The Effect of Semiconductor Materials on Solar Cell Efficiency

Shivam Vohra | Rockdale Magnet School for Science and Technology | 2018 Physical Energy

Introduction

- Rationale: Fossil fuels are slowly dwindling in supply, and clean energy sources such as solar panels are very inefficient.
- Solar energy is a form of energy that could be used to correct this issue. However, solar energy is not very efficient, but titanium dioxide and copper-indium-sulfide quantum dots can increase efficiency and power above 40% (Barron, 2014). Lead iodide also been used in solar cells to increase efficiency by 9% (Kim, 2012).
- Therefore, the purpose of this project is to use titanium dioxide and lead iodide combined with a more common quantum dot (cadmium selenide) to see the increase in voltage, amperage, power, and efficiency.

Hypothesis

- The scientific hypothesis of this project is that if lead iodide is applied to a solar cell semiconductor, then the average voltage, amperage, power and efficiency will increase.
- The null hypothesis is that when any substance is applied to the semiconductor, there will be no significant effect.

Background Information

- Solar cells are need in order to reduce the use of fossil fuels. A special type of nanoparticle in solar cells known as a quantum dot can be applied to the semiconductor of a solar cell to increase the electrical transport of electrons on a nanoparticle scale.
- Research conducted by Aaron Barron in 2014 showed that the addition of titanium dioxide with copper-indium-sulfide quantum dots increased the power and efficiency to above 40% with the power reaching above 100%
- In 2012, it was discovered that adding lead iodide to semiconductors of perovskite or thin-filmed solar cells could increase efficiency by 9% (Kim, 2012).
- According to a studies by Li and Afshar, metals can drastically improve solar cell efficiency.

Experimental Design Diagram

Title: The Effect of Semiconductor Materials on Solar Cell Efficiency

Hypothesis: If the semiconductor of a solar cell has a lead iodide infusion, then the solar cell will show a higher voltage and amperage than the other panels.

IV: Different Semiconductor Infusions

Levels of IV	Control: Silicon Cell	Silicon with TiO2	Silicon with PbI2	Quantum Dot (CdSe) with Lead Iodide	Quantum dot (CdSe) with TiO2
# of Trials	3	3	3	3	3

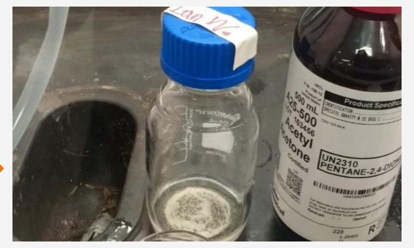
DV: Voltage and Amperage

Constants: Amount of each infusion, amount of light exposure, amount of time to let the infusions settle, and type of solar cell

Procedures

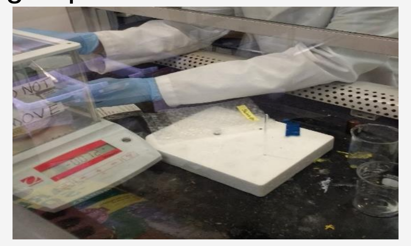
Materials: 0.5 g lead iodide, 0.5 g titanium dioxide, 0.5 g cadmium selenide, 10 mL octadecene, 15 mL ethanol and acetyl acetone, .05 mL Triton X-100 mixture, 0.6 mL oleic acid, autoclave, Erlenmeyer Flask, 3 150 mL beakers, 10 mL graduated cylinder, and a HotPlate.

Gather all materials needed to being experimentation.

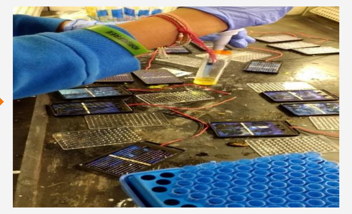


Mix together .5 gram of TiO_2, 15 mL of ethanol, 15 mL of acetyl acetone, and .05 mL of Triton X-100 mixture and autoclave for 30 minutes.

Weigh out 0.5 grams of PbI_2 and measure 10 mL of (DMF). Add the PbI_2 to the DMF beaker and mix. Heat the solution for 20 minutes at 80ºC.



Weigh .5 grams of CdSe powder with 10 mL of octadecene and .6 mL of oleic acid and mix. Heat the solution on a hotplate at 225ºC.



Remove the covers of each panel and apply 1 mL of each substance to 3 solar panels each. Test the panels for 1 minute for amperage and voltage.

Dispose of all liquids in the heavy metals waste and test tubes in the hazardous waste can.

Data Figures

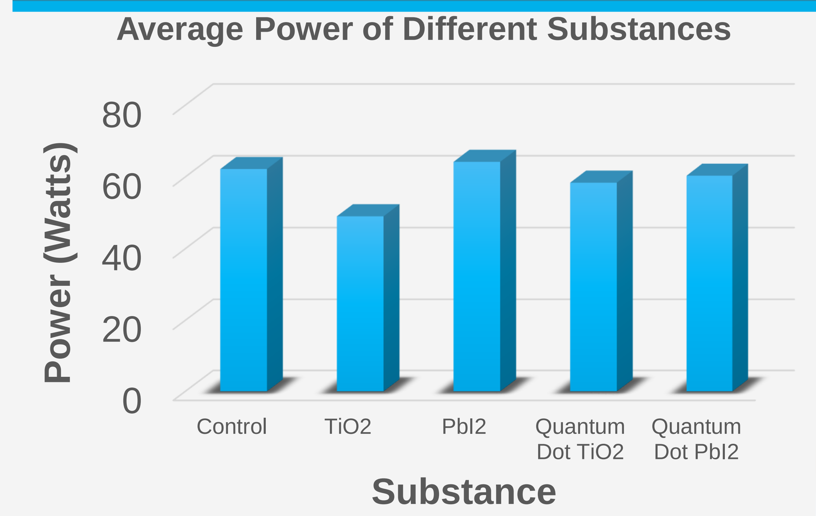


Figure 1: This graph displays the average powers of all substances. PbI_2 is greater than the control.

Average Amperage for Different Substances	
Subtances	Amperage (Millimps)
Control	121.667
TiO2	104.667
PbI2	127.400
Quantum Dot TiO2	118.233
Quantum Dot PbI2	119.500

Table 1: This table displays the averages of amperage for each of the different substances.

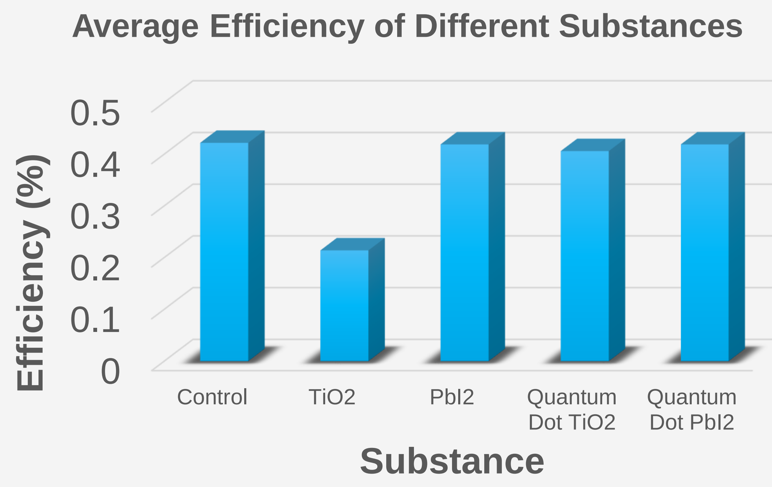


Figure 2: This graph displays the average efficiencies in which the control and PbI_2 are the highest.

Average Voltage for Different Substances	
Subtances	Voltage (Volts)
Control	0.507
TiO2	0.437
PbI2	0.503
Quantum Dot TiO2	0.487
Quantum Dot PbI2	0.503

Table 2: This table displays the averages of voltage for each of the different substances.

Data Analysis

The testing of the solar cells showed that there is no noticeable difference between regular solar cells and solar cells who have had their semiconductors infused with one of the metals or quantum dots. The ANOVA of the power production results demonstrated a p-value of .84. Since the p-value is much higher than the .05 degrees of freedom afforded to the result, it shows that the difference in results is not large enough to be statistically significant. Even when the control group of regular solar cells were directly compared to the lead iodide solar cells, which had the biggest difference in power production, had a p-value of .84, which is much higher than the degree of freedom afforded to it and is therefore statistically insignificant. However, the lead iodide solar cell was a lot more consistent in the amount of power produced, as the control solar cells had a standard deviation of 14.97, while the lead iodide infused solar cell only had a standard deviation of 6.45, which demonstrated that the lead iodide made power production more reliable at providing a certain amount of power. Further T-Tests between the lead iodide and control having significance because each t-critical value was higher than the t-value with the highest t-value was .114 while the lowest t-critical two-tailed was 3.18.

Average Standard Deviation of Different Substances	
Substance	Standard Deviation
Control	8.53
TiO2	16.26
PbI2	4.14
Quantum Dot TiO2	11.30
Quantum Dot PbI2	4.52

Table 3: The table above shows the average standard deviations for each substance.

ANOVA p-values for Dependent Variables	
Substance	P-Value
Voltage	0.93
Amperage	0.96
Power	0.97
Efficiency	0.93

Table 4: The table above shows the p-values for each dependent variable, each of which is above .9.

T-Test for Efficiency	
t Stat	0.11
P(T<=t) one-tail	0.46
t Critical one-tail	2.92
P(T<=t) two-tail	0.92
t Critical two-tail	4.30

Table 5: The table above shows an example of how a t-test between the control and lead iodide.

Bibliography/Acknowledgements

- Barron, A. *Optimizing Solar Energy Using Quantum CulnS2 & TiO_2*; Science Fair Project, RMSST, 2014.
- Cavallo, C., Di Pascasio, F., Latini, A., Bonomo, M., & Dini, D. (2017). Nanostructured Semiconductor Materials for Dye-Sensitized Solar Cells. *Journal Of Nanomaterials*, 1-31. doi:10.1155/2017/5323164
- Fonash, S. J. (2010). *Solar Cell Device Physics*. Burlington, MA: Academic Press.
- Kim, H., Lee, C., Im, J., Lee, K., Moehl, T., Marchioro, A., . . . Park, N. (2012). Lead Iodide Perovskite Sensitized All-Solid-State Submicron Thin Film Mesoscopic Solar Cell with Efficiency Exceeding 9%. *Scientific Reports, 2*. doi:10.1038/srep00591

- I would like to acknowledge Mr. Tyrone Huebsch, Mrs. Jennifer Kinsey, Mr. Scott Bolen, Ms. Shelly Seagraves, Mr. Atul Vohra, and Mrs. Sonia Vohra

Future Research

- In the future, larger solar cells could be used to test if the small difference in power production in the smaller solar cells was due to their size.
- The solar cells could be tested at different temperatures to see if it has an effect on their power production.
- New thin film solar cells can be used because the thin-film solar cells are said to have greater outputs of energy than the base silicon solar cells.