

## **Fabrication and characterization of cuprous oxide coated solar cell**

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### **ABSTRACT**

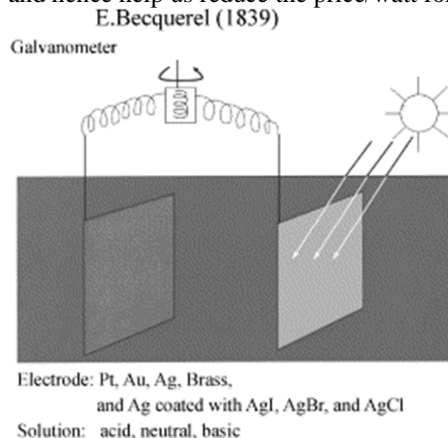
*Photovoltaic implies converting photon energy into an electric current using photovoltaic effect. A solar cell or photovoltaic cell is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect. Solar cells are the building blocks of photovoltaic modules known as solar panels. It can appear yellow or red depending on the size of the particles. Cuprous oxide ( $\text{Cu}_2\text{O}$ ) as an attractive semi-conductor material used as anode material in thin film lithium batteries and as solar cells. In our research, we used plastic as the cavity material and ocean water as salt solution (electrolyte). We performed our experiment first with pure water and then with salt water and compared the results. Distilled water was used for this purpose, and then regular table salt ( $\text{NaCl}$ ) was added to it to prepare the salt water solution. After comparing the results obtained we discovered that salt water was a better electrolyte. Hence, we used the aqueous sodium chloride ( $\text{NaCl}$ ) solution as the salt water electrolyte for our cell. Different concentrations of this solution were used and corresponding results were observed and recorded. The goal of this project work was to produce alternate solar cells made from cheap materials. We have succeeded in designing and testing alternative ionic solar cells that could serve as a model for a new solar cell. It consists of a PN junction made of Copper I and Copper (II) Oxide along with ionic salt water ( $\text{NaCl}$ ) solution*

### **INTRODUCTION**

Solar power involves the generation of electricity using the photon energy of the sun. This power can either be generated using the photovoltaic effect or indirectly using concentrated solar power. Photovoltaic implies converting photon energy into an electric current using photovoltaic effect, [1]. A solar cell or photovoltaic cell is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect which is a physical and chemical phenomenon. Solar cells are the building blocks of photovoltaic modules known as solar panels, [2]. Cuprous oxide is an inorganic compound. Its formula is  $\text{Cu}_2\text{O}$ . It can appear yellow or red depending on the size of the particles [3]. Copper oxide is one of the first photovoltaic cells invented, [4]. Cuprous oxide ( $\text{Cu}_2\text{O}$ ) as an attractive semi-conductor material could be used as anode material in thin film lithium batteries, [5] and as solar cells, [6, 7, 8,9]. In 1839, Edward Becquerel discovered its semiconductor properties and photovoltaic effect. Cuprous oxide is a p-type semiconductor with direct band gap of 2.0-2.2eV., [10]. This made it suitable for photovoltaic conversion. The band gap of nanocrystalline  $\text{Cu}_2\text{O}$  thin film is 2.06eV and the deposited  $\text{Cu}_2\text{O}$  exhibit a direct band gap of 2.0eV and shows an n-type behavior when used in a liquid/solid junction, [11]. Cuprous oxide attract much interest due to its high optical absorption coefficient in the visible region and its relatively good electrical properties [7]. Cuprous oxide in the form of nano particles has all the benefits offered by nano technology [12, 13].

**1.2 Copper oxide coated on copper electrodes**

Here, we used Becquerel model of 1839. In our setup we designed a solar cell that uses materials which are found abundantly in nature and that would eliminate the need for expensive semiconductor materials (such as doped silicon and germanium crystals, etc.) and hence help us reduce the price/watt for our cell.



**Figure 1.1: A.E Becquerel's cell apparatus**

In our research, we used plastic as the cavity material and ocean water as salt solution (electrolyte). We performed our experiment first with pure water and then with salt water and compared the results. Distilled water was used for this purpose, and then regular table salt (NaCl) was added to it to prepare the salt water solution. After comparing the results obtained we discovered that salt water was a better electrolyte. Hence, we used the aqueous sodium chloride (NaCl) solution as the salt water electrolyte for our cell. Different concentrations of this solution were used and corresponding results were observed and recorded. Thus, the following calculations were made to achieve salt water solution of concentrations 3.5% and 35%

Sodium	23.00g (Molecular Weight)
Chlorine	35.50g (Molecular Weight)
TOTAL	58.50g (NaCl)

To get 3.5% concentration of NaCl solution, we have,

$$\frac{3.5}{100} \times \frac{58.5}{1} = 2.0475\text{g of NaCl (dissolved in } 100\text{cm}^3 \text{ of water)}$$

For 35%, we have

$$\frac{35}{100} \times \frac{58.5}{1} = 20.475\text{g of NaCl (dissolved in } 100\text{cm}^3 \text{ of water)}$$

To constitute 2000cm<sup>3</sup> of the above solution,

$$\begin{array}{l} 2.0475\text{g} \\ X \end{array} \begin{array}{l} \longrightarrow \\ \longrightarrow \end{array} \begin{array}{l} 100\text{cm}^3 \\ 2000\text{cm}^3 \end{array}$$

$$\begin{aligned} X &= \frac{2.0475 \times 2000}{100} \\ &= 40.95\text{g of NaCl (dissolved in } 2000\text{cm}^3 \text{ Of water)} \end{aligned}$$

And,

$$\begin{array}{l} 20.475\text{g} \\ Y \end{array} \begin{array}{l} \longrightarrow \\ \longrightarrow \end{array} \begin{array}{l} 100\text{cm}^3 \\ 2000\text{cm}^3 \end{array}$$

$$\begin{aligned} Y &= \frac{20.475 \times 2000}{100} \\ &= 409.5\text{g of NaCl (dissolved in } 2000\text{cm}^3 \text{ of water)} \end{aligned}$$

We used copper as electrodes. Experiment was conducted to see whether the size of the electrodes had any effect on the produced potential difference or not. It was observed that the surface area of the electrodes was directly

proportional to the electric power produced. Hankel's experiments of 1877 suggested that one of the electrodes is of pure copper and the other of a uniform coating of cuprous oxide on top of it. The oxide layer, when coupled with the metal itself, helped in creating a P-N junction. This circumstance created a rectifier effect in the design, and facilitated the flow of electrons through the electrolyte and between the two electrodes.

We applied large amount of heat to the copper plate to create the oxide layer on the copper electrode. For that purpose, this copper plate was heated in a hot plate at a thermocouple temperature of about  $700^{\circ}\text{C}$  for almost an hour. The plate required oxygen from the air in order to get oxidized while it was being heated. At the end of this heat treatment, a reddish-brown layer of cuprous oxide ( $\text{Cu}_2\text{O}$ ) with some black patches of cupric oxide ( $\text{CuO}$ ), was clearly observed on the plate. This showed that the copper on the surface had been oxidized to either one of the two copper oxides, and the plate was ready to be used as an electrode in our cell. For the second electrode, we used pure copper plate. The mesh was chosen to be the electrode instead of a regular plate in order to maximize the light-exposed surface area of the metal in the electrolyte. We had determined in our initial experiment that a greater surface area for the electrodes lead to a greater output power, and this was the main reason why we used the copper mesh as the second electrode.

In our experiment, a 500W incandescent light bulb was used as the external light source, at a certain distance from the container. Its spectrum approximately approaches the spectrum of the sun light. The bulb was mounted on a tripod stand so that it was easier to shine it down on our solar cell. A multimeter was used to measure voltage and current values that we generated. The connection is shown on figure 1.1.

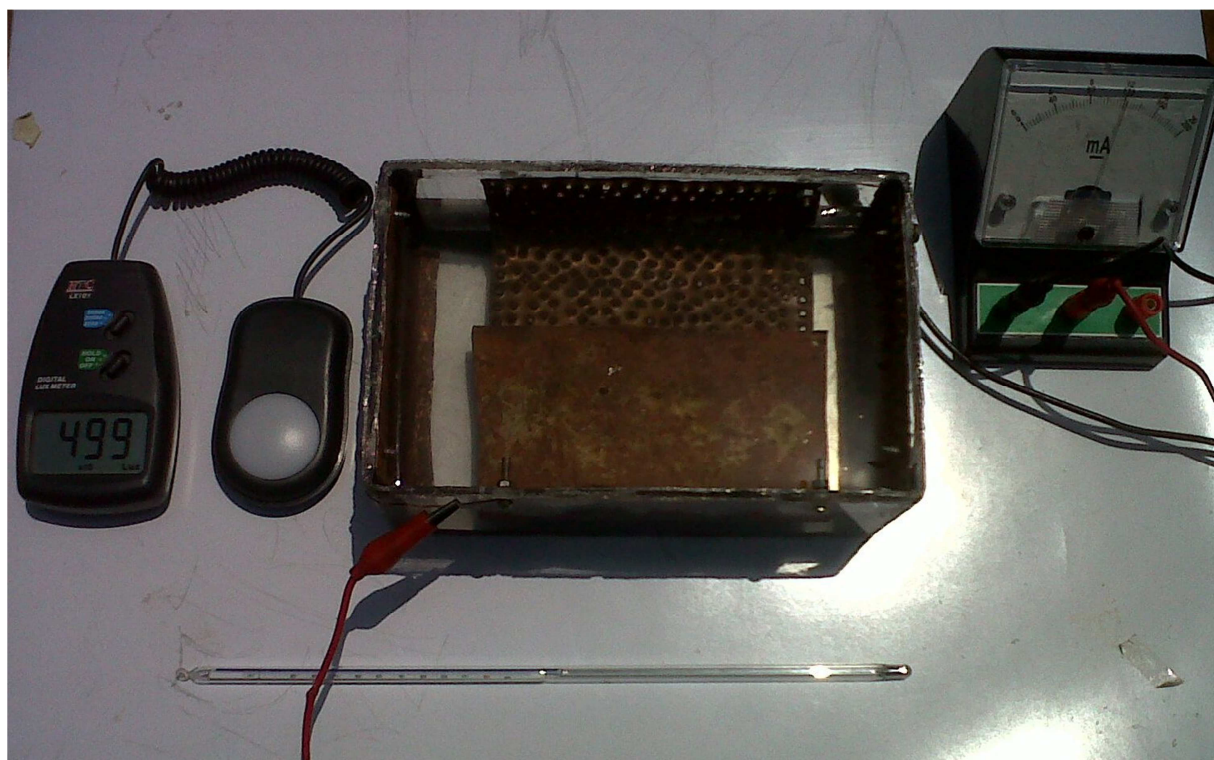


Figure 1.1: Photograph of the set up

We connected our probes to the electrodes and filled up the container with the different electrolytes. When we used distilled water as the electrolyte for our system in the absence light to the setup, a  $15\text{mV}$  voltage was produced between the two electrodes. This was because the copper plates and the distilled water together formed a capacitor in which the electrodes were initially charged statically. When light was applied to one of the electrodes from our 500W light bulb, the voltage reading on the multimeter changed to  $-30\text{mV}$ . This meant that a total potential difference of  $45\text{mV}$  was being produced when we had the distilled water as our electrolyte. When we conducted our

experiment using salt solution. The electricity produced by the setup depended on the concentration (salinity) of the ionic salt solution and on the intensity of light.

### 1.3 3.5% NaCl SOLUTION

The concentration of the salt in our electrolyte was first changed keeping all the other factors constant. A light intensity meter was used to keep our 500W bulb at a distance that resulted in 500lux of intensity. This is the average light intensity that reaches the Earth's surface every day.

Figure 1.1 below shows the graph of voltage versus time when the 500W light bulb was switched on and the solution was not stirred. When the light was off, a constant voltage of approximately 14 mV (milli-Volts) resulted. The spike in voltage to about 92 mV was observed when the light was turned on. It was also noticed that shortly after reaching the peak, the voltage decreased gradually to reach a constant value of 80 mV. The current versus time graph is shown in Figure 1.2. When the light was off, a constant current of 100  $\mu$ A (micro-amperes) was observed using LabView SignalExpress. The light caused a spike in current of 3.8 mA (mili-amperes) and as it stayed on, the current gradually stabilized following an exponential law.

The current and voltage generated prior to the light were due to a few reasons. The positive and negative ions in the salt solution acted as charge carriers to conduct charge between the negative and positive copper surfaces. The water acted as a capacitance dielectric and separated charges that are accumulated on the two separate plates. This showed the voltage observed while the bulb was off. Furthermore, the concentration of 3.5% matches the approximate 3.5% salinity of ocean water. This concentration was chosen to meet our goal to simulate copper electrodes in ocean water for the generation of power.

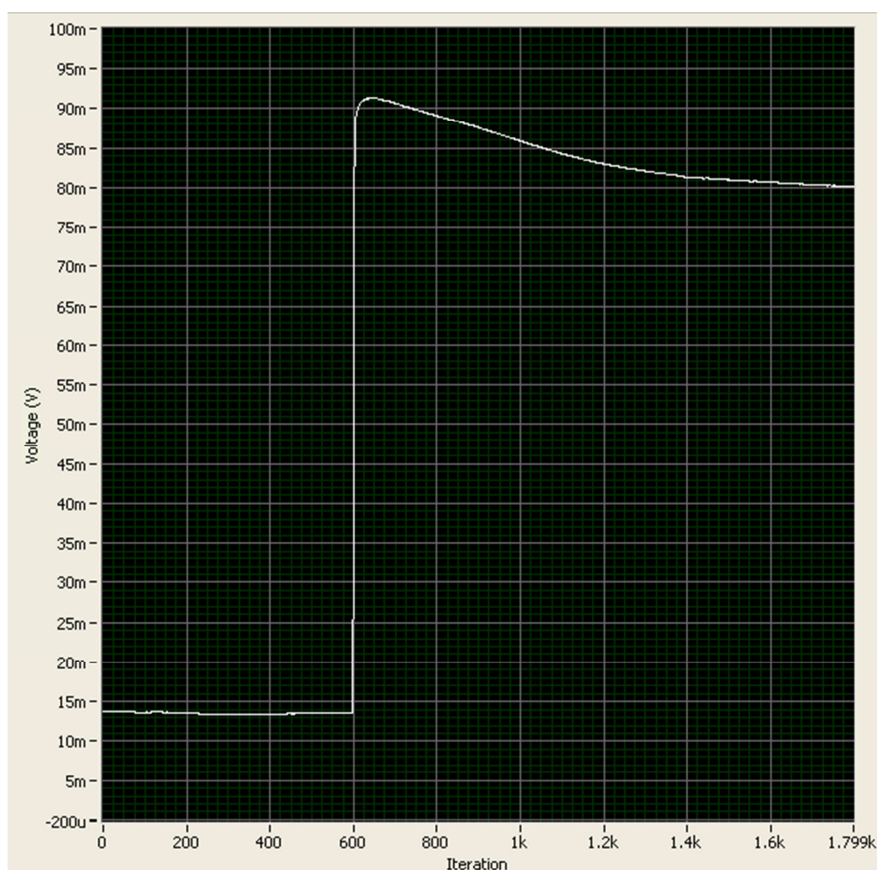


Figure 1.1: Graph of Voltage (V) vs Time (milliseconds; 1.4k=1.4seconds) with 3.5 % solution

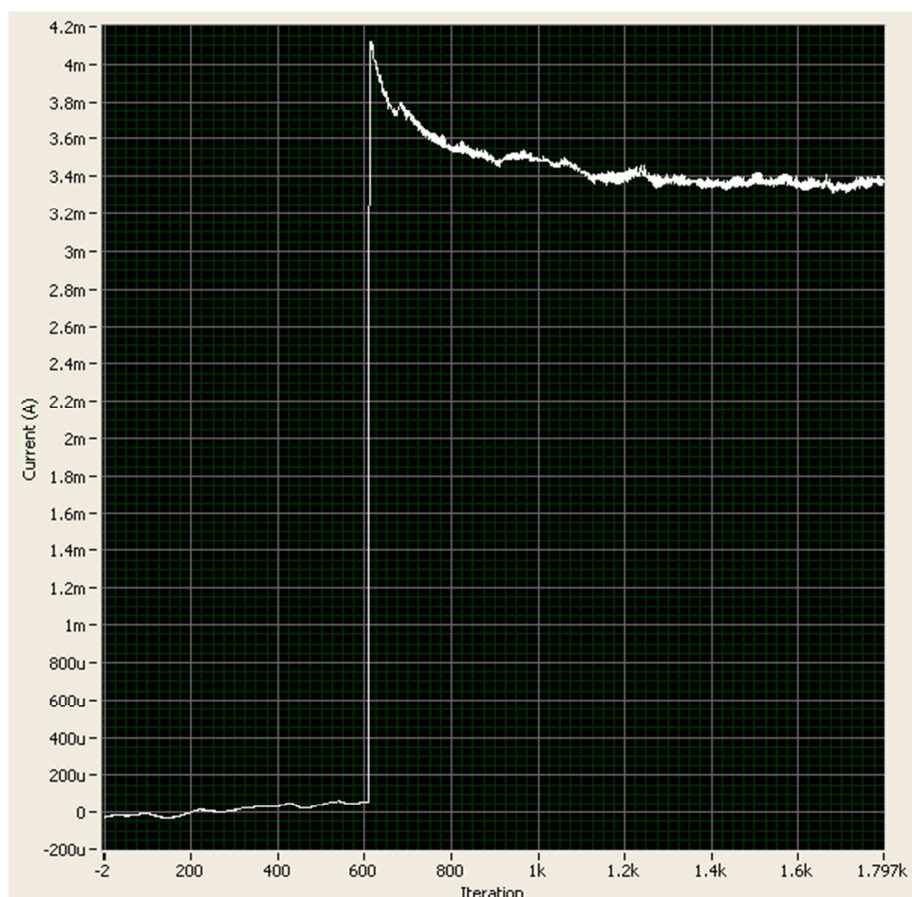


Figure 1.2: Graph of Current (A) vs Time (milliseconds; 1.4k=1.4seconds) with 3.5 % solution

#### 1.4 35% NaCl Solution

The concentration of the solution was changed to 35% by mass of NaCl. The solution was stirred well to allow the salt to dissolve and not saturate the solution. The same procedure was conducted to measure the voltage and current generated. The two graphs of voltage and current versus time can be seen in Figures 1.3 and 1.4 respectively. The voltage jump was from 162 mV to 210 mV. Note that even if the change is only 48 mV, the overall magnitude of the voltage has been more than double with an increased concentration and can be harnessed. Also, the initial peak current of 3.7 mA increased to 7.5 mA. This increase of 3.8 mA was observed and was close to the increase in the 3.5 % solution. The major differences can be seen in the profile of the curves. The voltage was increasing linearly when the light was off. There was a vertical spike and then a gradual increase (instead of a decrease as was the case with the 3.5% solution). The current profiles are also different. The 35 % solution creates a constant current before and after the spike, unlike the results for the 3.5 % solution.

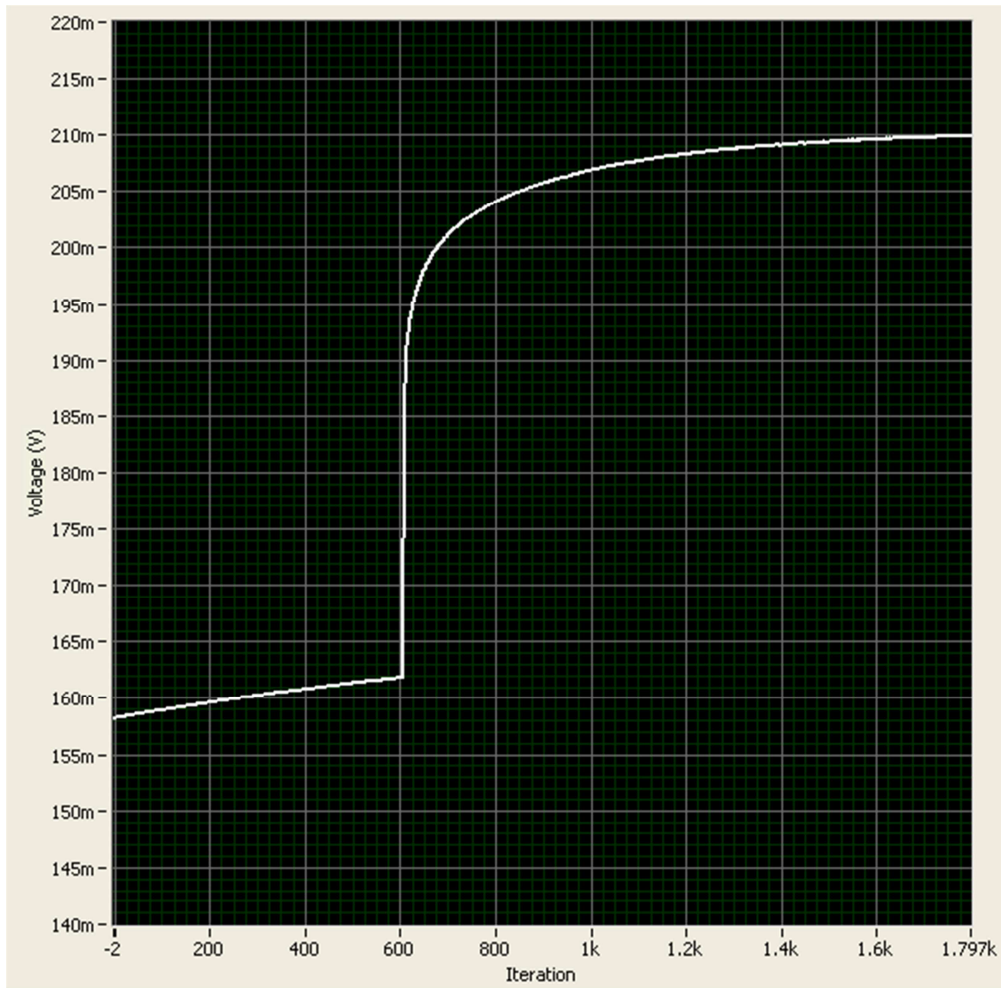


Figure 1.3: Graph of Voltage (V) vs Time (milliseconds; 1.4k=1.4seconds) with 35 % solution

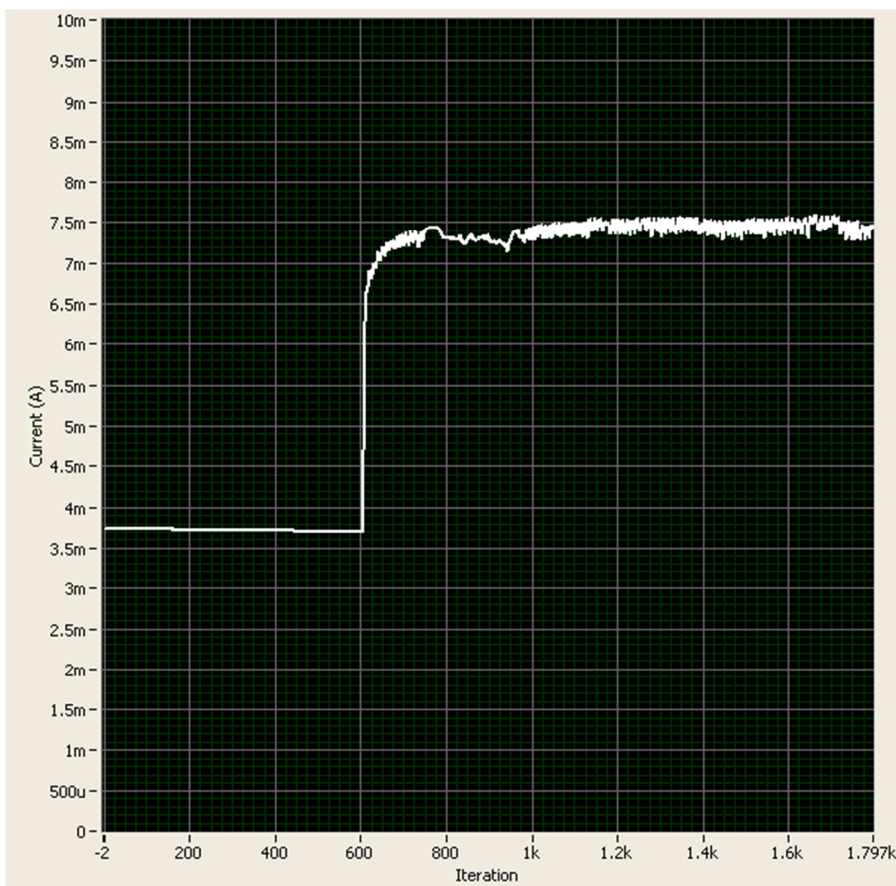
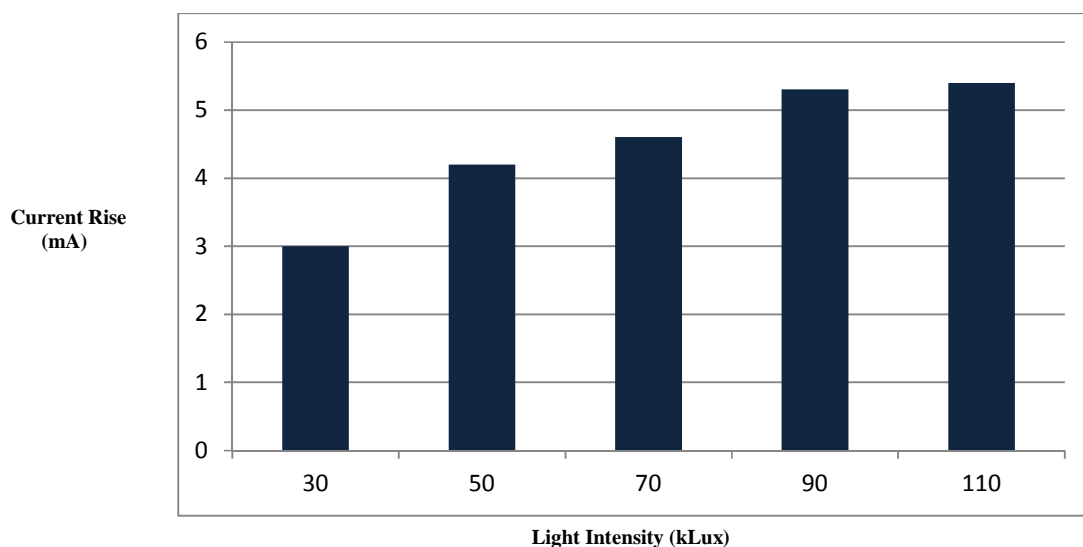


Figure 1.4: Graph of Current (A) vs Time (milliseconds; 1.4k=1.4seconds) with 35 % solution

Table 1.1: SUMMARY OF OUR EXPERIMENTAL RESULTS

Solution Concentration	Current Analysis			Voltage Analysis		
	Initial Current(mA)	Final Current(mA)	Current Rise(mA)	Initial Voltage(mV)	Final Voltage(mV)	Voltage Rise(mV)
3.5%	0	4.1	4.1	14	92	78
35%	3.7	7.5	3.8	162	210	48

**CURRENT VERSUS LIGHT INTENSITY**

**Figure 1.5. Current Rise (mA) vs Light Intensity (Klux)**

The effect of light intensity on the current was tested using a Lux meter to measure the light intensity of the 500 W light bulb. The light sensor was placed at the surface of our solar cell and the light bulb was moved towards or away to obtain the desired intensity in klux (kilo-lux).

Figure 1.5, above shows a bar chart of current in milli-amperes for different light intensities. The concentration of the solution was also set at a constant 3.5 % NaCl for varying intensities.

Intensities in increments of 20 klux were tested and the current increased until it reached 90 klux.

Further increasing the intensity i.e. moving the light bulb very close to the solar cell did not show a raise in current. The current stayed constant instead. Hence, the 90 klux flux acts as threshold intensity for the 3.5 % salt solution.

**CONCLUSION**

Our experiments proved to yield results that were higher than most experiments achieved. In some experiments, the current generated was 50 microamperes at 0.25 Volts. Our light intensities represented the average solar intensity that the Earth's surface receives every day. The goal of this project work was to produce alternate solar cells made from cheap materials. We have succeeded in designing and testing alternative ionic solar cells that could serve as a model for a new solar cell. It consists of a PN junction made of Copper I and Copper (II) Oxide along with ionic salt water (NaCl) solution.

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