THE EFFECTS OF SPACE ENVIRONMENTS ON SOLAR CELLS

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ABSTRACT

Solar cells are widely used to power satellite missions in space because they use the sun's light to generate electricity. This project was conducted to gain a better understanding of how solar cells perform under extreme environmental conditions like those found in space. In order to find the optimum light source that best simulates sunlight, eight solar cells were tested to get their baseline currents and voltages using six different types of light bulbs with varying intensities. Each solar cell was then remeasured for its voltage and current after being immersed in liquid nitrogen, baked in an oven, or exposed to radioactive strontium-90. It was found that extreme heat adversely affected the cells, whereas successive cooling possibly improved the performance of the cell. The radiation results indicated that exposure to beta decay caused changes in the solar cells, affecting their function in a manner that will become more apparent with further testing. This project yielded fundamental and crucial information for further experiments that will help understand how solar cells function under different conditions in space.

INTRODUCTION

Solar cells have been used on satellites since 1958 when the satellite Vanguard I used a less-than-one watt arrangement to power its radios. Following this mission, the satellites Explorer III, Vanguard II, and Sputnik 3 were launched, also powered by photovoltaic-powered solar cell arrangements[1]. Although these feats were not completely effective in utilizing the impure silicon-based solar cell, they opened the door to using solar energy to power satellites. By the 1960s, solar energy became the accepted energy source for many space-associated missions[1].

Solar cells are now widely used to power missions in space because they convert abundant light energy in space into electricity. A solar cell absorbs photons of light which eject electrons from the silicon layers and generating electrical currents[2]. As the importance of solar cells in space technology increases, there is a need to enhance their reliability and efficiency. The International Space Station itself contains over 250,000 solar cells that store energy in batteries when not in use[3]. This project aims to test solar cell performance under the conditions of extreme temperatures and radiation. As a part of this project, numerous solar cells will be exposed to a variety of conditions similar to what they might endure in space. Data obtained from this experiment will be helpful in understanding how solar cells function after being exposed to different conditions.

Currently, solar cells are used in a variety of applications. On Earth, solar cells are becoming more popular in industry and among individual consumers as their cost decreases and their availability and efficiency increase. Many private universities and companies have therefore committed themselves to developing a more affordable and energy-efficient solar cell. Researchers are exploring ways to incorporate less expensive elements and production methods to making solar cells. In addition to addressing the problem of cost, researchers are trying to find new ways to increase solar cell efficiency by decreasing the amount of light energy that is dissipated as heat. One method that has been utilized is the addition of quantum dots, or semiconductor crystals, to the silicon[4]. For example, NASA researchers have found that adding quantum dots in a solar cell increases its efficiency and durability by forming an electronic band around the p-n junction, or the region where positive and negative silicon layers meet[5]. Different types of solar cell structures such as silicon wires that recapture dissipated energy are also being explored to seek greater efficiency in cost and power generation[6]. While scientists have come up with many ways to reduce the cost, improve the overall effectiveness, and slow the decay of solar cells, there are many unexplored ways of improving the performance of future solar cells.

In this research project, Voltage vs. Intensity and Current vs. Voltage (IV) curves will be found for each cell by exposing them to artificial light set the baseline for its efficiency. Numerous lighting conditions will be tested to see how the cells react to different colors and wattages of light. The solar cells will then be exposed to a number of extreme environmental conditions such as temperature and radiation, and the Voltage vs. Intensity and Current vs. Voltage curves will be re-measured to see how the performance of the cell changes. Visual clues to changes in solar cell performance are obtained with a scanning electron microscope (SEM). The results obtained from this experiment will be used to gain a deeper understanding of how solar cells are affected by their surrounding environment.

THEORETICAL BACKGROUND

The Photoelectric Effect

Photovoltaic cells use the photoelectric effect to generate electricity. Albert Einstein received a Nobel Prize for describing the photoelectric effect in 1905[1]. When a photon strikes a metallic surface, its energy is transferred to an electron. If this energy is great enough, the electron will be liberated from its bond to the nucleus and used to generate current. Since the energy of a photon is directly related to its wavelength, the light striking the photovoltaic cell must meet a minimum wavelength to release the bound electron and generate a current[7]. The equation representing this effect is as follows:

$$hf = E_{ph} = K + \varphi,$$

where h represents Planck's constant, f represents the frequency of light, E_{ph} represents the photons energy, K represents the excited electron's kinetic energy, and φ represents the work function which is the energy required to liberate the electron from its bond[7]. As the frequency of light increases, the kinetic energy of the electron will increase, resulting in a greater electric current.

Doping Silicon

Silicon is the material now used to create most solar cells. Silicon is a semiconductor which has 4 valence electrons. In order to obtain a full octet in its valence shell, silicon forms a diamond face-centered cubic crystalline structure[7]. The bonds in these crystal structures are relatively stable and will not give up or accept electrons easily. The silicon crystals are doped with boron and phosphorous atoms. Approximately one boron atom and one phosphorous atom are added for every 1,000,000 silicon atoms[7]. A phosphorous atom contains 5 valence electrons. When it bonds with a silicon atom, one electron is left after the atoms fill their valence shell with 8 electrons. This material is known as negative or n-type as it has an extra electron[7]. Conversely, boron has only 3 valence electrons. When it bonds with silicon, it desires an extra electron to complete its valence shell. This material is called positive or p-type as it lacks an electron[7]. When light strikes a photovoltaic cell, it frees the extra electron bonded with the phosphorous atom in the n-type silicon which then flows to the boron atoms in the p-type silicon. This flow of electrons generates the electric current for the cell[7].

PROCEDURE

Before beginning the experiment, it was important to note that solar cells are very delicate. They are very brittle and prone to damage and cracks. Miniscule cracks can alter results on a much larger scale. Therefore, it was important that the solar cells were frequently examined for any cracks, and handled with caution during the testing.

The first steps of the experiment were designed to determine the baseline output of the solar cells. Unlike conventional batteries, each solar cell has a unique maximum voltage value. In order to determine the capacity of each solar cell, an apparatus was developed to measure the current and voltage of each cell at different light intensities and with different types of light (Fig. 1). Wires were soldered to the solar cell, which was then grounded onto a plastic base using electrical tape and Q-tips. A light bulb was inserted into a lamp. The height from light bulb to solar cell remained constant. An adjustable power supply was used to control the intensity of the light projected from the bulb. Wires connected the solar cell to a voltmeter to record the voltage and current at different intensities.

Six different types of light bulbs were used to test each solar cell: blue 50-Watt, white 65-Watt, yellow 25-Watt, white 75-Watt, blue 150-Watt, and blue 65-Watt bulbs (Fig. 2). The intensities of the light bulbs were controlled by an adjustable power supply scaled from 0% to 100% at ten even increments. Five trials were done for each type of bulb. The intensity, voltage, and current measurements were then used to create an Voltage vs. Intensity and Current vs. Voltage graph for each type of light bulb.

To reduce the impact of possible sources of error, several factors were taken into consideration. First of all, ambient light in the lab room could be absorbed by the solar cell and affect the voltage and current readings. Therefore, the four light bulbs were placed as close to the solar cell as possible. Overheating of the solar cell was another problem. In the case of a 150-watt bulb, the heat from the light was enough to melt or burn the solar cell. Hence, the light was turned off frequently to cool down the solar cell, and it was held much further from the cell than the other light bulbs.

For the completion of the experiment, the performance of the cells was tested under extreme conditions, mimicking those in space. Though the 150-watt bulb was determined as the optimum light source to test the cells, the 65-Watt bulb was also used due to limited resources. Two of the cells were tested after exposure to extreme cold. These solar cells were immersed in liquid nitrogen for 10 minutes, and then allowed to sit at room temperature for 15 minutes following that immersion. Liquid nitrogen exists at 77.2 K (-320.4°F). In this way, it was possible to test how solar cells perform after being exposed to extremely low. A third cell was immersed in the liquid nitrogen, but it became more brittle and the leads became detached. The leads were resoldered to the cell, but the results were not consistent with other trials and therefore were discarded.

To test the higher extremes of temperature, two more cells were baked in a toaster oven. They were baked for 30 minutes at 120°C, the average temperature of an object in Earth's orbit exposed to sunlight[9], and at 500°F, the highest temperature that metals reach in Earth's orbit in space[10]. A baking sheet lined with aluminum foil was placed in the oven which was preheated for five minutes to 120°C. The two cells were placed in the oven for 30 minutes. The solar cells were removed and their voltages and currents were then recorded. The process was repeated at 260°C for both solar cells. One of the cells cracked during the first baking, making the results unobtainable for that particular cell.

The solar cells were also tested for their performance when affected by radiation. Eleven samples of strontium-90, a radioactive substance, were placed on a cell to expose the cells to radiation. The radiation given off would be projected in the form of beta particles, or electrons. The strontium-90 remained on the cells for 48 hours, and then were removed. The intensity, voltage, and current were recorded.

After the solar cells were frozen and heated, they were observed under the scanning electron microscope (SEM). SEM images were taken for each solar cell and examined to note any changes in the surface structure of the cell.

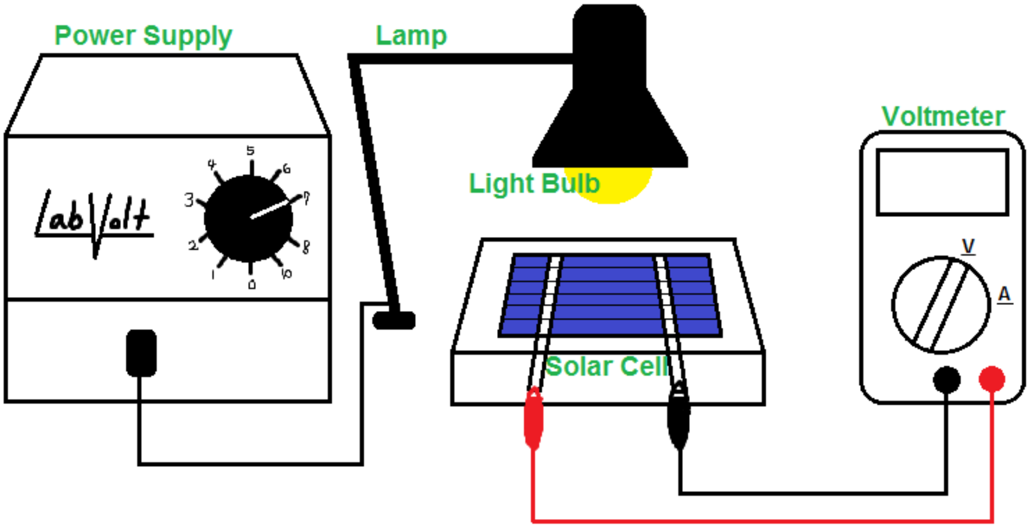

Figure 1 Apparatus used to measure voltage and current of the solar cell at various light intensities

Figure 2 The six types of light bulbs used to test each solar cell.

DATA AND RESULTS

To collect baseline data for each solar cell, our team split into five groups, each with one cell. First, each of the groups gathered data for each of the four colors, five individual times, resulting in a total of twenty-five trials per color. One cell cracked during testing, however, so data from that cell was discarded, leaving a total of twenty trials per color. Then we averaged the voltage and current values at each intensity for each bulb, over these twenty trials to produce the Voltage vs. Intensity graph and the Current vs. Voltage curve shown in Figures 3 and 4. One of the groups tested a cell using a different voltmeter. Using $V=IR$, we calculated the resistance of that particular meter to be 98.04 **Ω**. The meters that the other groups used had a resistance of only 1.88 **Ω**. So to unify the data we scaled the results from the different meter to match those of the other three.

The next step was to test the solar cell output for the three different wattages of blue light bulbs. This was done five times each, again giving a total of fifteen trials per bulb. The resulting Voltage vs. Intensity graph and Current vs. Voltage curve can be seen in Figures 5 and 6.

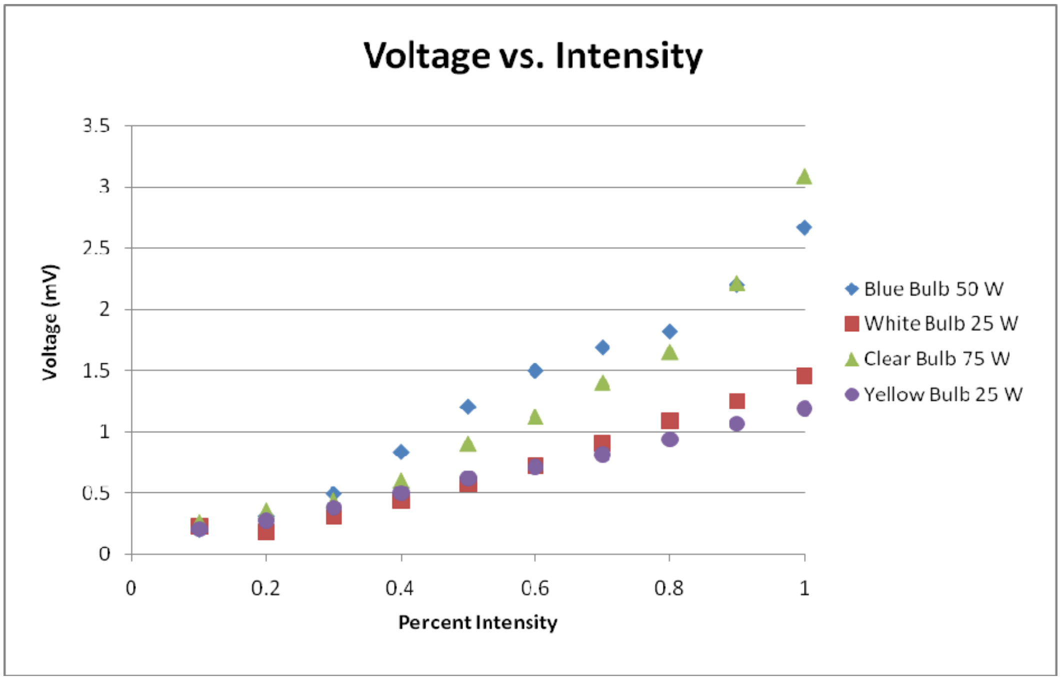

Figure 3 Voltage vs. Intensity for the different frequency light bulbs used to test each solar cell.

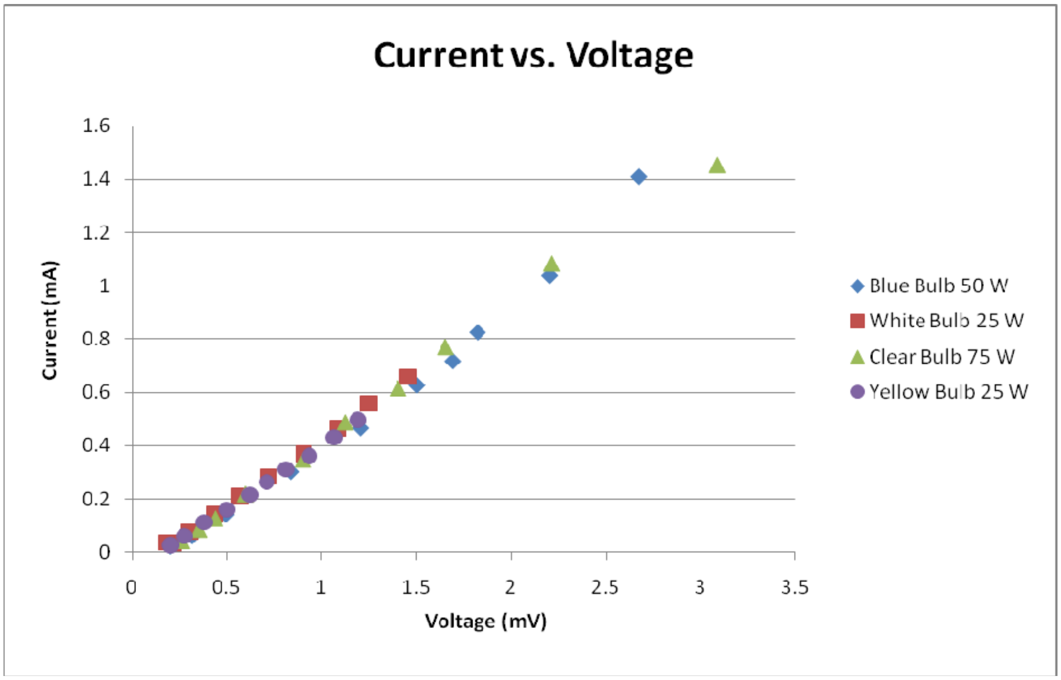

Figure 4 Current vs. Voltage for the different frequency light bulbs used to test each solar cell.

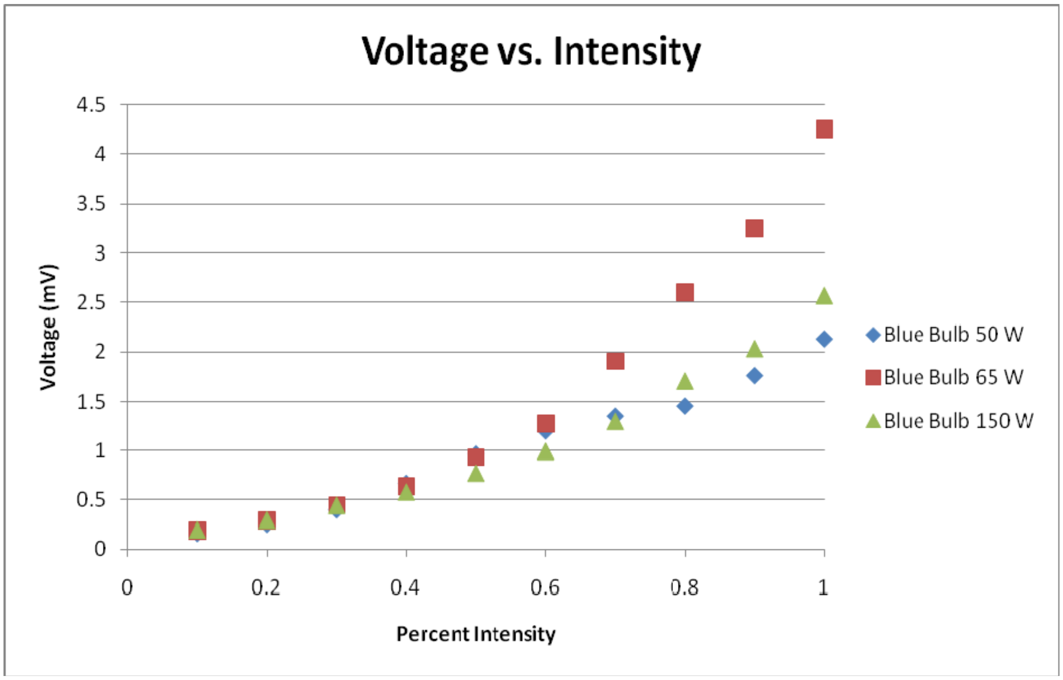

Figure 5 Voltage vs. Intensity for the different wattages of blue bulbs.

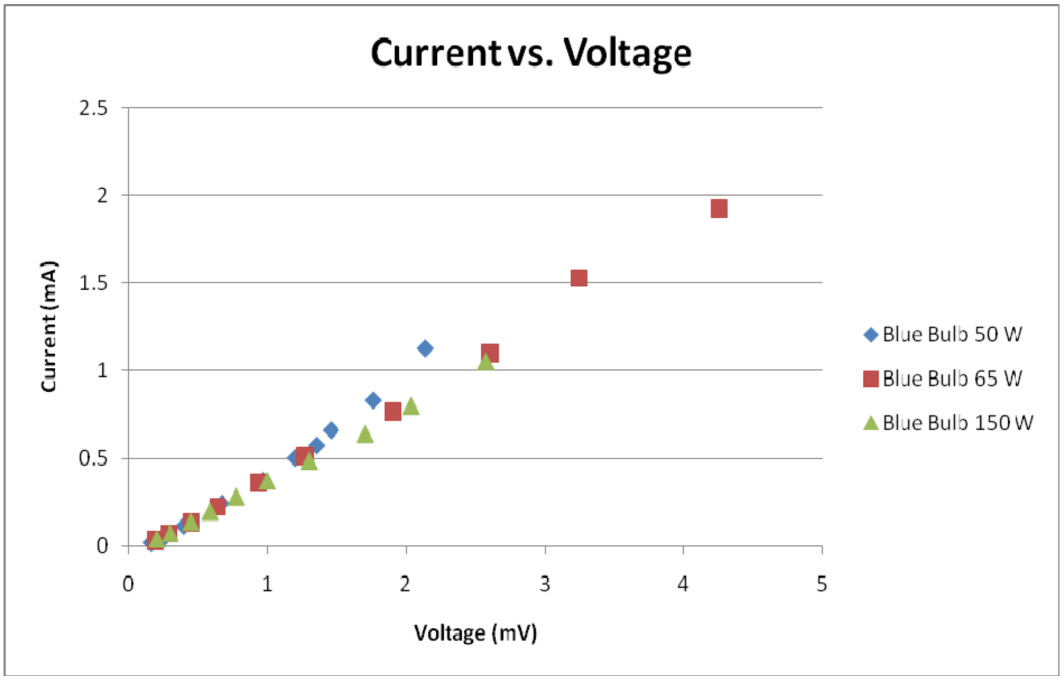

Figure 6 Current vs. Voltage for the different wattages of blue bulbs.

The final step was to test three factors, which were heat, radiation, and extreme cold, on the solar cells. To cool the cells, we immersed them in liquid nitrogen for 10-minute intervals up to four times. For heating, we placed two cells in a toaster oven for 30 minutes at two different temperatures. The Voltage vs. Intensity graph and Current vs. Voltage curve can be seen in Figures 11 and 12 for the heated cell. The Voltage vs. Intensity graph and Current vs. Voltage curve can be seen in Figures 7-10 for two cells, A and B, which were immersed in liquid nitrogen. For radiation exposure, we irradiated a cell with beta particles for 48 hours. The Voltage vs. Intensity graph and Current vs. Voltage curve can be seen in Figures 13 and 14.

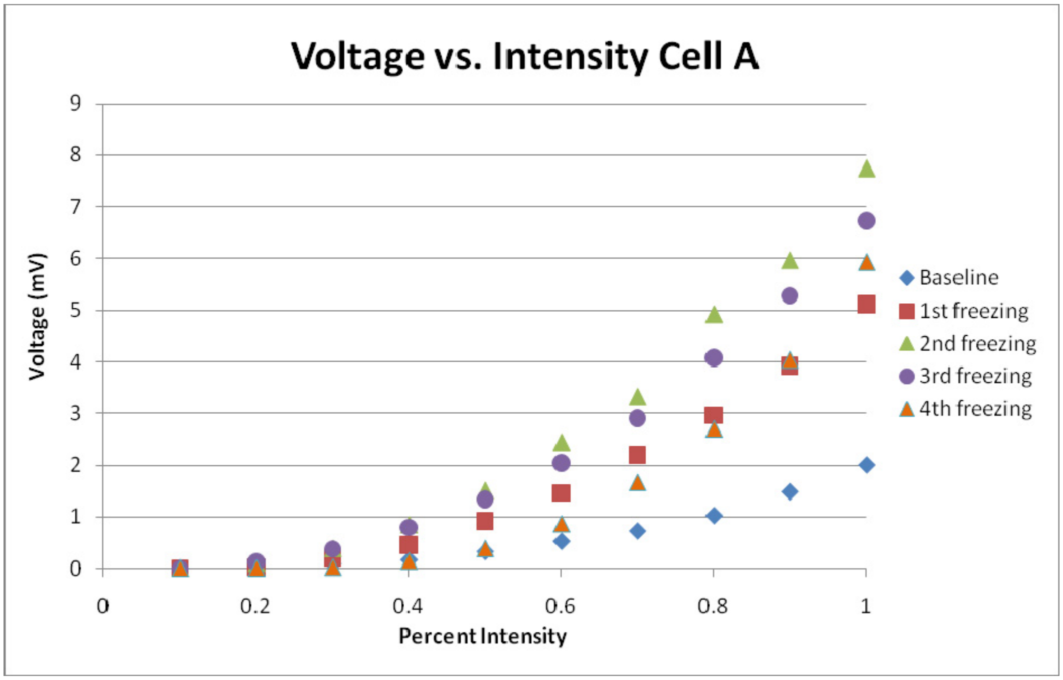

Figure 7 The Voltage vs. Intensity graph for Cell A, which was immersed in liquid nitrogen four times, in 10 minute intervals.

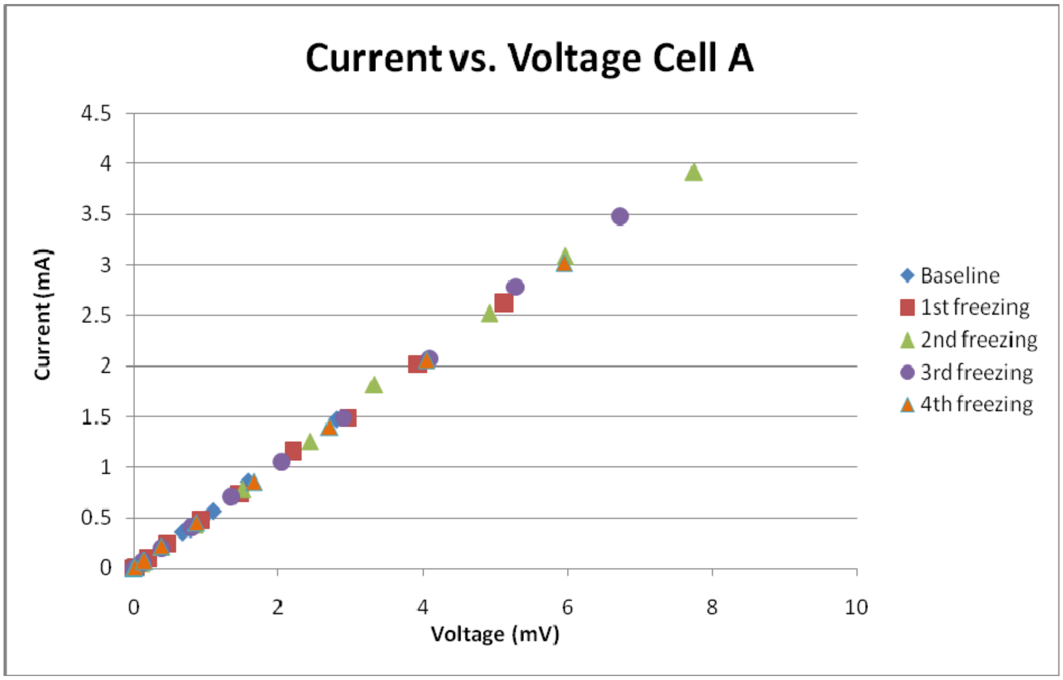

Figure 8 Current vs. Voltage for Cell A, which was immersed in liquid nitrogen four times in 10 minute intervals.

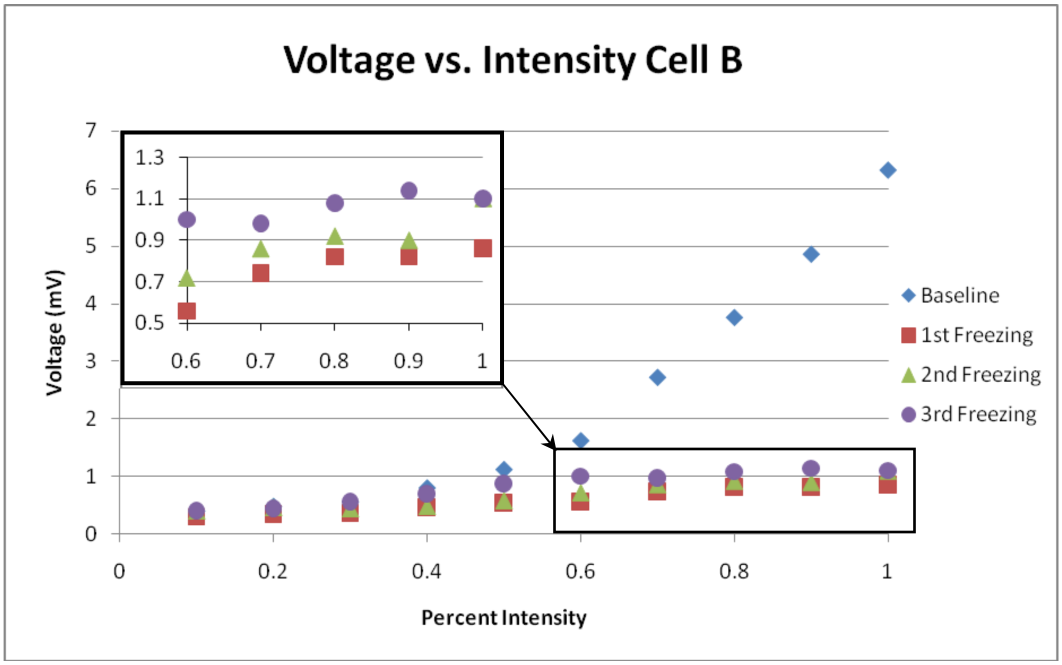

Figure 9 The Voltage vs. Intensity graph for Cell B, which was immersed in liquid nitrogen three times in 10 minute intervals. (See inset for differences between freezings)

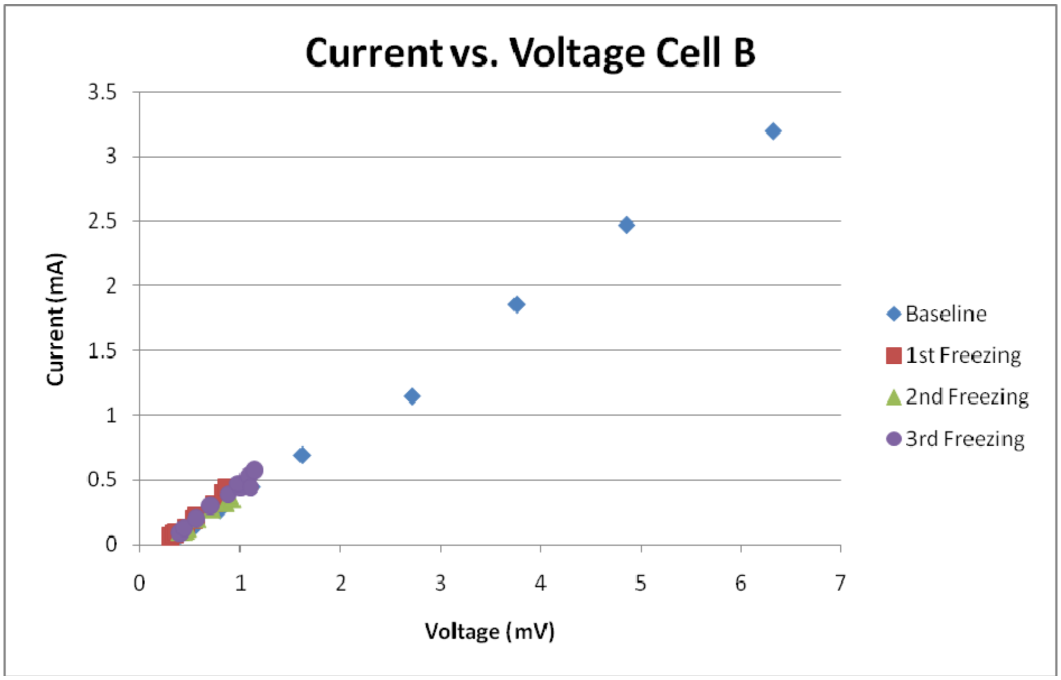

Figure 10 The Current vs. Voltage for Cell B, which was immersed in liquid nitrogen three times in 10 minute intervals.

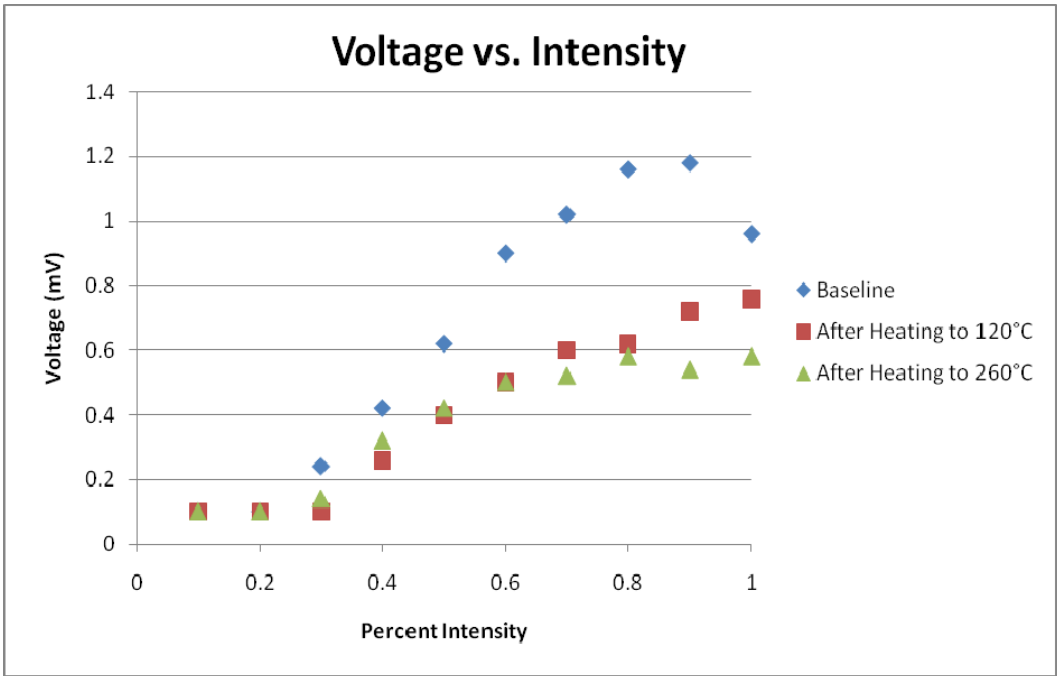

Figure 11 Voltage vs. Intensity for a cell exposed to heat at two different temperatures, 30 minutes at 120°C and 30 minutes at 260°C.

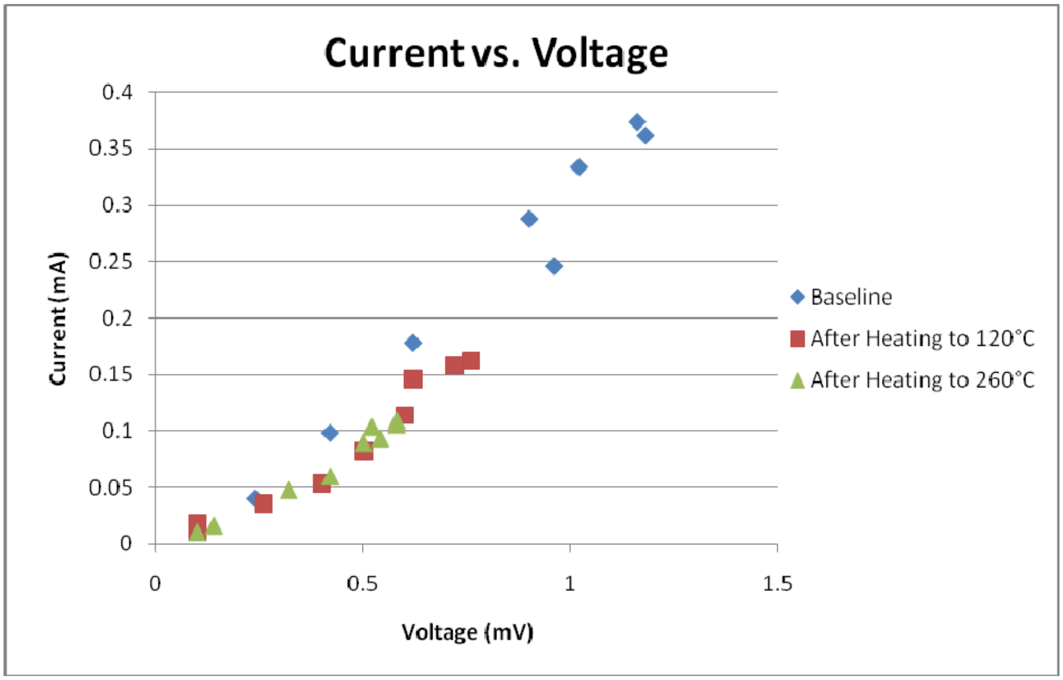

Figure 12 Current vs. Voltage for a cell exposed to heat at two different temperatures, 30 minutes at 120°C and 30 minutes at 260°C.

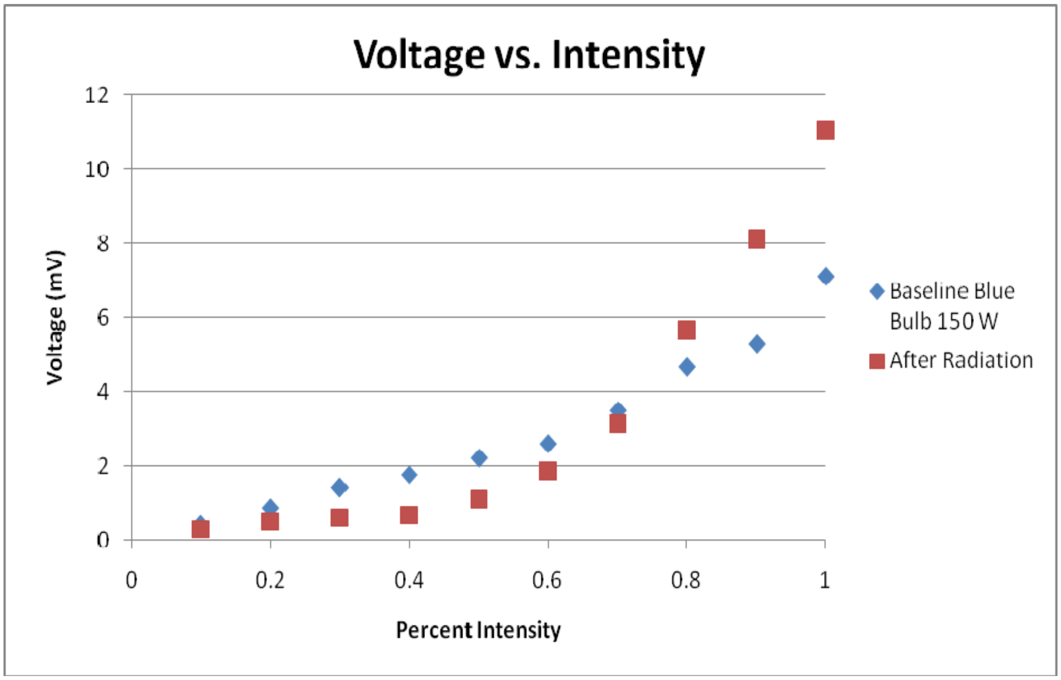

Figure 13 Voltage vs. Intensity for a cell irradiated by the beta decay of strontium-90 for 48 hours.

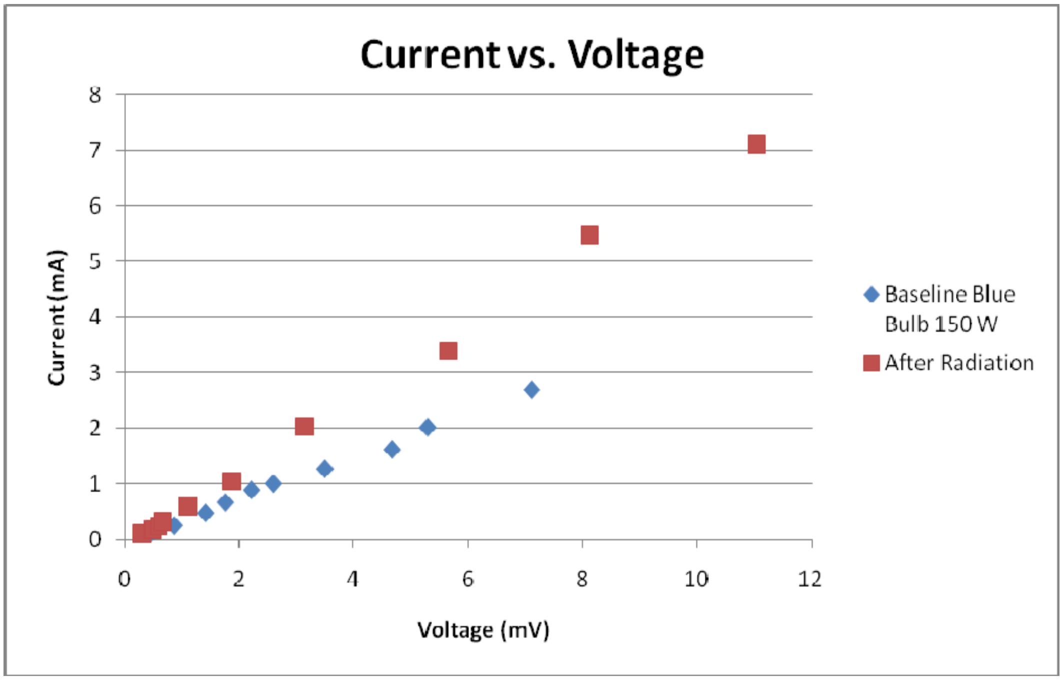

Figure 14 Intensity vs. Voltage for a cell irradiated by the beta decay of strontium-90 for 48 hours.

We looked at samples of the solar cells under the scanning electron microscope (SEM). Our first sample included a piece of a normal cell, a piece of a cell immersed in liquid nitrogen for 10 minutes, and a piece of a cell immersed in liquid nitrogen for 20 minutes. Images of these three samples can be seen in Figures 15-a, 15-b, and 15-c.

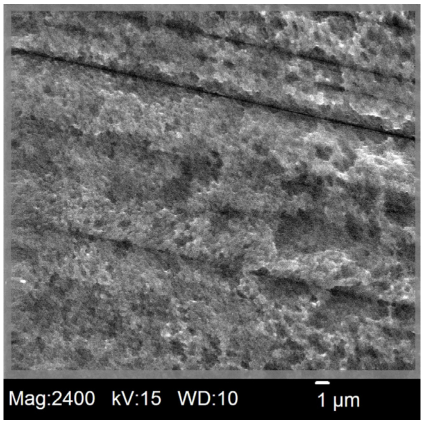

Figure 15-a Normal solar cell surface magnified at 2400.

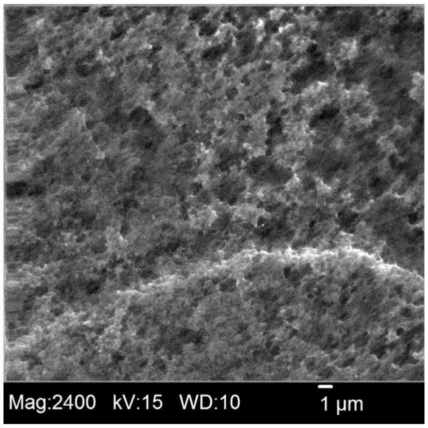

Figure 15-b Solar cell surface immersed in liquid nitrogen for 10 minutes at a magnification of 2400.

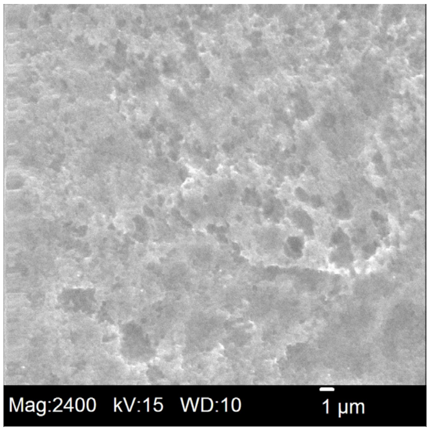

Figure 15-c Solar cell surface immersed in liquid nitrogen a total of 20 minutes at a magnification of 2400.

Our second sample included a pice of a normal cell, a piece of a cell heated at 120ºC for 30 minutes, and a piece of a cell heated at 260ºC for another 30 minutes. Images of the normal cell, and the one heated at 260ºC can e seen in Figures 16-a and 16-b.

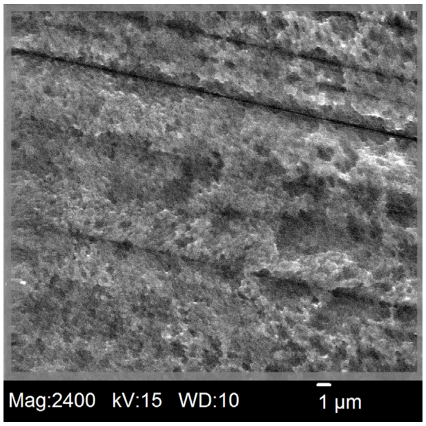

Figure 16-a Normal solar cell surface magnified at 2400x.

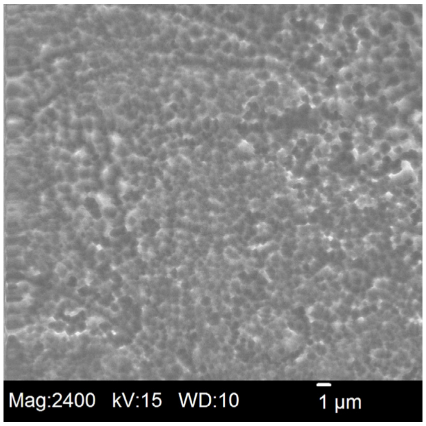

Figure 16-b Solar cell heated for 30 minutes at a temperature of 260°C.

DISCUSSION

Testing Different Wavelengths of Light

The data reveals how our solar cells responded to various colors of light. Ideally, the four different colors of light would all have the same wattage, and thus the same brightness. However, this was not the case. Therefore, we were forced to compare the bulbs that we had access to and make adjustments in our analysis for their wattage differences. Figure 3 shows the voltage output of the cells at various intensity levels. Higher voltages are seen with the 75-Watt clear bulb and the 50-Watt blue bulb, so it was assumed that these bulbs would make our solar cells work more efficiently. At the same time, the 25-Watt white bulb and the 25-Watt yellow bulb both give lower voltages, allowing us to assume that they failed to maximize the cells' potential. Even though these bulbs produced different voltages for a given intensity, the Current vs. Voltage curve had a constant slope no matter which bulb was used, as seen in Figure 4. This result is by no means a surprise, as it is expected that a lower wattage output from the bulb translates to a lower current and voltage output from the cell.

In regard to color differences, the easiest comparison to make is between the white bulb and the yellow bulb because they have the same wattage. In Figure 3, the white bulb performs slightly better than the yellow bulb, which is due to the fact that the yellow bulb is essentially a white light in a tinted glass casing, blocks some of the light that would otherwise pass through to the solar cell. Another simple comparison can be made between the blue bulb and the clear bulb, because these two bulbs performed about equally well. The bulbs produced similar voltage and current readings, but the clear bulb was 75 Watts while the blue bulb was only 50 Watts. This fact leads to the assumption that, with equal wattages, the blue bulb would perform better than the clear bulb. This too is expected, as the blue bulb is advertised as a plant light designed to mimic the sun. The relationship between the other bulbs is hard to determine. For example, it is unclear how the white and yellow bulbs relate to the clear bulb, because the clear bulb puts out three times as much power as the other two. Even with the different power outputs, the blue bulb emerges as the optimum choice to use with the solar cells.

Testing Different Wattages

The goal of this part of the experiment is to determine the effect of varying intensities of blue light on the efficiency of the solar cell. Based on the results in Figures 3 and 4, it seems intuitive that the bulbs would perform in order of the magnitude of their intensity. However, based on Figures 5 and 6, this was not the case. As expected, the 50-watt bulb produced the smallest amount of current and voltage for a given intensity. There is no reason it should have performed any differently. It puts out the same wavelength and frequency as the other bulbs, but with a smaller amplitude. We hypothesized that the 150-Watt bulb would produce the highest readings, because it has the largest wattage. However, the results show that the 65-Watt bulb outperformed the other two as seen in Figure 5. This was a bit of a surprise, but there is an explanation. When testing the 150-watt bulb, all of the groups experienced the same phenomenon. After about five minutes of continuously being exposed to the light, the solar cell began to give inconsistent and nonsensical readings on the voltmeter. This is presumably because the light was radiating a large amount of heat, affecting the cell to the point that it did not function properly. This problem forced us to turn the light off for a few minutes between readings to allow everything to cool down, as well as prompted us to move the bulb slightly further away from the solar cell to reduce the effect of the heat. It also provides a valid, two-part explanation for why the most powerful bulb does not produce the highest readings. First, the fact that the bulb had to be moved farther away from the cell certainly reduces its output, because light decreases in intensity as it travels away from its source. Moreover, there was the factor of the radiated heat. Even though no readings were taken until the setup had been allowed to completely cool down, the bulb began radiating heat immediately upon being turned back on. This meant that all of the readings were taken under some exposure to heat. As we will discuss later, solar cells do not perform as well when they are heated. This explains why the 65-Watt bulb gave the highest readings. It was weak enough that it could be placed close to the cell without overheating it, allowing the solar cell to perform optimally.

Testing Environmental Factors

For the third part of our experiment, our team researched and attempted to mimic the conditions that solar cells encounter in space. The first condition that we tested was extreme cold. The closest we could approach to the 3 Kelvin that is experienced in space was to expose the cells to liquid nitrogen, which is about 70 Kelvin. We received contradictory results with the two cells tested in liquid nitrogen, as shown in Figures 7 through 10. Cell A showed a large increase in output after being exposed to liquid nitrogen. After the first exposure, the cell's maximum output more than doubled from the baseline. The second exposure further increased the cell's output. However, after the third and fourth exposures the cell's, output began to decrease. After the fourth exposure, the cell performed about as well as it did after the first exposure. It is possible that this decline is due to deterioration of the cell from excessive freezing or from the handling of the cell between trials. While Cell A performed better after being frozen, Cell B showed a significant drop in output compared to its baseline as shown in Figures 9 and 10. However, consecutive exposures slightly increased the cell's output. The decline in the performance of Cell B could be due to invisible flaws in the cell that were created or exacerbated by the exposures. Moreover, the handling between trials could have resulted in an unseen crack or flaw that resulted in the cell that was not functioning properly. Interestingly, when we looked at the images from the SEM, there was a clear difference in the surface structure of the cell. Before exposure, there were visible striations all along the surface of the cell as seen in Figure 15-a. However, after being exposed to liquid nitrogen, these striations seemed to disappear, as seen in Figures 15-b and 15-c. We do not know the direct repercussions of this change in structure, but we do know that the freezing temperatures do change the surface structure of the cell in some physical way. Additionally, each cell can be considered unique due to the inconsistency of the doping of the solar cells. Therefore, it is plausible that the different compositions of the cells caused dissimilar results. Further testing should be conducted to determine more clearly the effects of liquid nitrogen immersion on the solar cell output.

As depicted in Figure 15-a, the intact solar cell is seen with distinct striations running across the entire body of the cell. The striations are all uniform and clearly visible at as low as 1000x magnification. First, the changes in the surface structure of the solar cell after immersing it in liquid nitrogen were observed. In contrast to the clear striations on the surface of the normal solar cells, the cells that were frozen in liquid nitrogen had a much smoother amorphous surface, and the striations eventually disappeared from the cell. It is possible that by removing the imperfections, freezing the cell allowed it to output more electricity.

While much of outer space is dominated by freezing temperatures, it is also possible to encounter extraordinarily hot temperatures when directly exposed to the sun's rays. Thus, we decided to test the effect of heat on solar cells' performance. Unlike the results obtained from freezing the solar cells, the data obtained after heating them, as displayed in Figures 11 and 12, clearly showed that their performance declined. Before putting the two solar cells into the oven, there was no observable damage to either cell. After heating the two cells in the oven at 120°C, one cell seemed to survive with no apparent damage, while the other was completely broken in two. The data obtained from the unbroken cell after heating it to 120°C shows a clear decline in both voltage and current, further demonstrating the destructive effect of heat on solar cells. When we took voltage and current measurements for this cell after the second heating at 260°C, the voltmeter gave us fluctuating results. It is likely that damage to the solar cell produced the unstable results. As shown from both our results and the SEM photographs in Figures 16-a and 16-b, exposure to high temperatures both increases a solar cell's vulnerability to physical damage as well as takes away from its capacity to absorb light and convert it to energy. We can conclude that heat seemed to change the surface structure of the cell.

Looking at a solar cell that was baked in a toaster oven for 30 minutes, there are some major alterations in the SEM images. As a matter of fact, the entire physical structure of the cell has been deformed, with not a single striation present anywhere on the cell. Rather, there are abrasions, resembling rough ridges, covering the entire solar cell. The surface of the cell is jagged, covered with small irregularities, as depicted in Figure 16-b. In place of the striations, there are also a few, irregular grooves underlying the cell, clearly demonstrating how badly the heat deformed the physical surface of the solar cell, which could explain why the cell performed so poorly.

There is a lot of extraneous radiation in space. Radiation has the potential to affect the performance of a solar cell. Strontium-90 is a radioactive isotope with a half-life of 28.8 years. It is a product of nuclear fission (which occurs on the Sun) and is commonly found in radioactive waste and nuclear fallout. It undergoes beta (β^{-}) decay, which involves the emission of electrons replicating the conditions observed in space. In our experiment strontium-90 samples were left for 48 hours on a solar cell. After the 48 hours passed, the cell was then retested. The data in Figure 13 shows a slight increase in the efficiency of the radiated solar cell, and in Figure 14 the Current vs. Voltage curve of the radiated solar cell is steeper than the Current vs. Voltage curve of the baseline cell. While comparing the intensity with the voltage generated, the data showed that the voltage in the radiated cell was less than the same intensities in the baseline cell, up until 70% intensity, at which point the radiated cell generated more voltage. A possible cause of these changes is that the electrons from the beta decay penetrated the p-n junctions of the solar cell thus increasing the current, which in turn would enlarge the slope of the Current vs. Voltage curve. This means that there could be positive effects if a solar cell is exposed to radiation. We did not use the SEM to take a closer look at the cells exposed to radiation because any changes caused by the firing of electrons at the cells would be atomic in nature, and thus invisible to the SEM. Unfortunately, more extensive testing is necessary to determine more clearly the effects of the radiation.

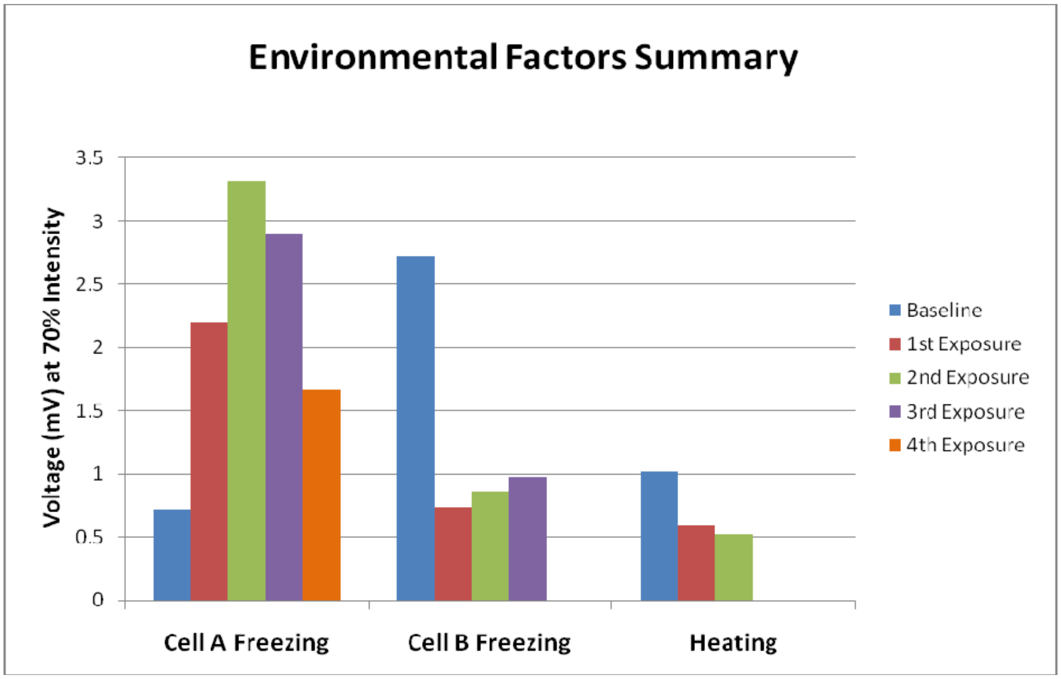

Figure 17 This graph shows our results for testing the environmental factors of freezing and heating.

Based on the data in Figure 17, both freezing and heating a solar cell significantly alters its performance. For Cell A, the first two exposures to liquid nitrogen produced spikes in the voltage values, and the two successive exposures slightly lowered the values, but never below the baseline. For Cell B, the first exposure resulted in a large decrease in voltage output, but the next two provided a slight boost from there, although the values never approached the initial value of the baseline. Obviously, even while these two cells underwent the same testing, they yielded almost opposite results. However, even while this data is contradictory, it is not useless. What we learn from this is that freezing the cells definitely affects their performance, and it is worthwhile to carry out more tests to determine exactly what that effect is.

For heating, the data paints a much clearer picture. Each exposure to the heat further reduces the voltage output, meaning that heat is detrimental to the performance of solar cells. This conclusion is verified by the fact that one of the cells exposed to heat was actually damaged so much that it could no longer be tested; while it provides us with no numerical data, it still contributes qualitatively to our conclusion. This too is an area where more testing should be carried out, because a solar cell is most often called upon to work in hot conditions, so improving performance under these conditions would be very beneficial for solar technology.

CONCLUSION

Since they are used as important power supplies in space, solar cells must be able to withstand harsh environmental conditions, including extremely high and low temperatures and radiation. In this project, the baseline was established by testing the solar cells under lights of different colors and wattages before the environmental factors were simulated on the cells. It was concluded that the blue light enabled the cells to produce the highest voltages and currents because it was most similar to sunlight. In addition, the 150-watt bulb was determined as the optimum light source to test solar cells because they produced the most voltage without harming the cells.

After they were tested under various types of light, the solar cells were placed in a toaster oven that simulates heat, liquid nitrogen that simulates cold, and strontium-90 that simulates radiation from beta decay. The experimental data produced varied results, which were elicited by the number of uncontrolled variables as well as the limited amount of data collected due to unpredicted damage in several cells. Despite some difficulties, the results allowed us to draw some important conclusions, providing a useful framework for future research. Only one solar cell survived the heating, and the data showed a definite decrease in cell performance. SEM images also showed the damage in the structure of heated solar cells, which indicated that high temperatures are detrimental to the operation of cells. On the other hand, the majority of the data from the solar cells immersed in cold liquid nitrogen suggested that the cell performs better in low temperatures. The SEM images show that the cell undergoes a change which might be a factor in the improved performance of the cell. Based on the changed performance of the cells after being exposed to strontium-90, it was concluded that radiation also influences solar cells in certain ways. The difference between the Current vs. Voltage curve of the baseline and the radiated cell indicated that radiation did have some effect on the performance of the cells, though data was insufficient to determine the details of the influence of radiation. In the future, research could focus on gaining a better understanding of how radiation actually affects these solar cells and having more trials under different temperatures in order to verify our conclusions. Through several trials and errors, this project produced fundamental data for future research on the performance of solar cells in space environments.

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