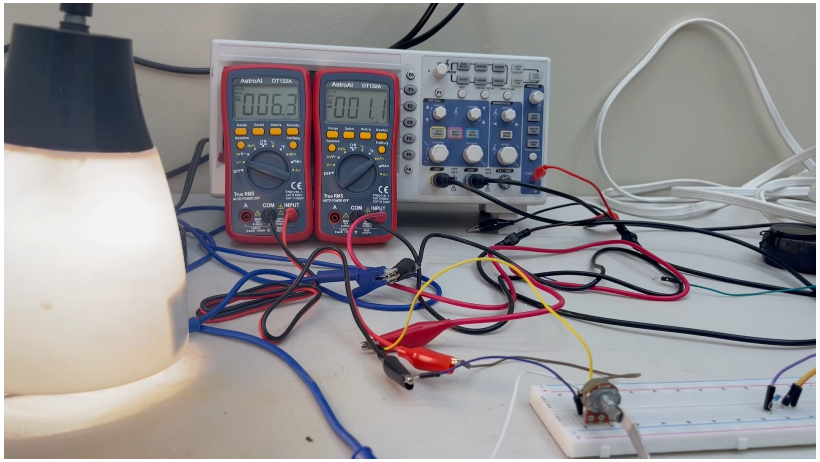
F. Juicy Solar Cell

Yuezhen (Lily) Dong

“A functional solar cell can be created using ***conducting glass slides, iodine, juice*** *(e.g. blackberry) and* ***titanium dioxide****. This type of cell is called a* ***Grätzel cell****. Make such a cell and investigate the necessary parameters to obtain* ***maximum efficiency****.”*



Problem Statement

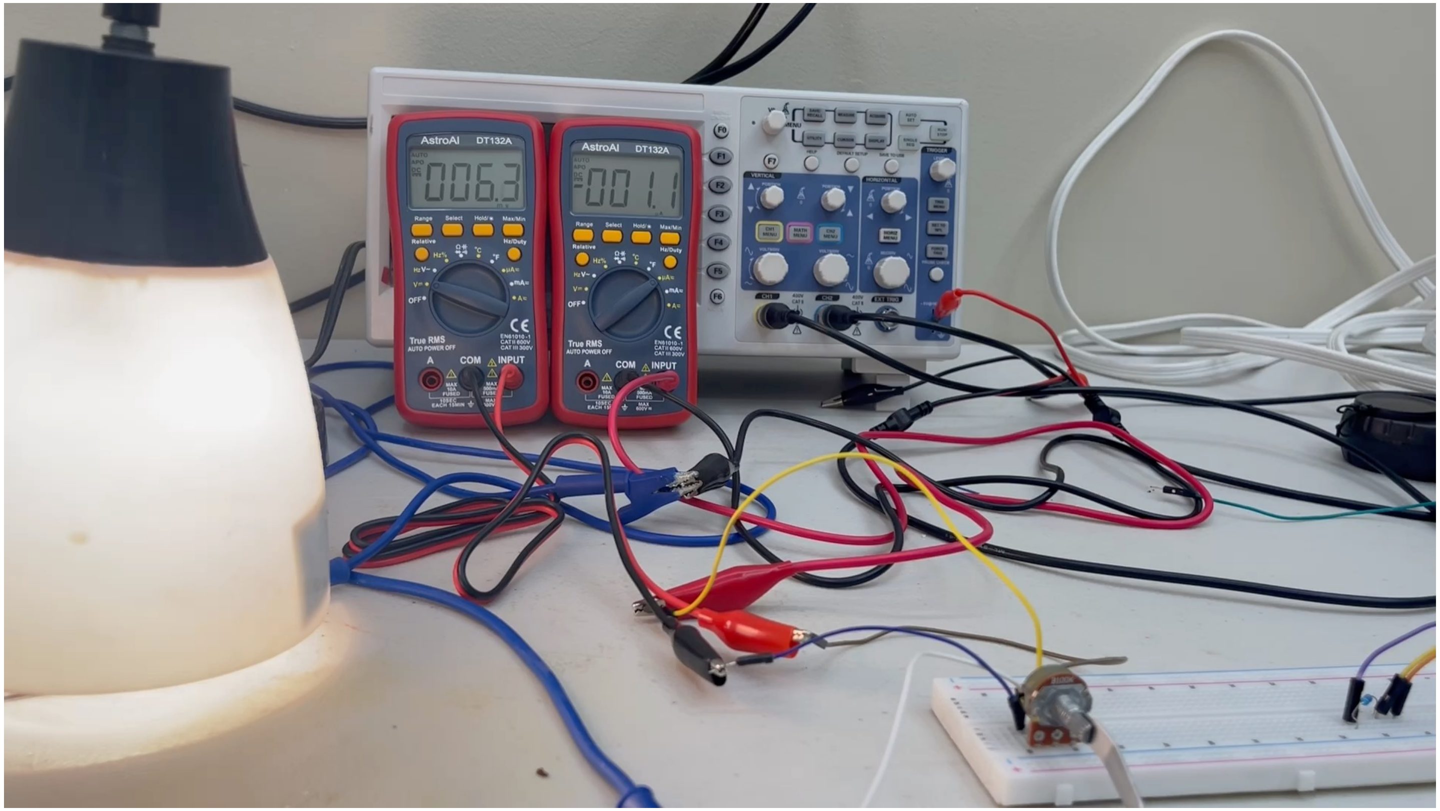
*" A functional solar cell can be created using **conducting glass slides, iodine, juice** (e.g. blackberry) and **titanium dioxide**. This type of cell is called a **Grätzel cell**. Make such a cell and investigate the necessary parameters to obtain **maximum efficiency**."*

Parameters:

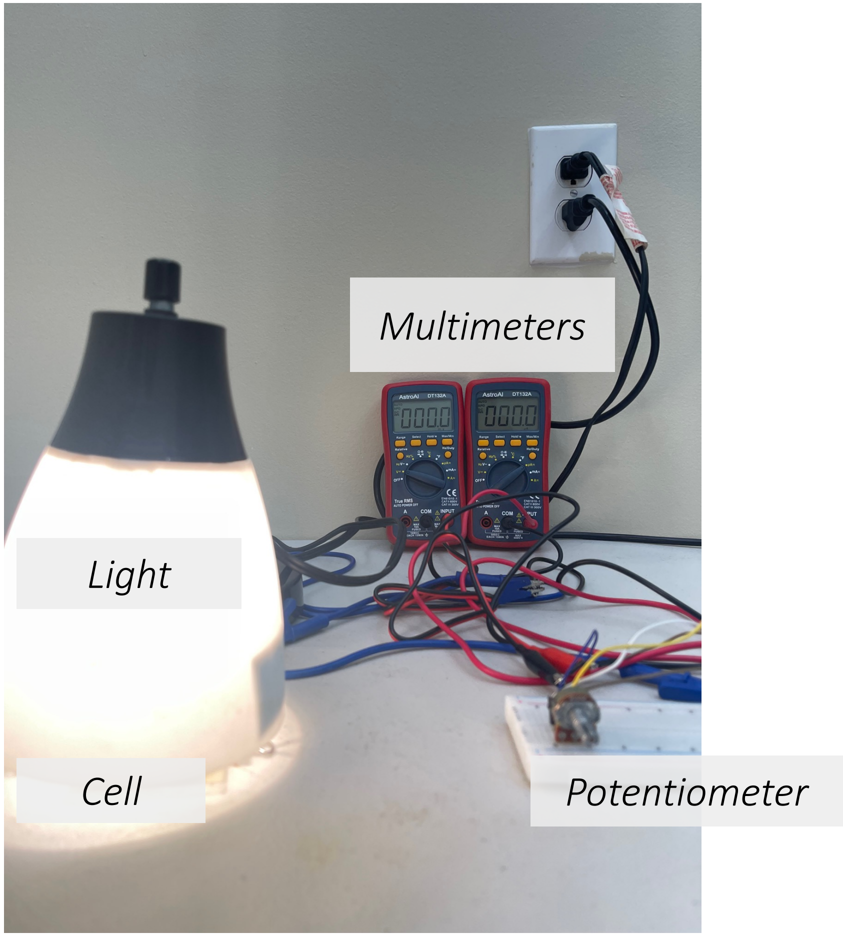
1. *Electrolyte Concentration*
2. *Glass Conductivity*
3. *TiO_2 Layer Thickness*
4. *Temperature of Electrolyte Solution*

Overview

Phenomenon

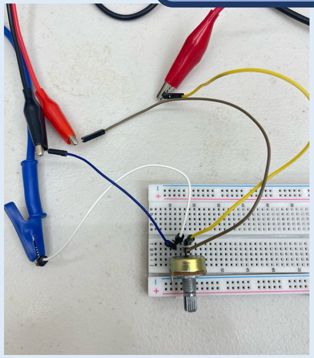


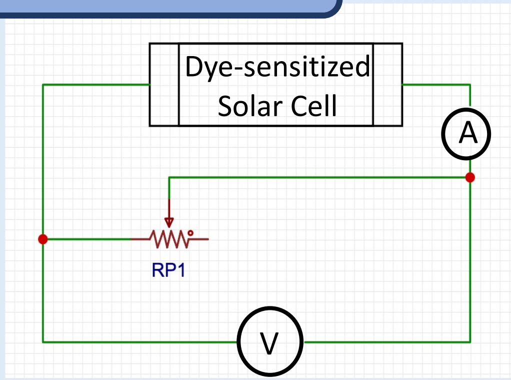
Experimental Setup



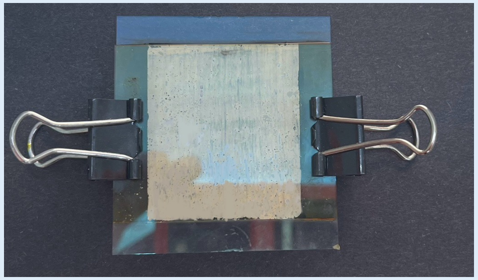
Experimental Setup

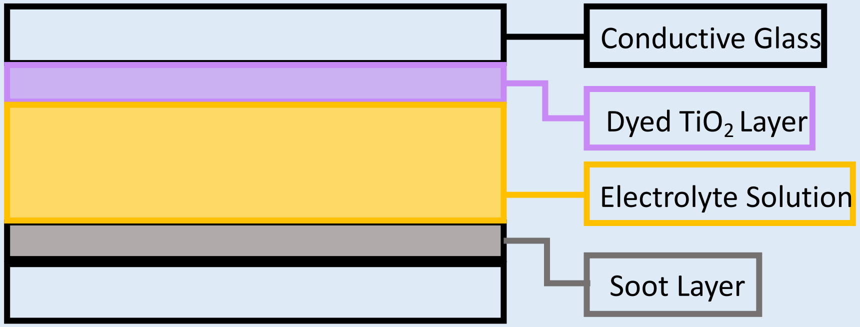
Potentiometer & Multimeters





Dye Sensitized Solar Cell





Experimental Measurement

Analytical Balance
($\pm$0.1 mg)

Lux Meter
($\pm$0.01 fc/lux)

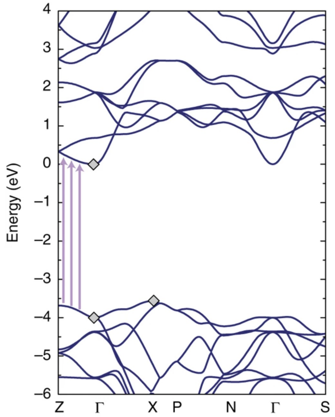
Multimeter
($\pm$ 0.5%+3 mV
$\pm$2.0%+5 μA)

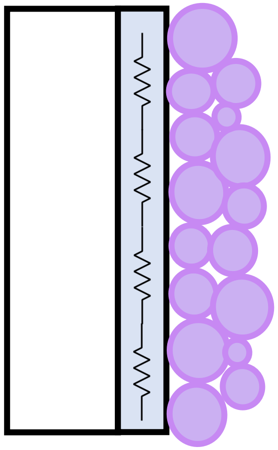
Digital Caliper
($\pm$0.01 mm)

Digital Micrometer
($\pm$1 μm)

Theoretical Model

Theoretical Model

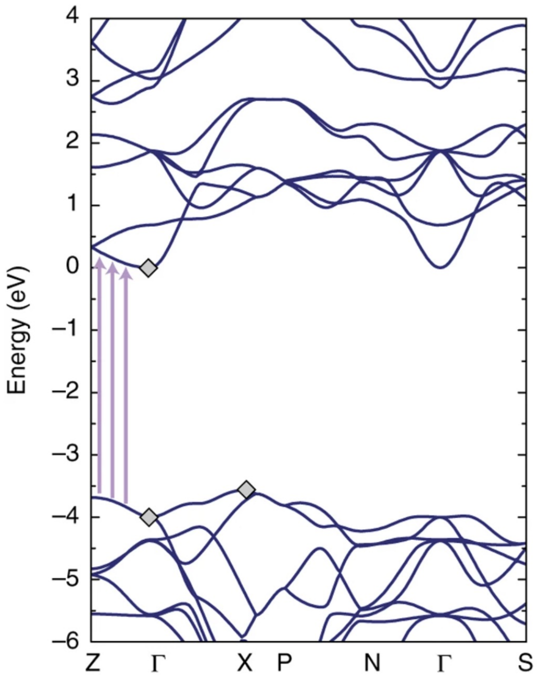




Working Principle

Cell Efficiency

Band Theory



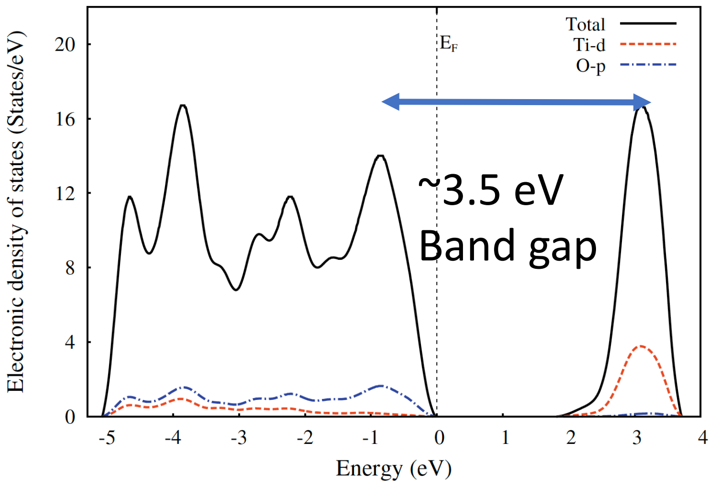
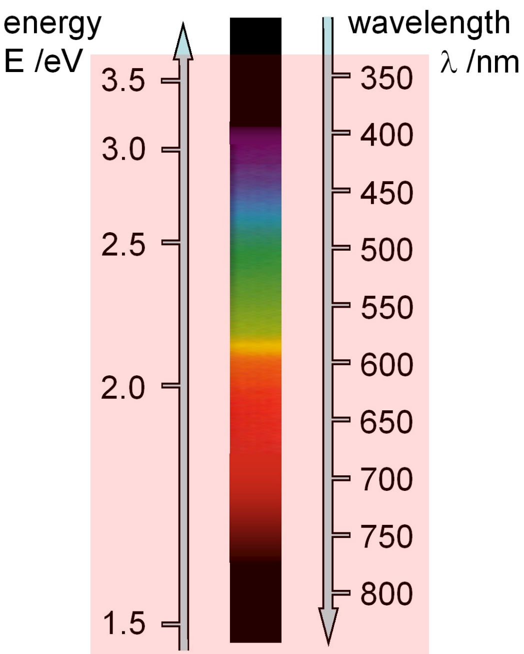


Fig. 3. Total and partial density of states of anatase TiO_2.

(Baldini et al., 2017)
(Sotoudeh et al., 2014)



Only UV Photon has sufficient energy to be absorbed by TiO_2. NOT useful as solar cell

Working Principle

Cell Efficiency

HOMO-LUMO Gap of Anthocyanin Dye

(Sotoudeh et al., 2014)

Table 1. Excited Energy and first-level excitation composition

Molecule	Gas Phase	
	E (eV)	Excitation Composition
Cyanidin-3-monoglucoside	2.565	H-2→L (8.36%) H→L (91.79%)
Petunidin-3-monoglucoside	2.538	H-1→L (69.80%) H→L (28.61%)
Malvidin-3-monoglucoside	2.537	H-1→L (73.52%) H→L (25.25%)

Anthocyanins Derivatives

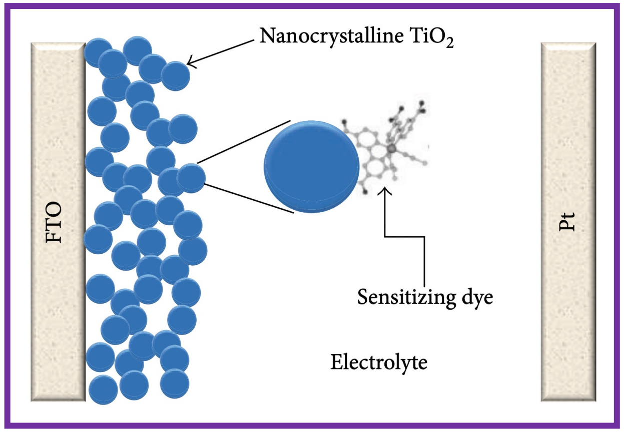
HOMO LUMO gap around 2.53 - 2.57 eV (490 - 484 nm)

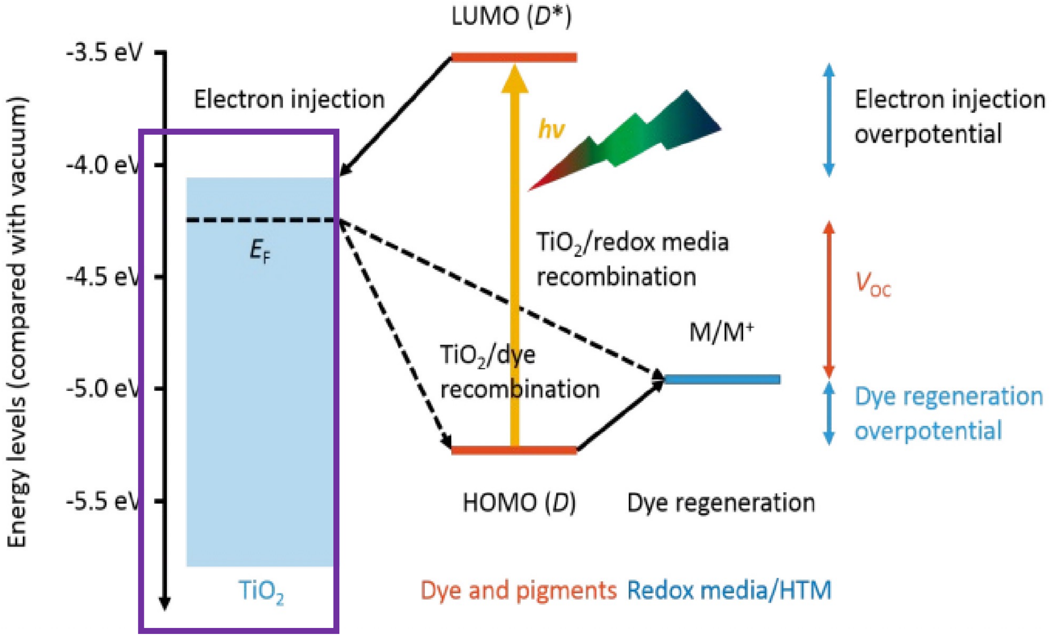
Tabel 2. Absorption (λ_{max}) and Oscilattor Strength (f) Anthocyanin

Molecule	Theory		Exp	Difference Shift (%)
	λ_{max} (nm)	f	λ_{max} (nm)	
Cyanidin-3-monoglucoside	483.44	0.4247	527	-8.3
Petunidin-3-monoglucoside	488.46	0.1603	527	-7.3
Malvidin-3-monoglucoside	488.64	0.1496	531	-8.0

Experimentally determined to be ~ 530 nm

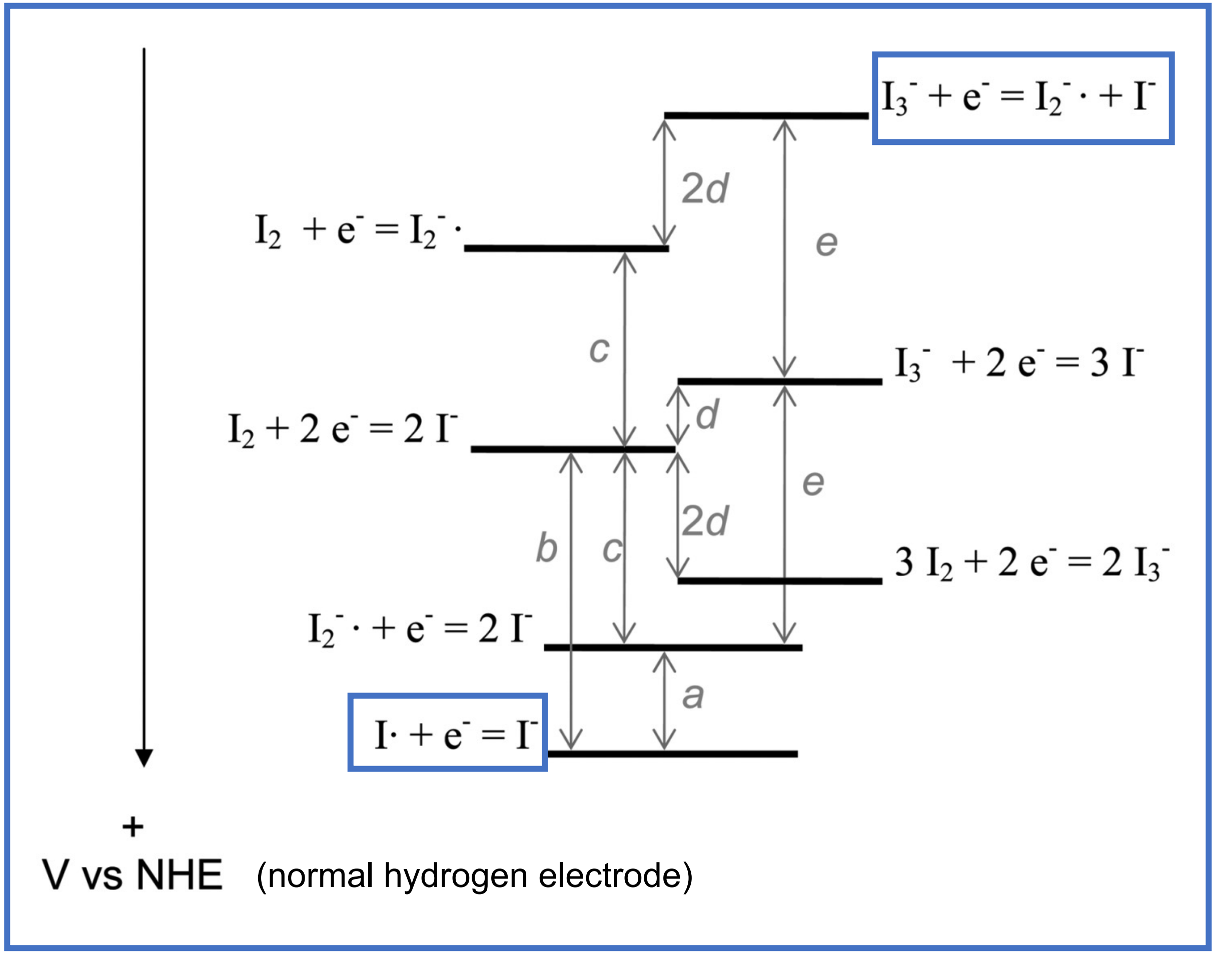
Cell Reaction





(Gao et al., 2015)

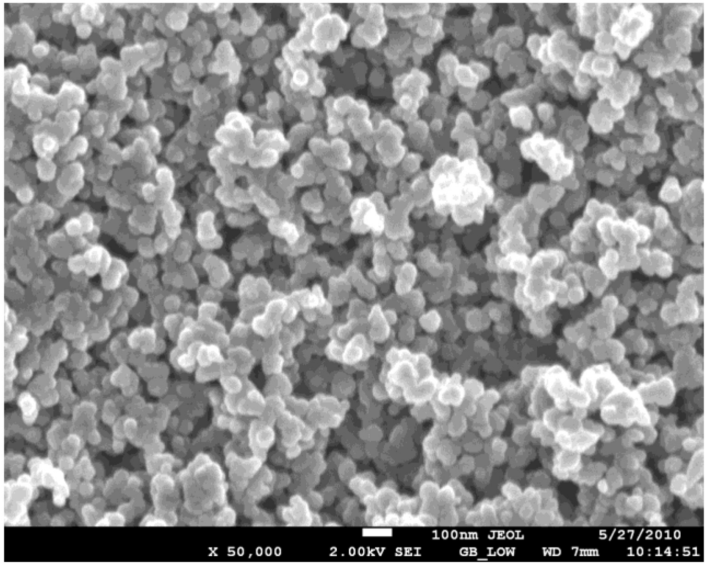
Amorphous Carbon Catalyst Layer

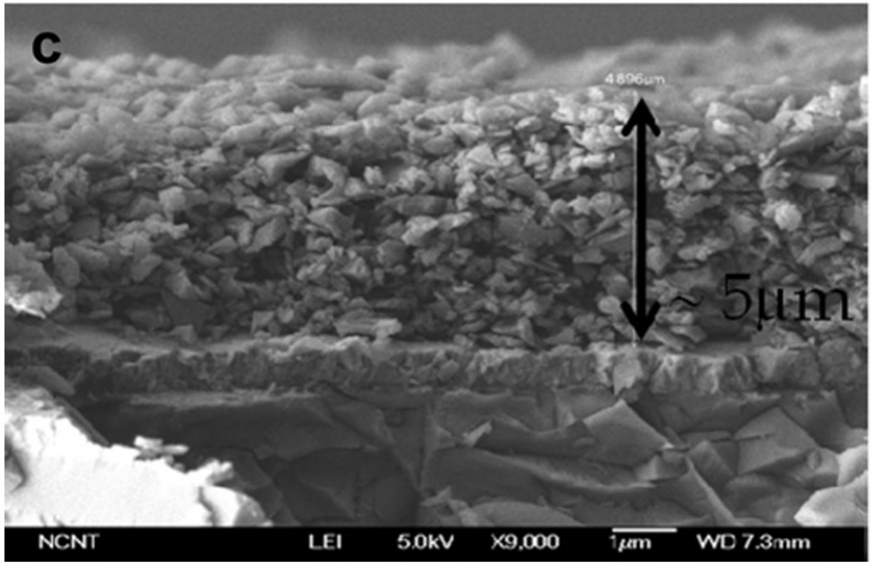


Known reaction intermediates

(Boschloo & Hagfeldt, 2009)

Amorphous Carbon Catalyst Layer

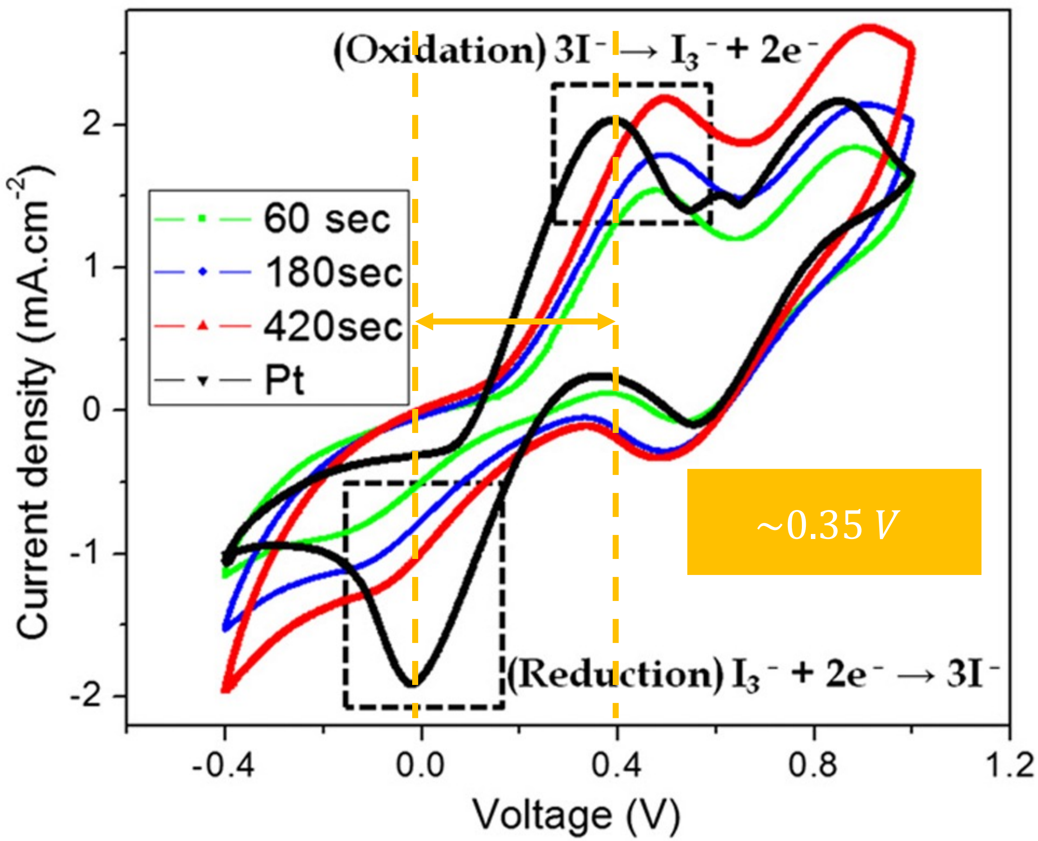




Carbon is similar to Pt at catalyzing redox iodine redox reaction

(Shooto & Dikio, 2011)

Amorphous Carbon Catalytic Performance



(Shooto & Dikio, 2011)

Iodine triiodide Redox Couple

$I_3^- + 2\,e^- \rightarrow\ 3I^-$ At counter electrode (CE)

$3I^- \rightarrow I_3^- + 2\,e^-$ At dye

Tafel Equation:

$$\eta = \pm A \cdot \log_{10}\left(\frac{i}{i_0}\right)$$

Where:
$\eta =$ overpotential (ie. potential above the formal potential)
$A =$ Tafel slope (determined by reaction pathway)
$i =$ current density
$i_0 =$ exchange current density
(current density at zero overpotential)

Iodine triiodide Redox Reaction Diffusion Kinetics

Iodine diffusion flux (moles of I^- crossing a surface s). Assuming I_3^- largely immobile

$$\left(\frac{dn}{dt}\right)_s = -\left[D_{I_3} + \frac{k\delta^2\pi}{4} c_{I,s}\right]\frac{dc_{I,s}}{dx}$$

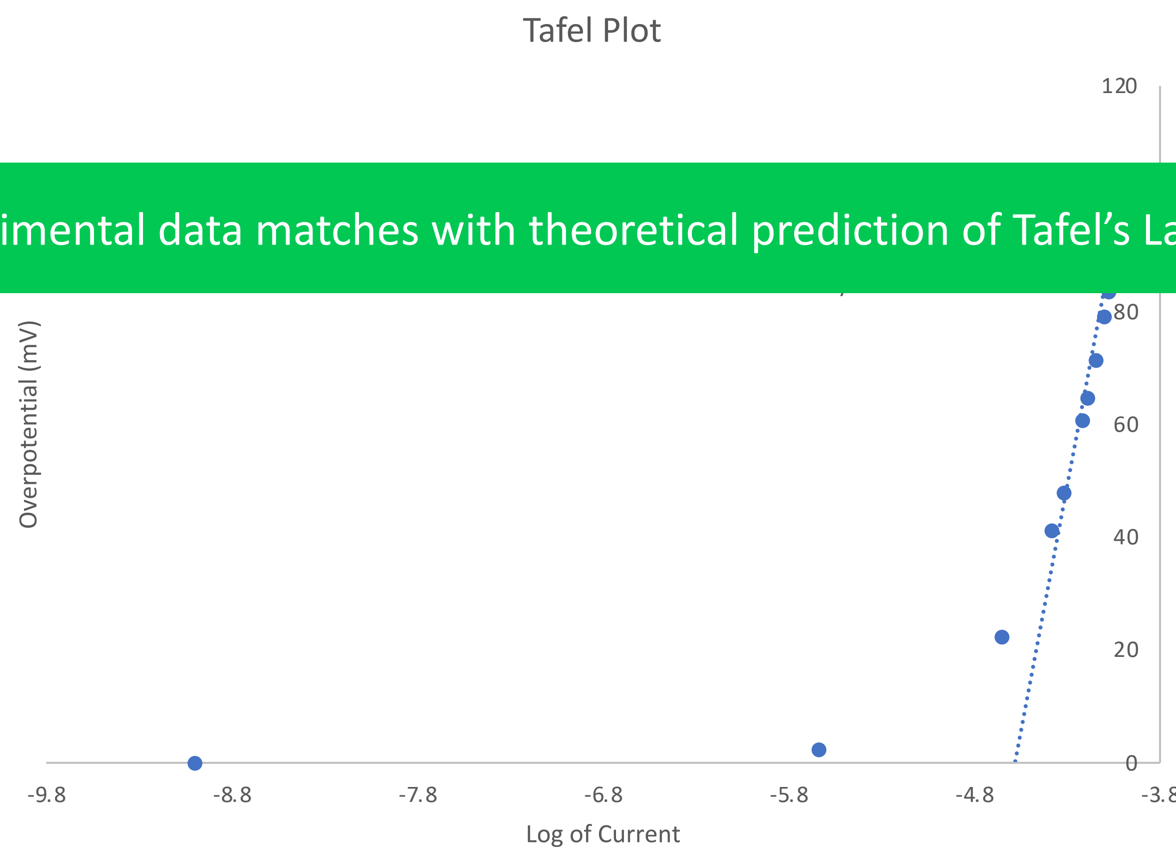
(Ruff et al., 1971)

Where:
n = number of I^- atoms
D_{I_3} = diffusion coefficient of triiodide ions [8.6×10^{-10} m^2 sec^{-1}] (solvent viscosity dependent)
k = rate constant of reaction [2.4×10^9 M^{-1}sec^{-1} at room temperature]
$c_{I,s}, c_{I_{3,s}}$ = concentration of iodine and triiodide ions on the surface in question
[0.1 M] [0.5M] respectively

Successfully predicts order of magnitude of cell current. Identifies diffusion as rate limiting

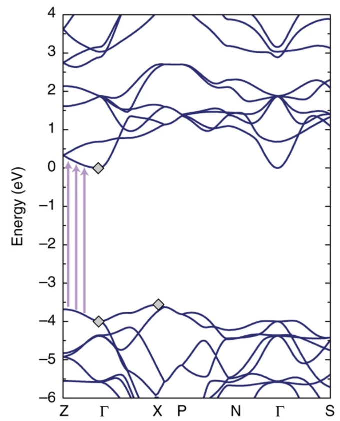
Predict electrical current of our cell to be O (10^{-5}) A

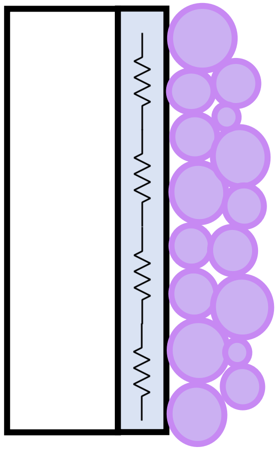
Fitting Tafel Slope



Experimental data matches with theoretical prediction of Tafel's Law

Theoretical Model

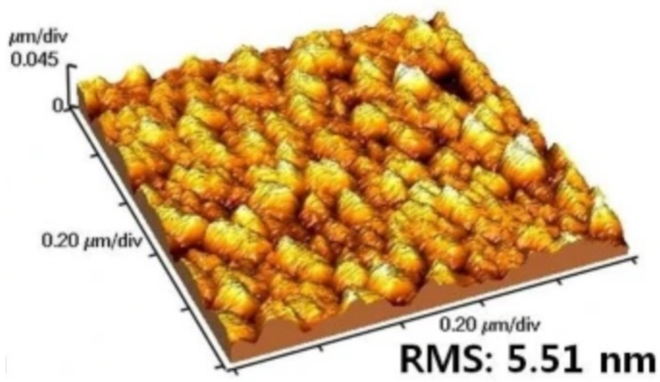




Straw Geometry

Cell Efficiency

TiO_2 Thickness



Thick Layer

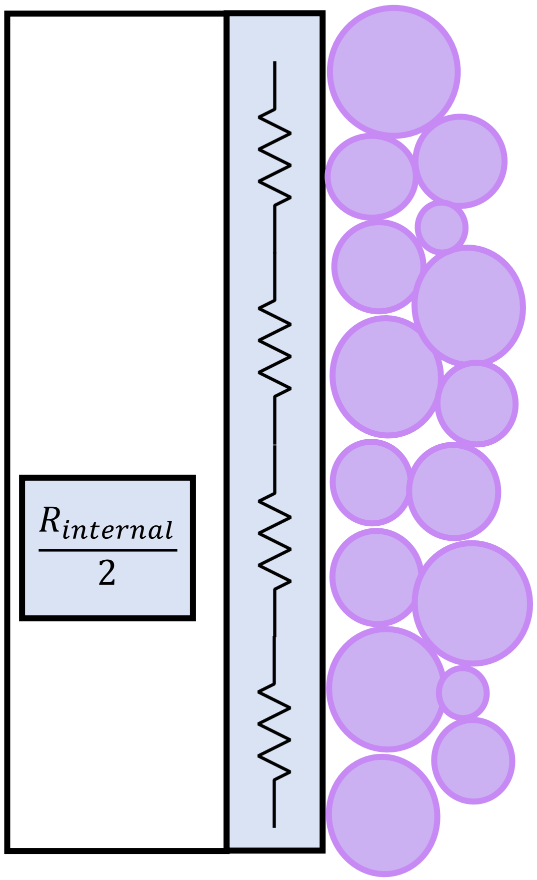
Resistance of electrons increase

Thin Layer

Insufficient area for dye to attach

(Nam et al., 2012)

Glass Conductivity



Using Ohm's Law:

$$V_{load} = V_{cell} - IR_{internal}$$

$$V_{load}I = P = V_{cell} \cdot I - I^2 R_{internal}$$

Substitute in:

$$\frac{R_{internal}}{2} = \frac{R_s l}{w}$$

Where:
R_s = sheet resistance

$$\boxed{P = -\frac{V_{load}^2 + V_{cell}V_{load}}{R}}$$

Electrolyte Solution & Temperature

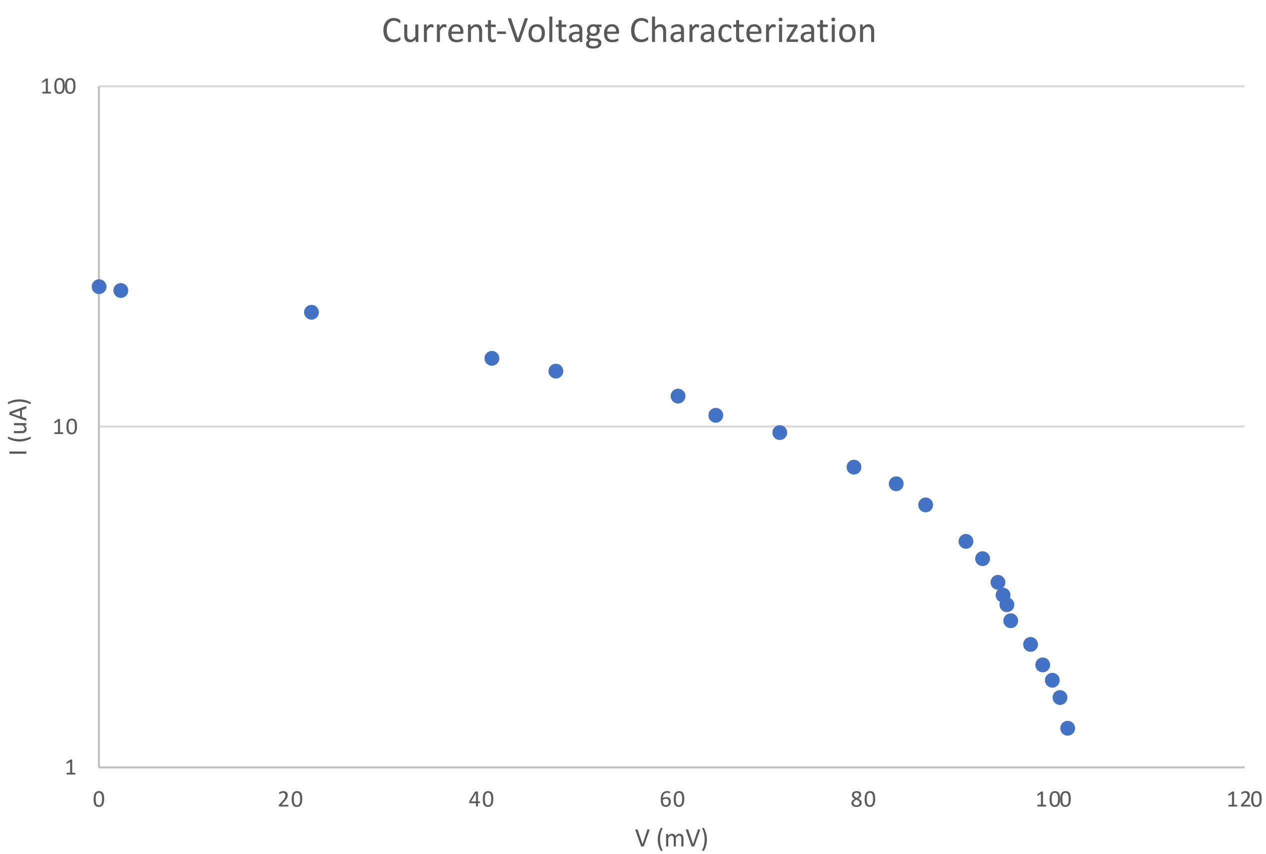
Using Nernst Equation:

$$V_{cell} = E^0 - \frac{RT}{zF} \ln \boxed{Q}$$

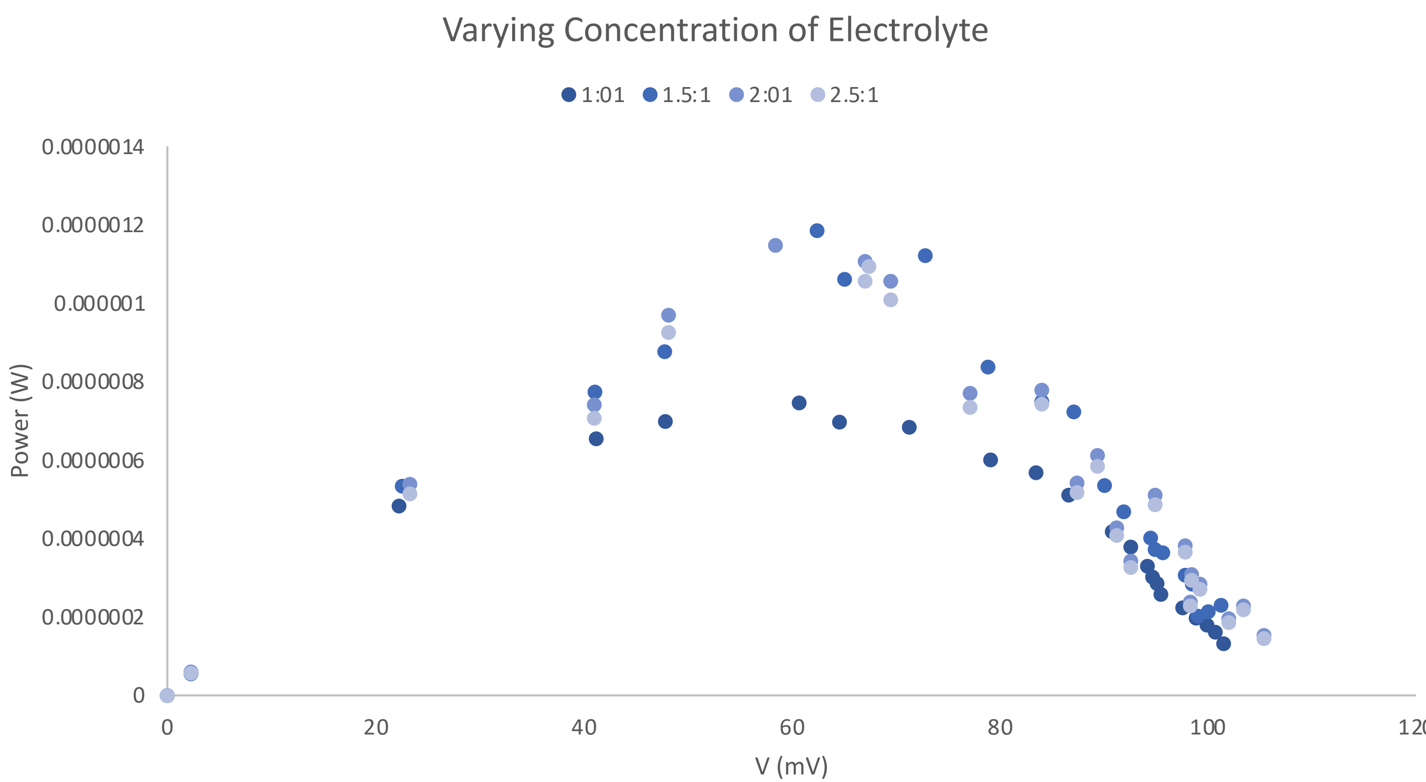
Depends on ratio of concentration of product & reactant

Where:
V_{cell} = cell potential
E^0 = standard potential
z = ion charge
F = Faraday constant
Q = reaction quotient

Preliminary Characterization



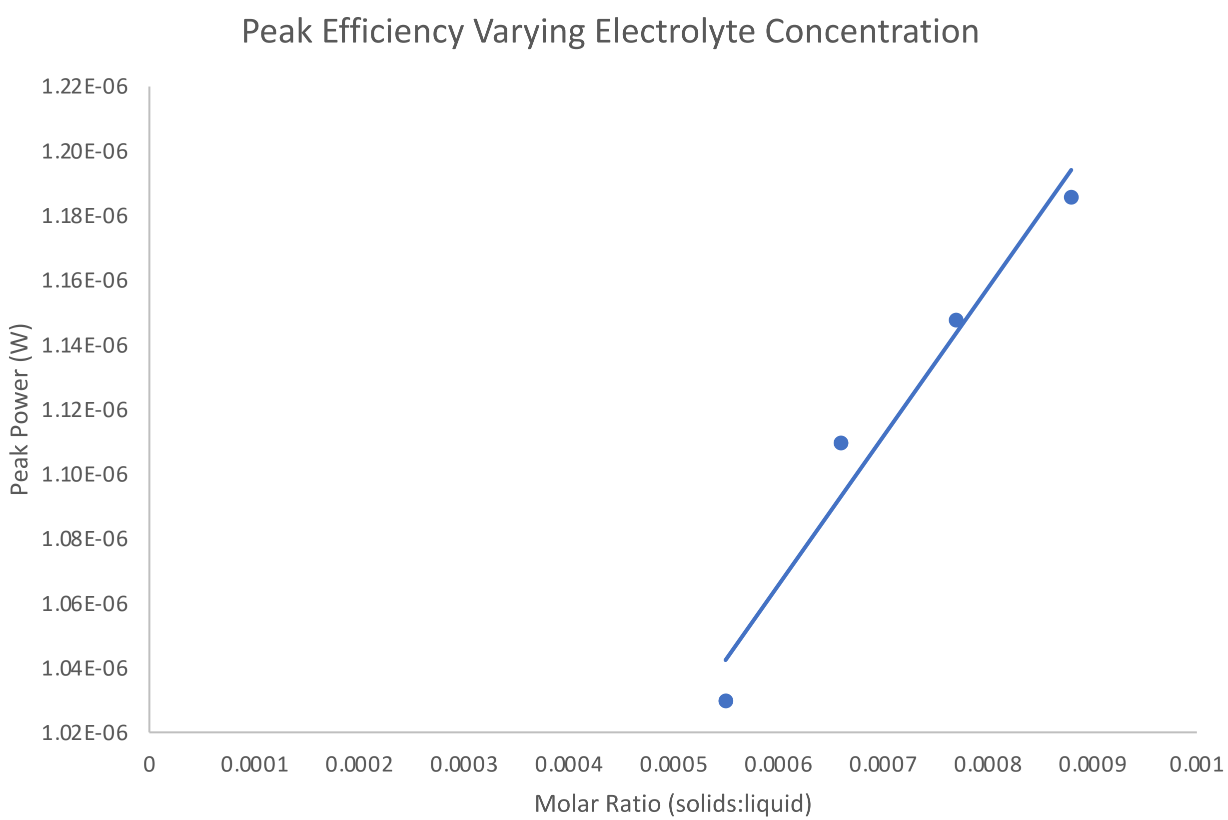
Varying Electrolyte Concentration



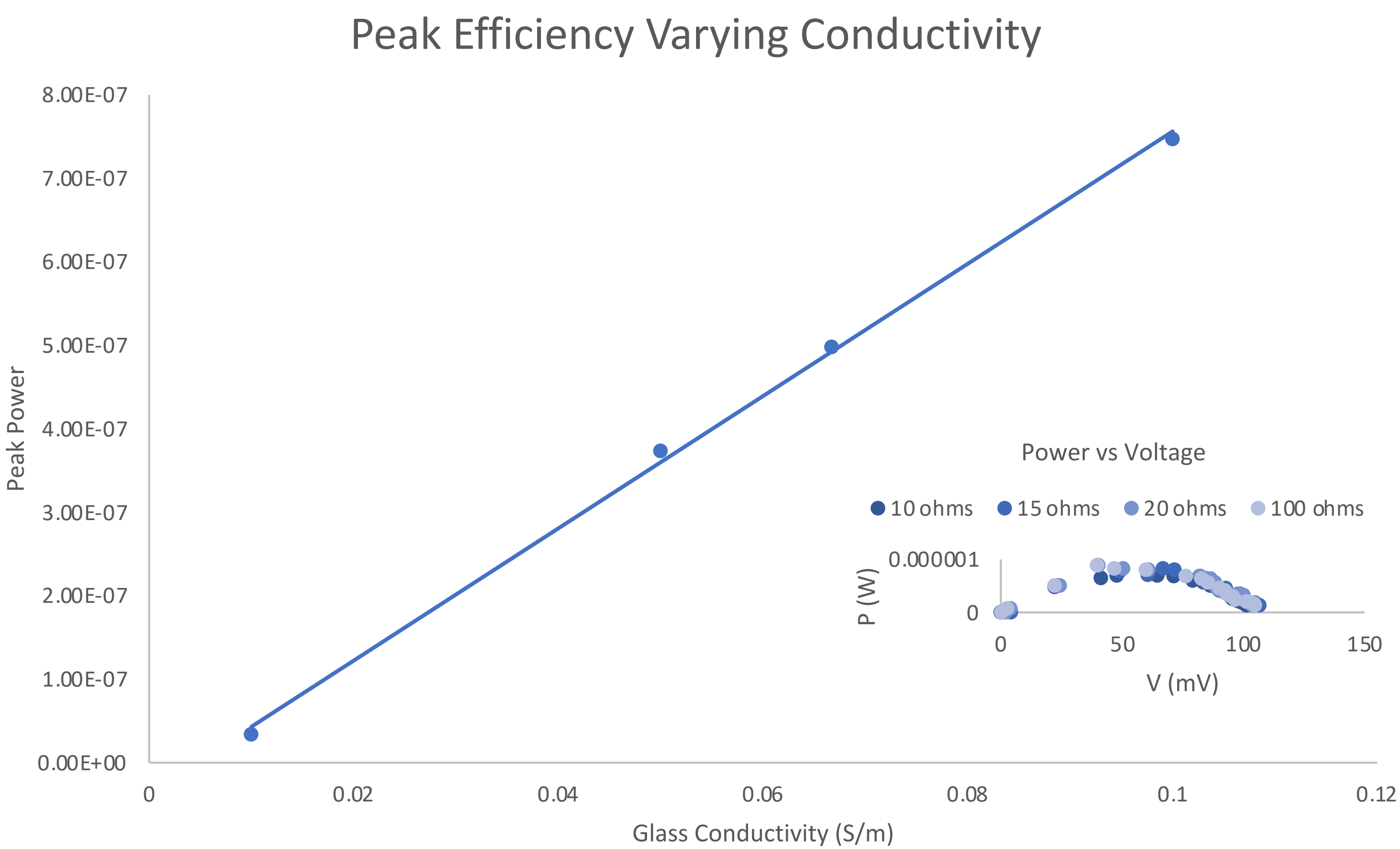
Working Principle

Cell Efficiency

Increase in electrolyte concentration increases the cell of efficiency

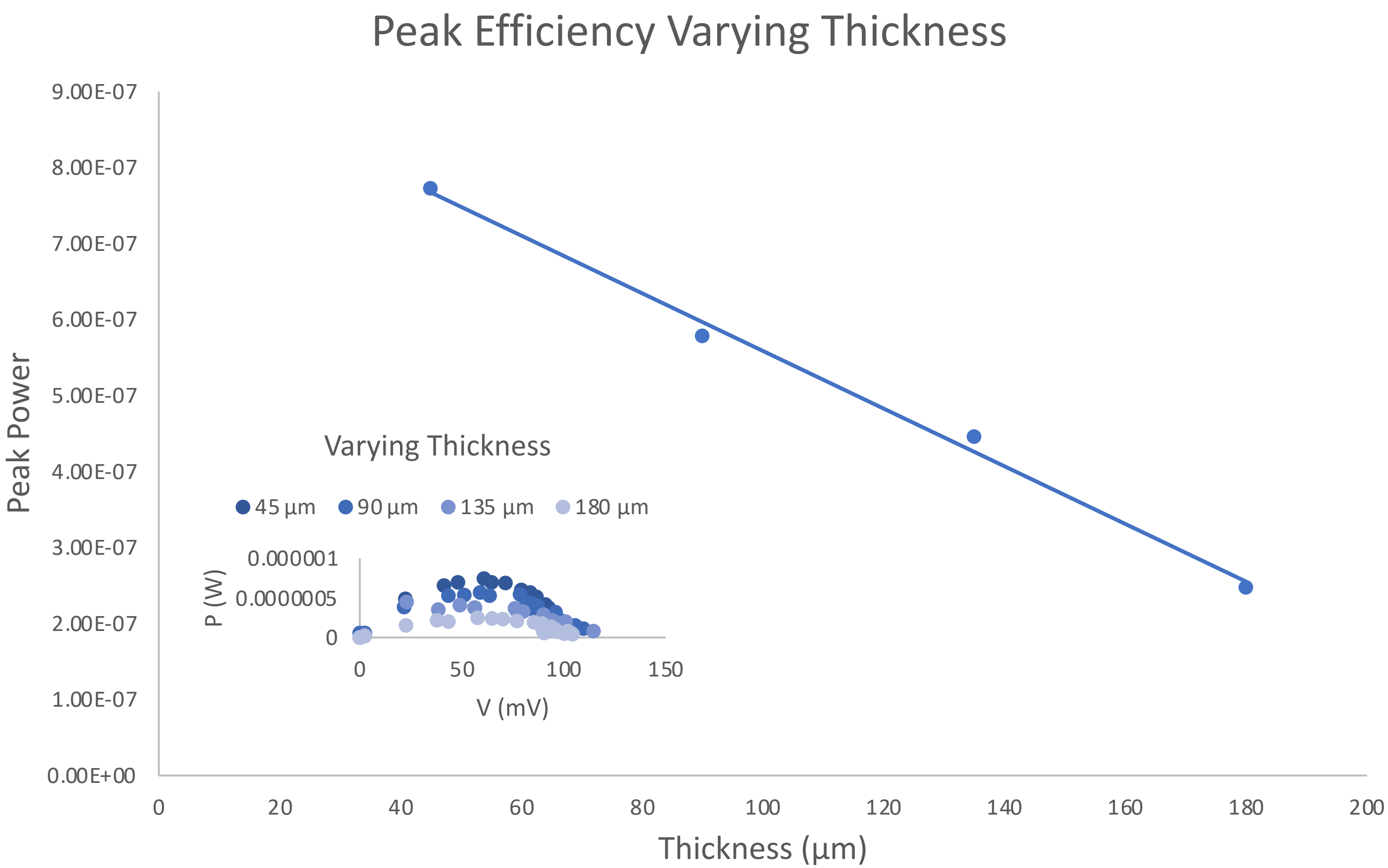


Varying Glass Conductivity



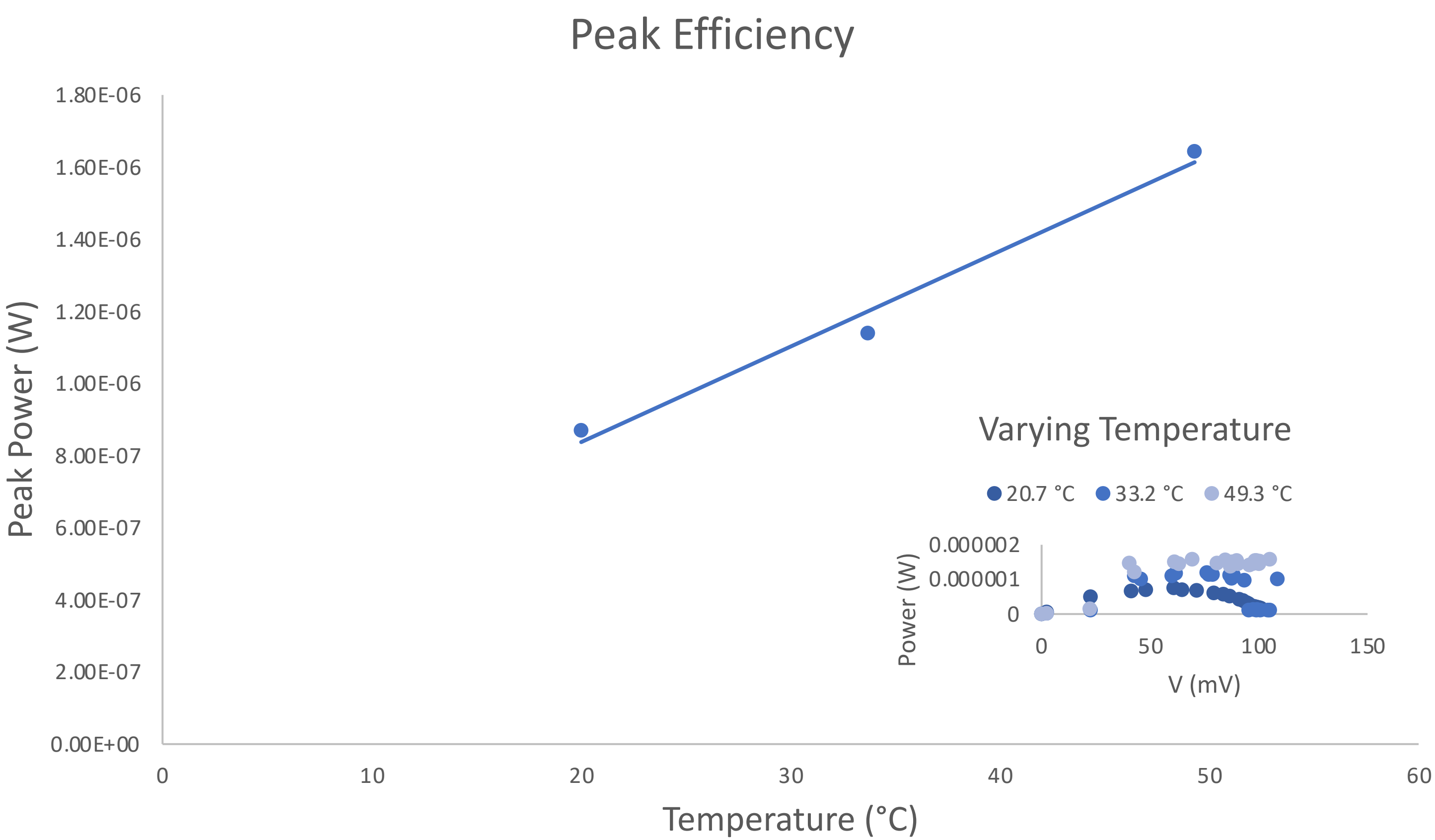
Increase in glass conductivity increases the cell of efficiency

Varying TiO_2 Layer Thickness

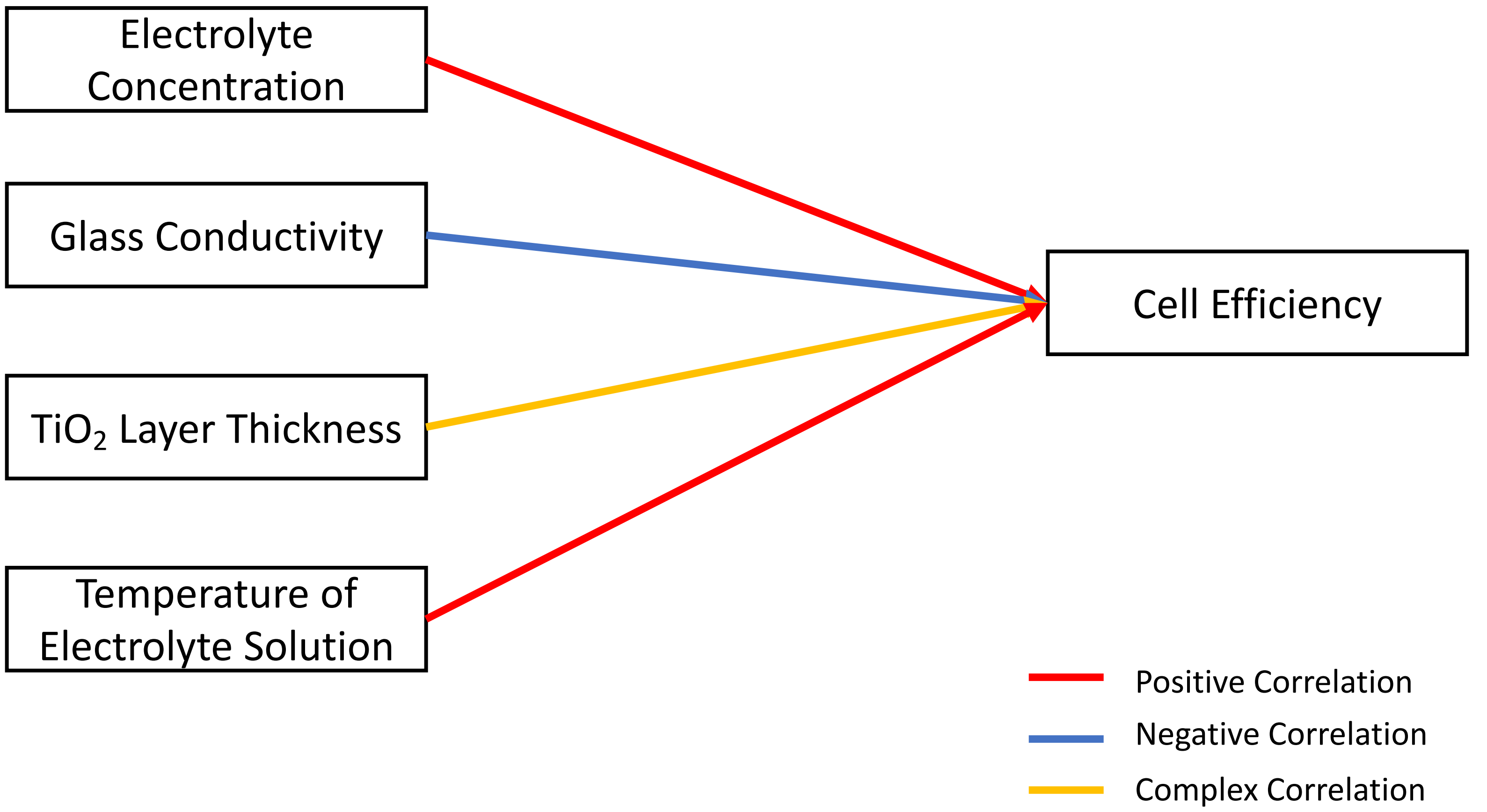


Increase in TiO_2 decreases the cell efficiency

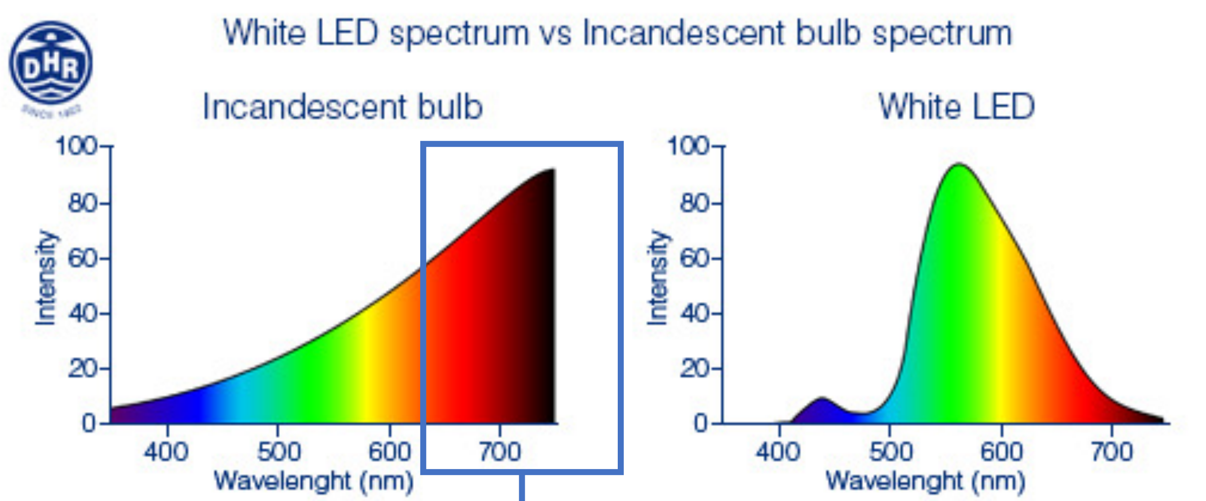
Varying Temperature



Key Parameters


Electrolyte Concentration
Glass Conductivity
TiO_2 Layer Thickness
Temperature of Electrolyte Solution
Cell Efficiency
Positive Correlation
Negative Correlation
Complex Correlation

Further Insights



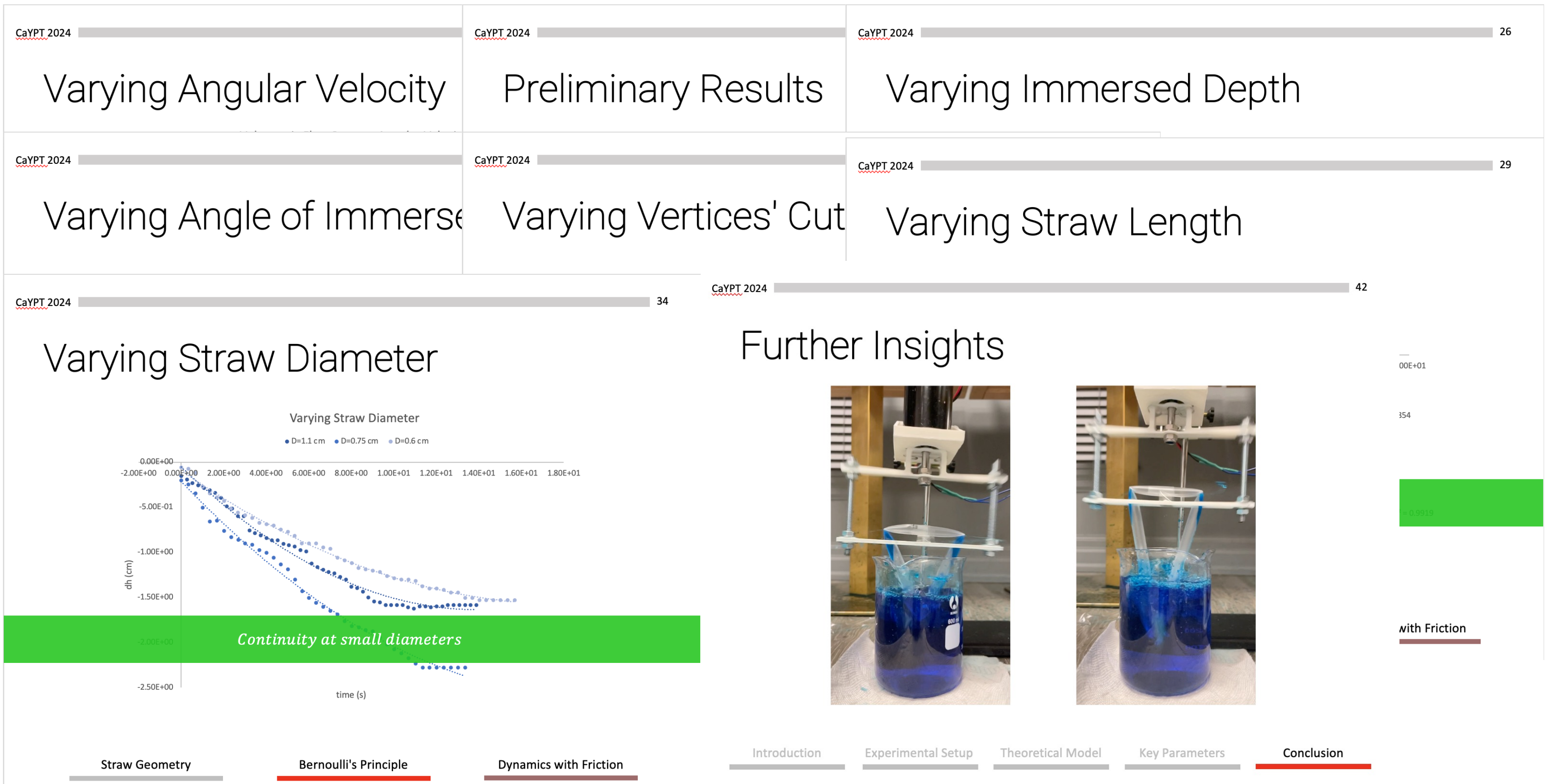
most of the light generated is red to IR

Conclusion

*"A functional solar cell can be created using **conducting glass slides, iodine, juice** (e.g. blackberry) and **titanium dioxide**. This type of cell is called a **Grätzel cell**. Make such a cell and investigate the necessary parameters to obtain **maximum efficiency**."*

Electrolyte concentration, glass conductivity, TiO_2 layer thickness, and the temperature of electrolyte concentration are the **most relevant** parameter to the problem. The **maximum efficiency** could be obtained by **increasing the electrolyte concentration, decreasing glass conductivity, increasing temperature of electrolyte solution, and increasing the thickness TiO_2 layer** to the **optimal thickness.**

Conclusion


Varying Angular Velocity
Preliminary Results
Varying Immersed Depth
Varying Angle of Immerse
Varying Vertices' Cut
Varying Straw Length
Varying Straw Diameter
Varying Straw Diameter
D=1.1 cm
D=0.75 cm
D=0.6 cm
dh (cm)
time (s)
Continuity at small diameters
Straw Geometry
Bernoulli's Principle
Dynamics with Friction
Further Insights
Introduction
Experimental Setup
Theoretical Model
Key Parameters
Conclusion

Thank you for listening

References

[1] [*https://theses.hal.science/tel-03953103/document*](https://theses.hal.science/tel-03953103/document)
[2] International Journal of Thermal Sciences 115 (2017) 29e42
[3] [*https://www.sfu.ca/~mbahrami/ENSC%20388/Notes/Natural%20Convection.pdf*](https://www.sfu.ca/~mbahrami/ENSC%20388/Notes/Natural%20Convection.pdf)
[4] https://www.researchgate.net/publication/48412257
[5]On the departure behaviors of bubble at nucleate pool boiling