Effectiveness of Different Dyes on Dye-sensitized Solar Cells

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Abstract

Dye-sensitized solar cells (DSSCs) are a new breakthrough concept in the world of photovoltaic cells. They are an organic alternative to the already commercially wide-spread solar panels. They use anthocyanins, which are flavonoids found in many plant foods, to facilitate the photovoltaic effect. So far, DSSCs are very hard to make without sacrificing efficiency and lifespan, and so the focus of this study is improving upon the process of making DSSCs, more specifically on how to dye the cell itself. Two procedures were used to dye the dye-sensitized solar cells: a boiling reduction and a crushing method. When testing, the aim in finding efficiency was to find a general curve between voltage and current that can be correlated to a commercial photovoltaic cell.

Introduction

The need for more cost-and power-efficient renewable energy resources has risen in the past two decades. The newer dye-sensitized solar cells (DSSCs) have been identified as a more cost-and power-efficient alternative to synthetic solar cells. Dye-sensitized solar cells use an organic dye based in blueberries and blackberries as a way to facilitate the photovoltaic effect, rather than much more expensive synthetic dyes. Synthetic dyes used by many manufacturers consist of rare metals that are scarce and hard to obtain. This makes the amount of energy used while making solar panels less efficient than desirable for consumers. On the other hand, DSSCs use an organic dye composed of anthocyanins. Anthocyanins are a group of flavonoids found in fruits, leaves and flowers; they are water-soluble plant pigments that carry very vivid coloration (Vien & Hsu, 2013). Anthocyanins are used in DSSCs as a metal free nontoxic alternative to Ruthenium-based dyes. The fact that these dyes can naturally decompose without releasing toxins makes them very important for the future of renewable energy, sustainability, and safety. These anthocyanins have shown that they are comparable, efficiency-wise, to regular solar panels at around 11%-15% conversion efficiency (Nazeeruddin, Baranoff & Gratzel, 2011). Comparable efficiency and the cheap inherent nature of growing plant dyes compared to synthesizing dyes makes DSSCs a viable alternative to study more extensively.

DSSCs are important because the world needs better energy sources to fuel humankind’s energy needs, many of which can't be sustained by fossils such as natural gas, coal, etc. These sources are non-renewable, which leaves renewable energies, which are energy resources that can be used over and over again for years. The two biggest renewable energy sources right now are nuclear and solar (Nazeeruddin, Baranoff & Gratzel, 2011). Nuclear energy is still limited by the amount of available uranium in the earth, leaving only solar energy. Solar energy is quite renewable, as the sun will long outlast mankind's ability to collect energy from it, making it a true renewable energy source. Solar panels are quite expensive, however, and don't convert nearly enough energy to make up for their fabrication costs. So researchers turned to plants' organic dyes, which are used in substitution for synthetic dyes on regular solar panels to alleviate this problem.

Many dye-sensitized solar cells that have been studied are small, but this allows for study of the inner electronics and measurement of efficiency much easier. The inner workings of a solar cell are very intricate; they use a p and n junction, which is a semiconductor that allows control of the flow of any current, in order to achieve the flow of electrons which is just called current. A p and n junction, or a semiconductor, is comprised of p-and n-type silicon. N-type silicon has phosphorus atoms placed throughout its molecular structure providing a free electron to the whole structure making that silicon slightly negatively charged. On the other hand, p-type silicon has boron atoms in place of some silicon atoms. This creates an area where there is no electron present to neutralize the charge, leaving an area called a 'hole' and making that whole molecular structure slightly positively charged. When putting these two silicon variations in series, a p-type then n-type then p-type (PNP configuration) or a n-type then p-type then n-type (NPN configuration), one can control the flow of electricity. For example, one can also use light to free electrons in a material that are then attracted to the p-type layer and go through the circuit and create a current. This concept is the basis of all solar panels, which connect that system to a machine that needs power and a material that, when hit by light, frees electrons in the material. The materials, for the latter, are quite expensive to make and are generally made of silicon, which can be used in the actual working parts of the diode. In DSSCs, organic dyes replace the material that frees the electrons which, in turn, reduces waste products and non-decomposing materials and making the need for silicon lower. There is reason to believe that improvements in the process of dyeing DSSCs can make them more efficient, particularly in this area.

Methods and Materials

The cells were created by finding the conductive side of a piece of conductive glass. They were then cut in to smaller pieces of around 1/2” by 1” and taped around the edge with scotch tape leaving a smaller area of space as seen in *Figure 1*, this is so that there was consistency in the size and the amount of paste in each cell. The paste as seen in *Figure 1* was made when a beaker was taken and both TiO_2 powder and concentrated acetic were stirred together, with a stir rod, until it had the consistency of paint. The paste itself was spread when the stir rod was used to scoop some paste up and evenly spread on the exposed conductive glass, then allowed to dry for 10 minutes. After the 10 minutes was over, the cells’ tape were taken off and then they were placed on a hot plate at > 270 °C and allowed to heat up for 10 minutes in order to undergo sintering, as seen in *Figure 2*, which allows the paste to become more porous and allow the dye to absorb better. The phase transition, as mentioned above, was observed by the paste turning brown for a few seconds then back to white once again, once the 10 minutes were over the cells were taken off the heat and allowed to cool down to room temperature.

Figure 1 Conductive Glass with TiO_2 Paste Drying on It

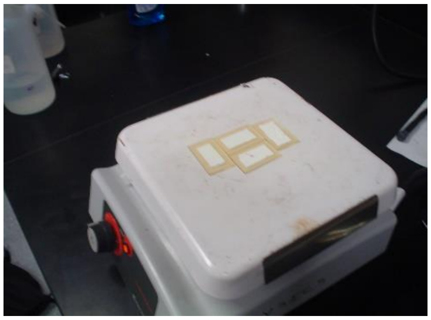

Figure 2 Conductive Glass on a Hot Plate

The berry reduction dye was created when another beaker was taken, and 5 black berries were put in a small

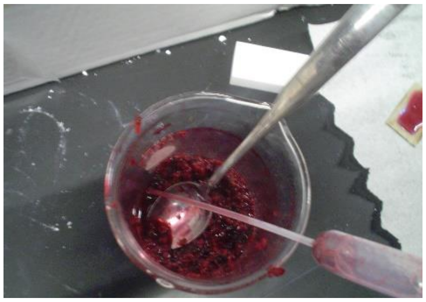

Figure 3 Berry Reduction Dye

amount of water. Then the beaker was put on to the hotplate and the berries were slowly broken down with a spoon to let the dye out of the berries. Once the water was completely darkened as seen in *Figure 3*, the dye was ready to be used.

The squished berry dye was created when a Ziploc bag was taken and 4 blackberries were put inside and squished until only seeds, dye, and fruit skin could be seen, as seen in *Figure 4*. Then the dye and the fruit skin and seeds were separated from each other so that the dye could be easily accessed.

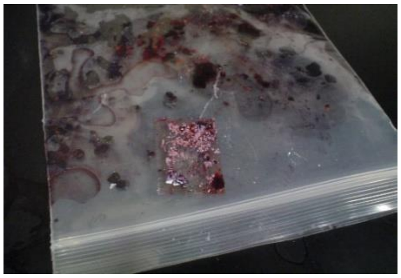

Figure 4 Squished Berry Dye

Once both dyes were prepped, two cells were designated to be dyed with the reduction and the other two were dyed with the squished berries. The dye was transported with a pipette and spread all over the TiO_2 paste, as seen in *Figure 5*, so that all of it could absorb the dye for consistent current generation. Then the dyes were allowed to absorb at room temperature for 10 minutes. The cells were then washed with deionized water and isopropyl alcohol so that no excess dye would stay on the cell. The cells then were dabbed with KimWipes™ very gently, so that no dye was wiped off, until they were completely dry so that only the dyed TiO_2 paste was present on the cell.

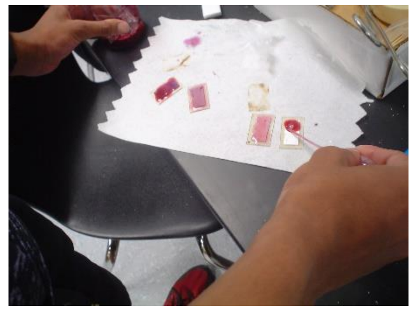

Figure 5 Dyeing the Cells with Both Dyes

The top of the cell was made when another ½” x 1” piece of conductive glass was taken and put over a candle flame to allow a layer of soot to form, as seen in *Figure 6*. This layer of soot was so the electrolyte and the top of the cell could conduct better. Once the soot layer was added the glass was allowed to cool down enough so it could

Figure 6 Applying Soot Layer

be handled with hands. Once cooled down, the dyed piece of glass and the soot piece of glass were connected using small binder clips, as seen in *Figure 7*. Once the cell was clipped together a potassium iodide electrolyte was added so that there would be electrons for the light to interact with and free for the dye to capture. A drop of electrolyte was added to the inside of the cell and allowed to soak over the dyed paste by alternatingly clamping and unclamping the binder clips, giving the yellow hue as seen in *Figure 7*. This was done to both the reduction cell and the squished berry cell.

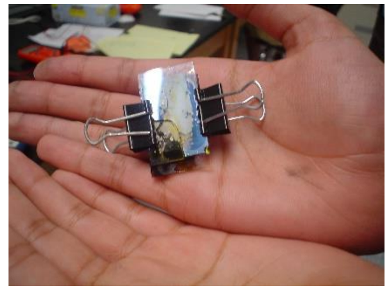

Figure 7 Completed Cell

The cell was tested by using two multimeters in a loop so that the cell's current and voltage could be measured, as seen in *Figure 8*. The multimeters were hooked up to a DC Power Supply, as seen in *Figure 10*, so that a voltage sweep could be performed. The cell was connected using alligator clips. The black wire was connected to the dyed part of the cell and the red wire was connected to the blackened part of the cell, as seen in *Figure 9*. The cell was first tested at .01 V and, if the cell worked, there would be a negative current. This means that the cell is pushing more current in the opposite direction than that of the DC Power supply, which was set at 1/3 of its current knob. This was to prove the cell was actually producing measurable current. From .01 V all the cells were tested in increments of .05 V all the way to .4V. Once all the data points were recorded, they were plotted on a graph in Excel.

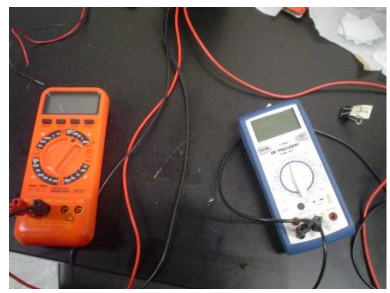

Figure 8 Voltage and Current Multimeters

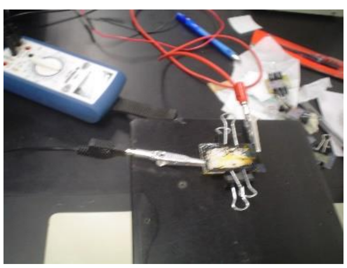

Figure 9 Cell Hookup

Figure 10 DC Power Supply

Results

In *Figure 11* the regular Photovolatic Cell's curve is portrayed. The cell was tested on different voltages than the DSSCs this is due to the size difference and the sheer fact that DSSCs aren't as efficient as regular solar panels. The DSSCs usually open looped at around 1 volt and so they were only tested to .4V so that a proper curve could be observed. The regular solar panel increases exponentially because at 2 volts it produced ~100 microamps, then at 2.5 volts it produced ~400 microamps, when a linear graph would only go up another ~100 microamps.

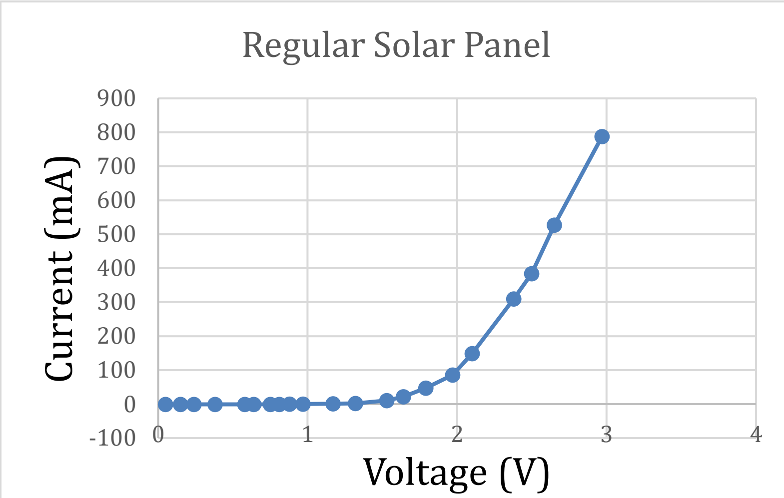

Figure 11 Squished Berry Cell

In *Figure 2*, the curve of the Berry Reduction Cell is portrayed. The Cell was only tested from .01 V to .4V due to the scale of the Cell compared to the regular PV Cell. This Cell's curve is more linear as at around .2 V it is around -20 amps, but at .3 V it was at around 17 microamps; when an exponential graph would be around 25-30 microamps at this point.

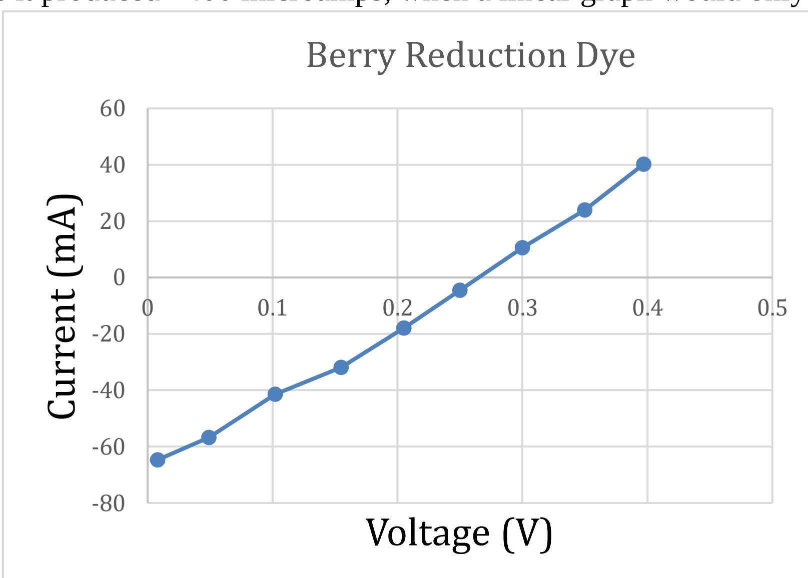

Figure 12 Berry Reduction Cell

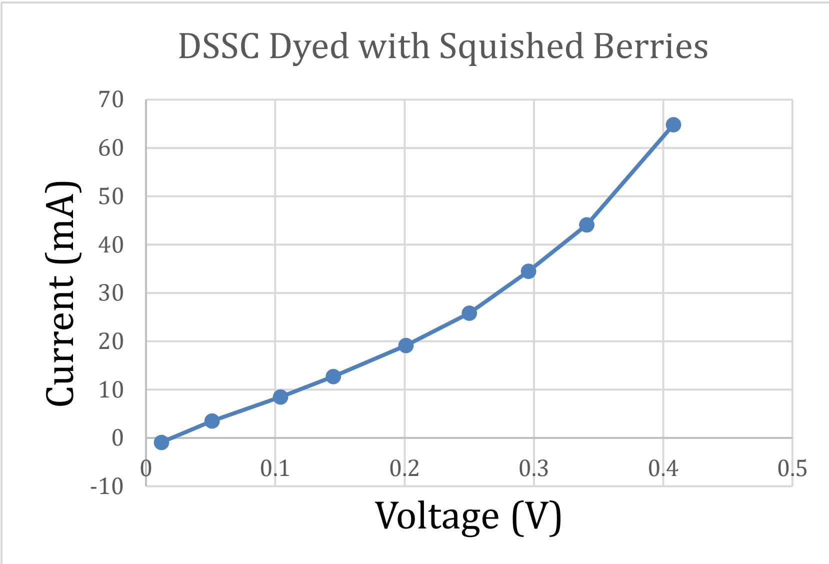

Figure 13 Squished Berry Cell

The Squished Berry Cell was also tested from .01 V to .4V, as seen in *Figure 13*, since it was the same size as the other DSSC. Here the curve looks like the regular solar panel. Where at .2 V the rate of change is more exponential than *Figure 12*. This means that the Squished Berry Cell did better, in comparison to the regular Solar Cell.

Discussion

To reiterate, the goal of this study was to find a way to make DSSCs more efficient, in comparison to regular solar cells. More specifically, how to dye them more efficiently. DSSCs should first perform similarly to regular solar cells before improvements upon efficiency can be made. The efficiency was graphed on an IV Curve to visualize efficiency. The negative values were key in to knowing if the cell even produced significant data.

Every time data was recorded newly made cells were used, due to their low lifespan. A DSSC's is life span are directly connected to the leakage of the Potassium Iodide from the inside of the cell. The fewer free electrons there are, the less current the cell can create. The significance of knowing that squishing berries for dye is better is so that other parts of the fabrication of DSSCs can be improved. As each step of the fabrication process is improved, the more efficient the cells can become. Further research can look in to the application of either the soot layer or the paste itself. The soot layer, or the carbon layer, could be studied to see if a better application of it can improve efficiency. The making of the paste could be improved by finding out about what concentration acetic acid should be used for certain amounts of TiO_2 paste. This could help with the consistency of the cells and hopefully make a control for future scientists to test on.

References

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