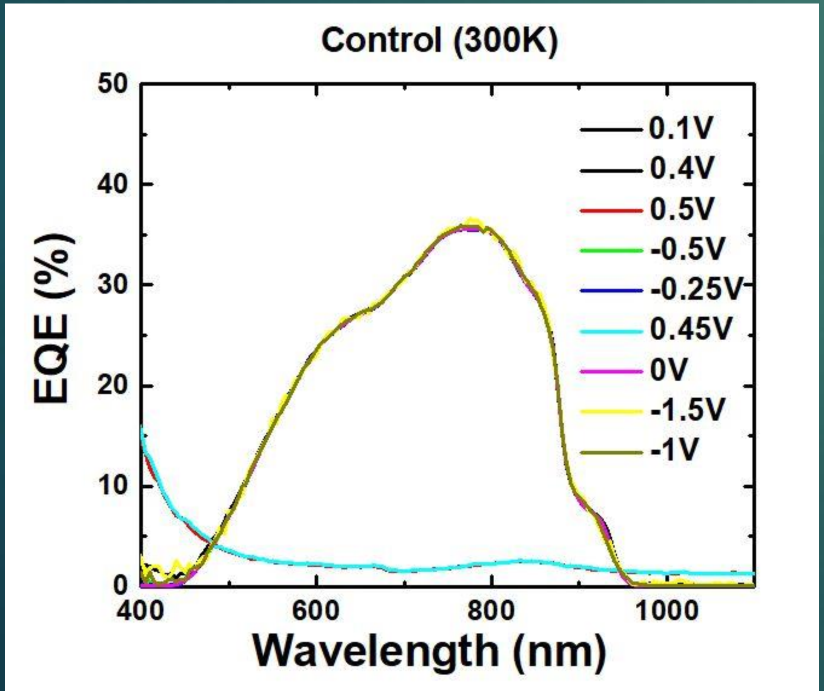


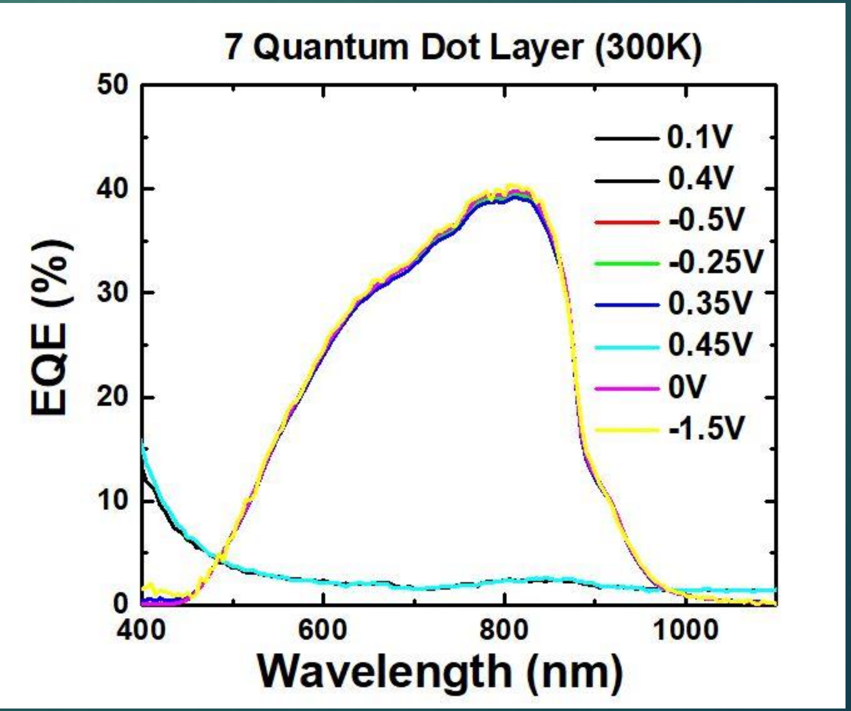

Control
77K → 340K
Relative EQE (%)
Wavelength (nm)


7 Quantum Dot Layer
77K → 340K
Relative EQE (%)
Wavelength (nm)


Control (77K)
EQE (%)
Wavelength (nm)
0.1V
-0.5V
-0.25V
0.91V
0.96V
0V
1.01V
-1.5V
-1V


7 Quantum Dot Layer (77K)
EQE (%)
Wavelength (nm)
0.1V
-0.5V
-0.25V
0.82V
0.77V
0V
0.87V
-1.5V
-1V


Control (300K)
EQE (%)
Wavelength (nm)
0.1V
0.4V
0.5V
-0.5V
-0.25V
0.45V
0V
-1.5V
-1V


7 Quantum Dot Layer (300K)
EQE (%)
Wavelength (nm)
0.1V
0.4V
-0.5V
-0.25V
0.35V
0.45V
0V
-1.5V

Conclusions

- Investigated the potential of Quantum Dots to increase the efficiency of a single gap solar cell using JV measurements and Bias Dependent and Temperature Dependent EQE measurements
- Temperature dependent EQE measurements shows that carriers are being trapped at lower temperatures
- Reverse Bias in Bias dependent EQE measurements show an increase in EQE indicating that the carriers are being trapped.

Acknowledgements

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