The Effect of Semiconductor Materials on Solar Cell Efficiency

Shivam Vohra

Rockdale Magnet School for Science and Technology

Research Problem and Overview

- Fossil fuels are the predominant source of energy in the United States and the world as a whole, making up 80% of fuels used to generate energy,
- These fuels release multiple pollutants and greenhouse gases into the atmosphere.
- Solar energy could replace fossil fuels; however, the efficiency of solar panels is below 20%.
- A proposed solution to this problem involves the implication of heavy metals such as lead iodide and titanium dioxide with cadmium selenide quantum dots which will boost the effectiveness of the semiconductor.
- Question: Will the application of heavy metal and quantum dot mixtures to the semiconductor of a solar cell increase the overall cell efficiency?
  - This will allow for solar panels to be able to compete with fossil fuels allowing for decreased fossil fuel use leading to decreases environmental pollution.

Experimental Design

<table>
<tr><td colspan="6">Title: The Effect of Semiconductor Materials on Solar Cell Efficiency</td></tr>
<tr><td colspan="6">Hypothesis: If the semiconductor of a solar cell has a lead iodide coating, then the solar cell will show a higher voltage and amperage than the other panels.</td></tr>
<tr><td colspan="6">IV: Different Semiconductor Infusions</td></tr>
<tr><td>Levels of IV</td><td>Control: Silicon Cell</td><td>Silicon with TiO_2</td><td>Silicon with PbI_2</td><td>Quantum Dot (CdSe) with Lead Iodide</td><td>Quantum dot (CdSe) with TiO_2</td></tr>
<tr><td># of Trials</td><td>3</td><td>3</td><td>3</td><td>3</td><td>3</td></tr>
<tr><td colspan="6">DV: Voltage and Amperage</td></tr>
<tr><td colspan="6">Constants: Amount of each infusion, amount of light exposure, amount of time to let the infusions settle, and type of solar cell</td></tr>
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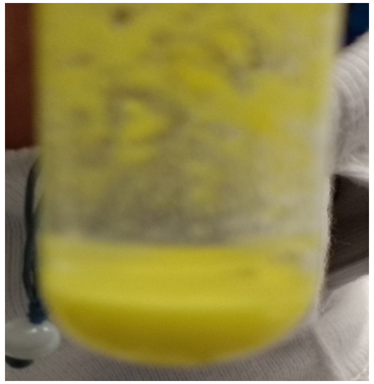
Materials

- Titanium Dioxide Powder
- Cadmium Selenide Powder
- Lead Iodide Powder
- Dimethylformamide
- Acetyl Acetone
- Ethanol
- Autoclave
- Oleic Acid
- Octadecene
- Test Tubes
- Solar Panels
- Voltmeter
- Erlenmeyer Flask
- Hot Plate

Methods and Materials (Day 1)

1. The titanium dioxide mixture was created by mixing together 0.5 g TiO_2 powder with 10 mL ethanol, 10 mL acetyl acetone, and .05 mL Triton X-100.

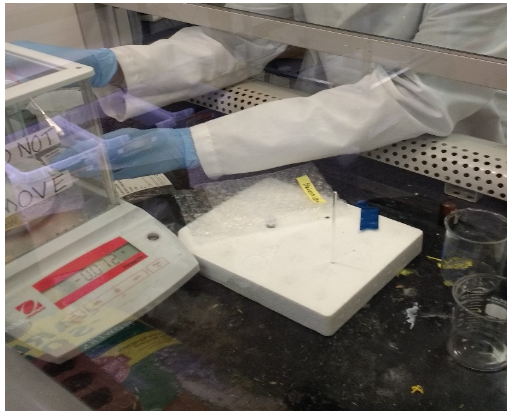
2. This mixture was then put in an autoclave for 30 minutes at 100C.
3. Lead iodide was created by combining 0.5 g PbI_2 with 10 mL DMF. This mixture was heated for 20 minutes at 80C.

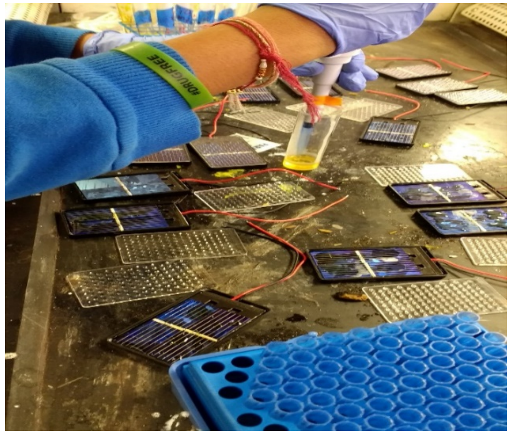


4. Each of the mixtures were placed in 4 different test tubes.

Methods and Materials (Day 2 and Day 3)

1. Cadmium Selenide quantum dots were made my combining 0.5 mL oleic acid, 10 mL octadecene, and 0.5 g CdSe.
2. This mixture was heated at 100C while 4 second samples were collected. Each sample was put into two of the PbI2 and TiO2 tubes.
3. 3 mL samples of each of the four test tubes were placed in 3 solar panels per material.
4. A voltmeter was attached to each panel and the voltage and amperage was collected with a 120 V lamp.





Data Collection

- To collect data, a voltmeter was used and the voltage in volts and amperage in milliamps was collected.

- The first data collected was the voltage and amperage:

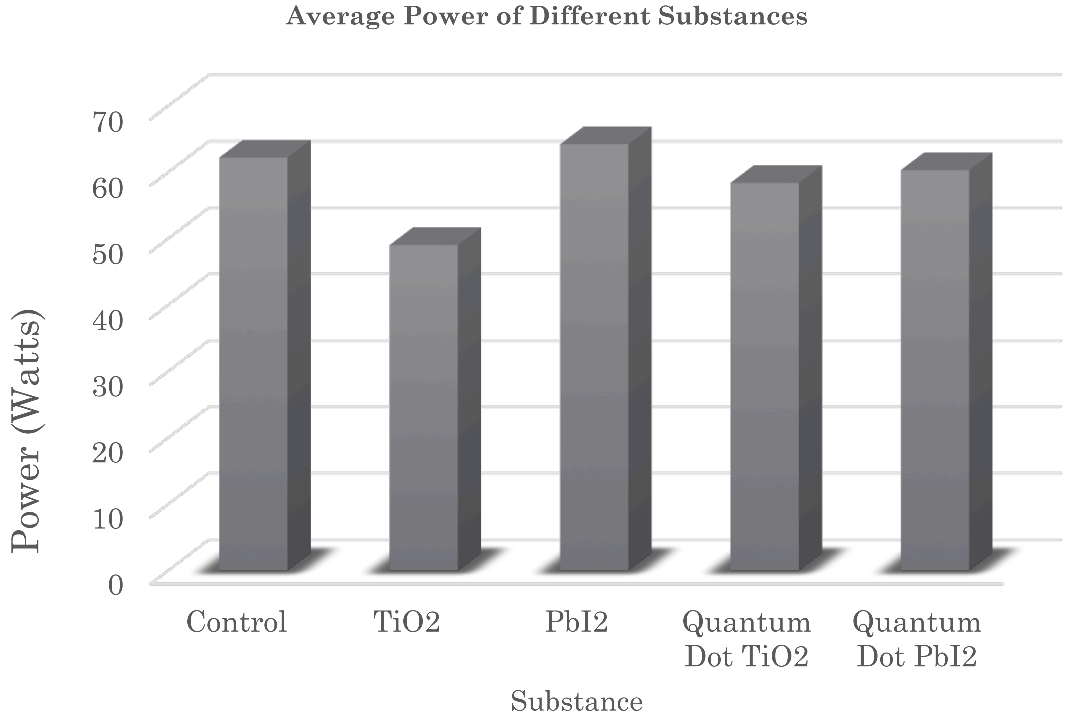
Average Amperage for Different Substances	
Subtances	Amperage (MilliAmps)
Control	121.667
TiO2	104.667
PbI2	127.400
Quantum Dot TiO2	118.233
Quantum Dot PbI2	119.500

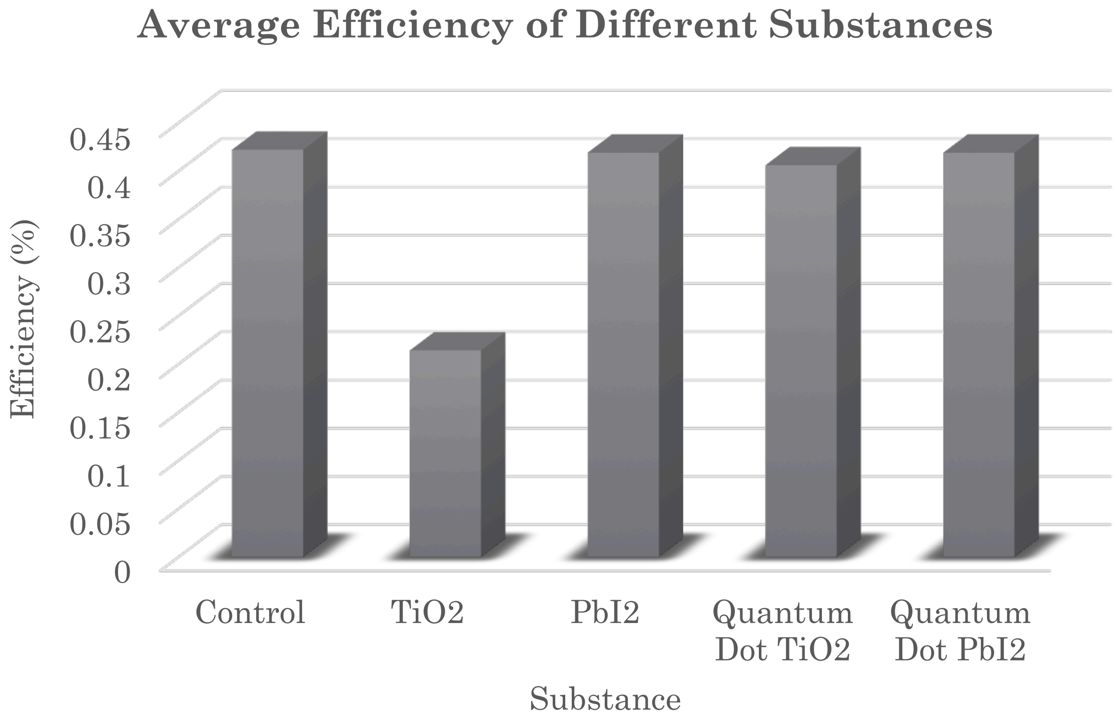
Average Voltage for Different Substances	
Subtances	Voltage (Volts)
Control	0.507
TiO2	0.437
PbI2	0.503
Quantum Dot TiO2	0.487
Quantum Dot PbI2	0.503

- It can be seen that the lead iodide and control silicon have the highest production rates with the lead iodide having a higher amperage.

Data Collection

- The last two data sets consisted of the efficiency and power outputs:





- The data above shows the dominance of the control silicon and lead iodide. The lead iodide has a higher power output, but is less efficient.

Data Analysis

- The first step in analyzing data included an analysis of standard deviations.

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

- The data shows that lead iodide was more precise in its outputs throughout meaning that the output is more consistent as opposed to the control silicon and titanium dioxide.

Data Analysis

- In terms of inferential statistics, an ANOVA test was conducted (Analysis of Variance test):

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

T-Test for Efficiency	
t Stat	0.114048
P(T<=t) one-tail	0.459808
t Critical one-tail	2.919986
P(T<=t) two-tail	0.919617
t Critical two-tail	4.302653

- All of the p values were above .90 meaning there is less than 10% significance in the results.

- Therefore, a t-test was conducted because the lead iodide and control have different variances. where the t-critical two tailed value is higher than the t-value meaning the data is significant between the lead iodide and control.

Discussions and Conclusions

- The lead iodide and control have been shown to be the most effective semiconductor materials"
  - The application of lead iodide was more consistent than the control.
  - The lead iodide led the control with a more effective current as well as a higher power output.
  - This does not support the hypothesis since the lead iodide did not lead in all categories.
- The application of quantum dots was accurate with other data seeing that the outputs were increased with quantum dots.
- The titanium dioxide was the least effective, primarily due to different solutes used in the making of the films.
- Lastly, lead iodide does cost less than the silicon with lead iodide costing at most $12 per pound while silicon costs four times as much.

Discussions and Conclusions

- Limitations:
  - Not being able to afford cadmium oxide and selenium by themselves.
  - The initial capabilities of the solar panels before experimentation began.
  - Solar cells were on a very miniscule scale compared to those used in industry.
- Implications of Research:
  - It can be said that it was determined that lead iodide is more consist when outputting energy. This would need to be tested on a larger scale to reign true.
  - Different temperatures and types of solar cells can be used as well.