



***A Comparative Study of Mono-Crystalline and Poly-Crystalline Silicon Solar Cells under Different Climatic Conditions of Bangladesh.***

**A Thesis submitted to the**

**Department of Electrical & Electronic Engineering, BRAC University**

**In partial fulfillment of the requirements for the**

**Bachelor of Science degree in Electrical and Electronic Engineering**

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***Declaration:***

We hereby declare that this thesis titled “ Performance analysis of mono-crystalline and polycrystalline silicon solar cells under different climatic conditions: A comparative analysis” and the work presented in it and submitted to the Department of Electrical and Electronics Engineering of BRAC University is our own and has been generated by us as the result of our own original research. It was not submitted elsewhere for the award of any other degree or any other publication.

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## **ABSTRACT**

The objective of our thesis is to analyze the performance of two types of silicon solar panels- mono-crystalline and polycrystalline under different climatic conditions of Bangladesh. Temperature, wind speed, solar irradiation affects the performance of solar panel. In our work different parameters of the solar cells such as open circuit voltage, short circuit current, series resistance of a photovoltaic cell, maximum power output point, fill factor, maximum working current, and maximum working voltage have been calculated under different temperature and illumination conditions. Experiments have been conducted in both indoor and outdoor. Series resistance was measured in dark condition. It showed an increase in series resistance for both mono-crystalline and polycrystalline solar panel with the increment of temperature. Current sensitivity of the panels was measured with the change of temperature under same illumination condition. Energy was calculated utilizing the data taken in the month of June-July. It was observed that polycrystalline panel has 4.3% energy level more than the mono crystalline panel.

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# CHAPTER 1

## INTRODUCTION

### **1.1 Background:**

Solar energy a gift from the nature provided by our very own Solar System's sun which is abundantly available and clean. For domestic and industrial applications the heat, light, electricity etc., are provided by the solar technologies. With the concerned depletion of the major conventional energy resources such as Coal, Petroleum and Natural gas, coupled with the environmental degradation caused by the process of harnessing these energy sources, it has become an important sector to invest in renewable energy resources that would power the future sufficiently without polluting the environment through greenhouse gas emission. The Sun's energy potential is immense, but despite this endless solar energy resource, collecting it is a challenge mainly due to the limited efficiency of the array cells. The best conversion efficiency of most commercially available solar cells is in the range 10-20% [1]. The recent discovery and development in the technology of solar cells shows significant improvement but the fact that the maximum solar cell efficiency still yet to meet expectations for which more and more researches need to be carried out and some are still ongoing projects are going on for the improvement of efficiency of Solar energy.

Renewable Energy natural source of energy which keeps on replenished naturally in a regular time cycle like hydro power, solar energy, wind energy, tidal energy, and biomass fuels etc. At present the demand for energy is increasing day by day in Bangladesh due to various reasons such as increasing population, the desire for improving the living standard and general economic and industrial growth. The power generation system is principally depended on imported petroleum oil and own natural gas. On the other hand, as the information about the deposits of fossil fuels in Bangladesh, if they are consumed at the present rate, the reversed natural gas and coal will deplete by the year 2020 to 2030 according to BPDB. Sustainable social and economic development depends on ability of power generation capacity of a country. There is no other way for accelerating development except to increase the power generation by fuel diversification. Development of Renewable Energy is one of the important strategies adopted as part of fuel and natural gas diversification.

Therefore, the renewable energy can contribute to the delivery of alternative energy to the users which also comes as cheap as possible and probably the key issue for technological inventions in solving energy problems in the rural areas.

Both indoor and outdoor experiments has been performed in a controlled environmental factors for indoors and for outdoors most important factors was not possible to control during day time with temperature and illumination, obtaining the relationship of the panel parameters.

## **1.2 Motivation**

Power crisis a major issue the world is trying to deal with. All the traditional power energy sources like fossil fuel are becoming limited day by day and also expensive too. So, the solution is alternative source of energy that is solar energy which is clean and emission free. Solar energy is plentiful and has greatest availability compared to other energy sources.

Bangladesh is a developing country and for the growth and advancement energy and power is essential. A poor country like Bangladesh the power or energy should be cost effective. Solar is the solution of this not only that the rural and remote areas where there is still no electricity solar can be the solar is blessings for then. Due to the geographical location of our country, we get sun approximately 300 days a year. Compared to many other countries like many parts of Russia, Canada, Sweden and Norway, we are in a much better location for proper utilizing solar energy.

Considering economical, environmental and easier implementation, we were motivated to working on it. We strongly believe that in the coming future, Bangladesh and other countries will be benefited from the solar energy and other renewable sources of energy.

## **1.3 Scope of work**

This thesis work represents the variation or relationship between parameters, that is  $I_{sc}$  (short circuit current),  $V_{oc}$  (open circuit voltage),  $R_s$  (series resistance), and  $P_{max}$  (maximum power output) of the two types of solar cell, with temperature and illumination. Multimeter has been used to measure the temperature, Voltage and current of both the panels which was recorded using video camera for all parameters at a time. RTC circuits keeps the track of the real time



and date of the measured data and relay is used for switching purpose, for taking data between the two panels respectively within a given time interval. Analysis has been done by MATLAB simulation after getting the curves obtained from the experimental data which eventually help us to come up with conclusion after comprises.

#### **1.4 Thesis organization:**

This thesis is organized and arranged in such a way or order in, so that everyone can understand it easily that is why the simplest explanations and experiments are described and explained using short summary at start, and then eventually we move towards the important factors that needs to be explained. Calculations from the environment or the factors or parameters are well elaborated, before approaching towards modeling of the PV cell. Basic properties and theories of the solar cell are described well enough, from there we come out with the procedure of caring out the indoor analysis, and the experiments are explained step by step along including diagrams. The content of the chapters in this paper are explained below:

##### **1.4.1 Basic theory of solar cell:**

This chapter basically discuss about the structure, operation of a solar cell, including the properties, characteristics and differences between mono-crystalline and poly-crystalline silicon solar cells. The discussion is followed by the explanation of the existing simple electrical model of a solar cell.

##### **1.4.2 Experimental result and analysis.**

The chapter starts with a brief introduction of the indoors and out door experiment and how the system is used to examine several parameters of the solar panel. The block diagrams, along with the circuit setup diagram, explain the experiments conducted. The results are described by the graphs obtained from the MATLAB simulation of the experimental data. This chapter basically gives the overview, how the various parameters ( $I_{sc}$ ,  $V_{oc}$ ,  $P_{max}$ , and  $R_s$ ) behave when temperature changes, and we also calculated the value of the ideality factor of the panel's indoor and outdoor conditions. All these values played a vital role in our

analytical calculation of the energy extracted from the panels.

### **1.4.3 Economic and future**

We have discussed about economical prospective and future work that can be done in larger scale using the data.

### **1.4.4 Conclusion:**

The last chapter discuss about the efficient output from the solar cell that varies with season according to the climatic condition of Dhaka city, and later gives an conclusion on the works we have done up to date.

## CHAPTER 2

### Background and overview

#### 2.1 Introduction

In 1839 Becquerel first discovered that sunlight could be converted directly into electricity, when he observed the photo galvanic effect. But the first solar cell, was developed by Chapin, Fuller and Pearson, revealed in 1954. It had an efficiency of 6% only. In 1956, the invention of 10% efficient silicon solar cell was discovered. Only two years later, the first solar cells were used on the Vanguard I orbiting satellite. Since then, the use of solar electricity (also known as photovoltaic) is going on increasing year by year and some have been in continuous outdoor operation on Earth or in space for over 30 years.

#### 2.2 Solar cell



Figure-the crystalline silicon based solar cell

Solar cell like the crystalline silicon based solar cell shown in above is a solid state semiconductor p-n junction device that converts sunlight into direct-current electricity through the principle of photo-voltaic effect. The first conventional photovoltaic cells were produced in the late 1950s, and were principally deployed to provide electrical power for orbital satellites. During this initial deployment, excessive cost of manufacturing and poor

efficiency of solar modules were some of the major challenges that limit their competitiveness as a major source for meeting the increasing energy demand that has continued till now. However, recent improvements in design, manufacturing, performance, reduced cost and quality of solar cells and modules have not only opened up the doors for their deployments in applications like powering remote terrestrial applications, rural electrification projects, battery charging for navigational aids, water pumping, telecommunications equipment and critical military installations, but has also propelled solar power system as a competitive means to meeting the ever increasing power need for the world economy.

### 2.3 P-N Junction

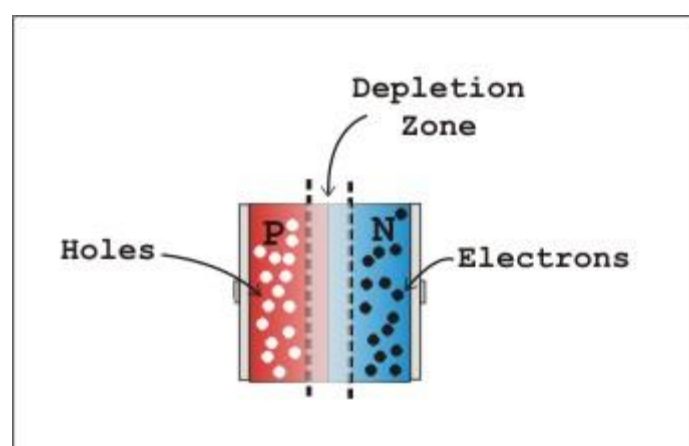


Figure- PN junction

Solar cell is simply a PN junction device, like a diode that is forward biased with a photo-voltage. Based on this simple definition, it's necessary to review how the PN-junction of a semiconductor diode functions. PN junction is formed when a P-type and an N-type semiconductors are interfaced together. The PN-Junction is the region or a boundary that is formed by doping or by epitaxial growth of a layer of crystal doped with one type of dopant on top of a layer of crystal. A dopant is a material (Impurity) that is purposely introduced or mixed into an extremely pure (Intrinsic or un-doped - Crystal Silicon for example) semiconductor material for the purpose of changing or optimizing its electrical properties for specific application. A dopant could be n-type or p-type material. Thus, a P-type Doping is the introduction of impurity atoms with one less valence electron- (Like Boron) than silicon

(acceptor impurities), resulting in excess positive charge carriers (holes). Whereas, an N-type doping is the introduction of impurity atoms with one more valence electron (like Phosphorous) than silicon (donor impurities), resulting in excess negative charge carriers (electrons).

## 2.4 Ideal Solar Cell

When a solar cell is illuminated by sun-light photons energy of the incident light is converted to direct current electricity through the process of photovoltaic effect of the solar cell. Incident light causes electron-hole pairs to be generated in the semiconductor and the concentration of minor electrons increases (electrons in the p-type region and holes in the n-type region) in the depletion region. This increase in the concentration of minority carriers results in the flow of the minority carriers across the depletion region into the quasi-neutral regions. These photo-generated carriers cause the flow of photo-generated current,  $I_{\text{photons}}$ . When the junction is in the open-circuit condition, no net current can flow inside the p-n junction, thus the current resulting from the flux of photo generated and thermally-generated carriers is balanced by the opposite recombination current.

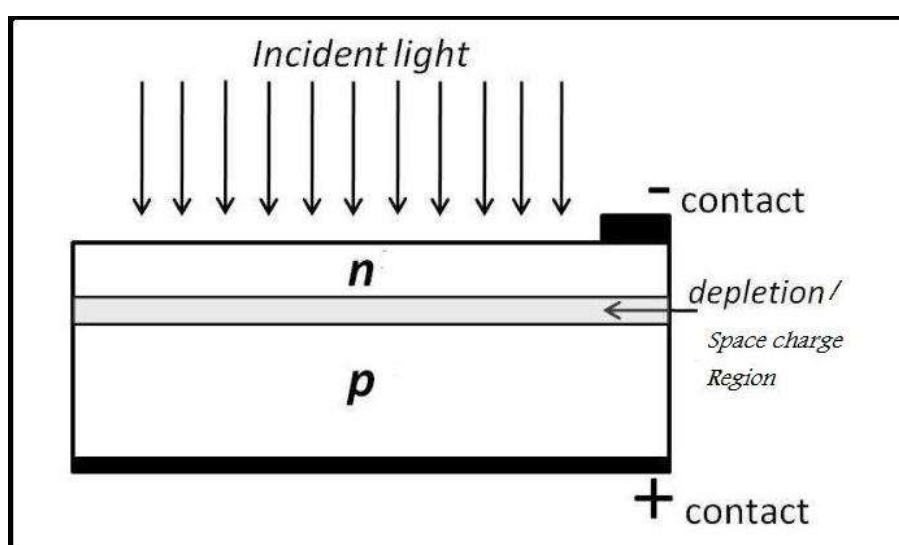


Figure- Solar cell is illuminated by sun-light

## 2.5 Material and structure of solar cell

Solar cells consist of a top and bottom metallic grid, which collect the diffused charge carriers and collect the cell to the load. A thin layer of anti-reflective coating covers the top side of the cell to decrease the reflection of light from the cell. To protect the cells from outer environment a glass sheet is spread above it. A variety of materials and processes can potentially satisfy the requirements for photovoltaic energy conversion, but in practice nearly all photovoltaic energy conversion uses semiconductor materials in the form of a  $p$ - $n$  junction.[2]

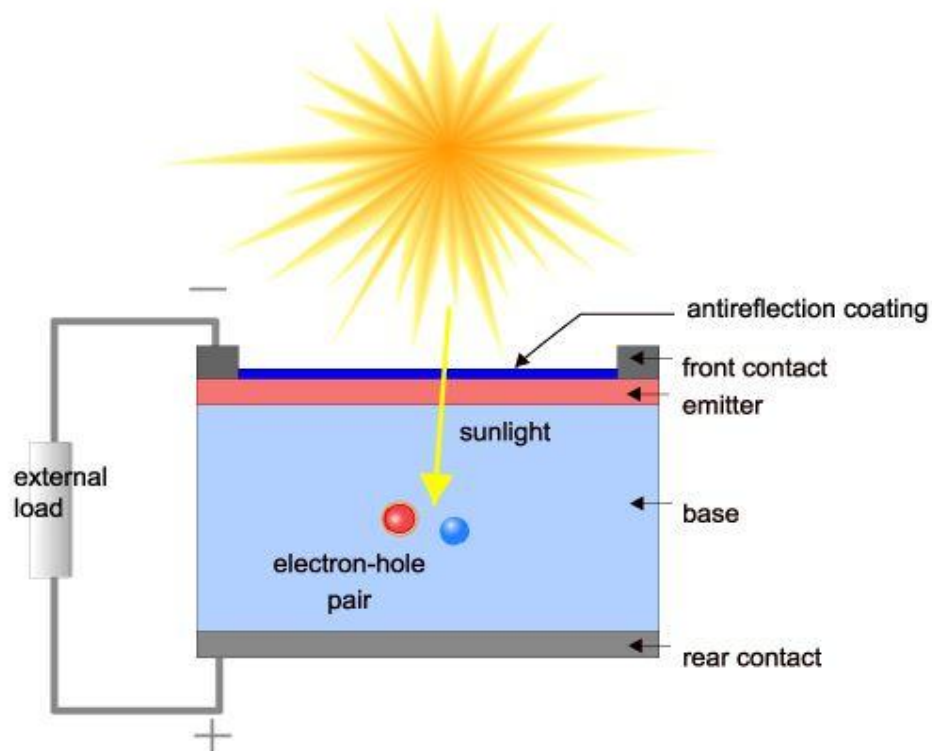


Figure 4-Structure of Solar Cell[2]

## **2.6 Types of Solar Cells**

Solar cells can be classified according to semiconductor materials of the cell, the crystalline structure of the material, and the number of junctions of the cell. There are any types of solar cells according to the crystalline structure of the material but our analysis was with only two types of solar cells. They are

1. Single-crystalline or mono crystalline cells.
2. Multi-crystalline or polycrystalline cells.

### **2.6.1 Mono-crystalline Solar cell**



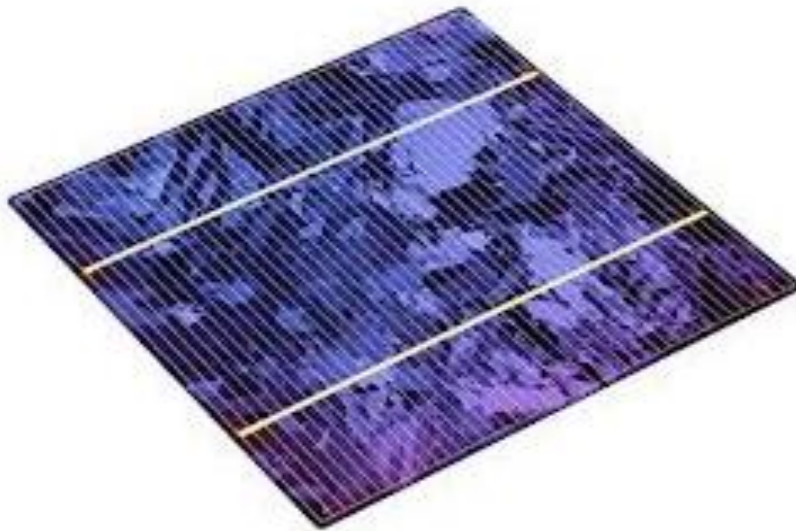
**Fig Mono-crystalline cells**

Mono-crystalline cells are the most important type, since they have the highest conversion efficiency, and the base material, Mono-crystalline solar cells are made from so-called single crystalline solar cells and easily recognizable from its color and its uniform look, is already well known in the field of semiconductor production. To achieve its highest possible performance and cost effective the four side of its cells are cut to make cylindrical. From which cylindrical wafers can be obtained. The wafers produced in this way, then, undergoes several production steps.

1. Grinding and cleaning
2. Doping
3. Metallization
4. Antireflection coating

### **2.6.2 Poly-crystalline CellsSolar cell**

Poly-crystalline solar cells are also known as multi-crystalline solar cells. The manufacturing process for mono-crystalline silicon is highly energy-intensive and also very expensive. Poly-Si develops, when a silicon melt is cooled down slowly and controlled. Poly-crystalline silicon are melted and poured into square mold, which is cooled and cut into perfectly square wafers. The wafers are not uniform for that they also differ in color deep and light blue.



**Figure-Poly-crystalline solar cells**



## 2.7 Ideality factor

The ideality factor is a measure of how closely the panel follows the ideal diode equation. The derivation of the simple diode equation uses certain assumption about the cell. In practice, there are second order effects so that the diode does not follow the simple diode equation and the ideality factor provides a way of describing them. In case of solar cells it follow as it is. Using practical data's we came up with lots of I-V characteristics curve which follows the ideality factoring.

Equation for n,

$$n = \frac{V_{oc2} - V_{oc1}}{V_t + \ln\left(\frac{I_{sc2}}{I_{sc1}}\right)}; V_t = \frac{KT}{q}$$

## 2.8 Declination angle calculation

We need to consider the **declination angle**. It can be elaborate as the angle of deviation along the sun directly above the equator,  $\delta$ . When we take direction in account if angles towards the north along the equator are considered to be positive and the south negative. At any given time of the year, n, the declination can be found from

$$\delta = 23.45^\circ \sin\left(\frac{360(n-80)}{365}\right)$$

Since the sun is directly overhead on the first day of summer at solar noon on the Tropic of Cancer. It can be describe in form of equation where  $\emptyset$  represents the latitude, or angular distance from the equator. Another parameter is zenith angle which becomes zero when the declination and the latitude are equal, this is only true at latitude during solar noon. This equation is mainly used to locate the position of the sun. So by using this equation we find the zenith angle.

$$\theta_z = \emptyset - \delta$$

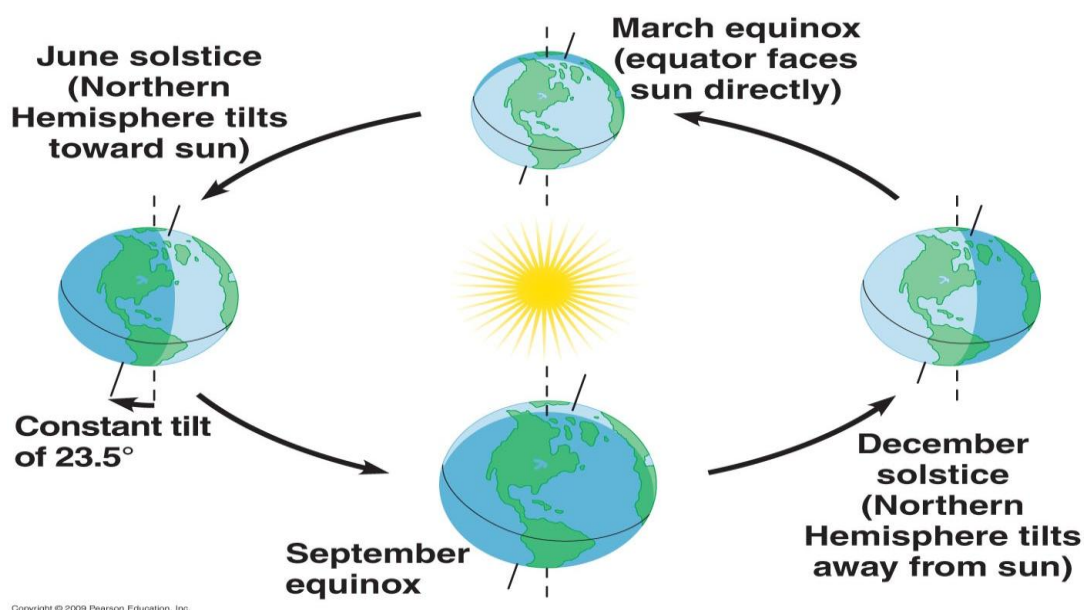
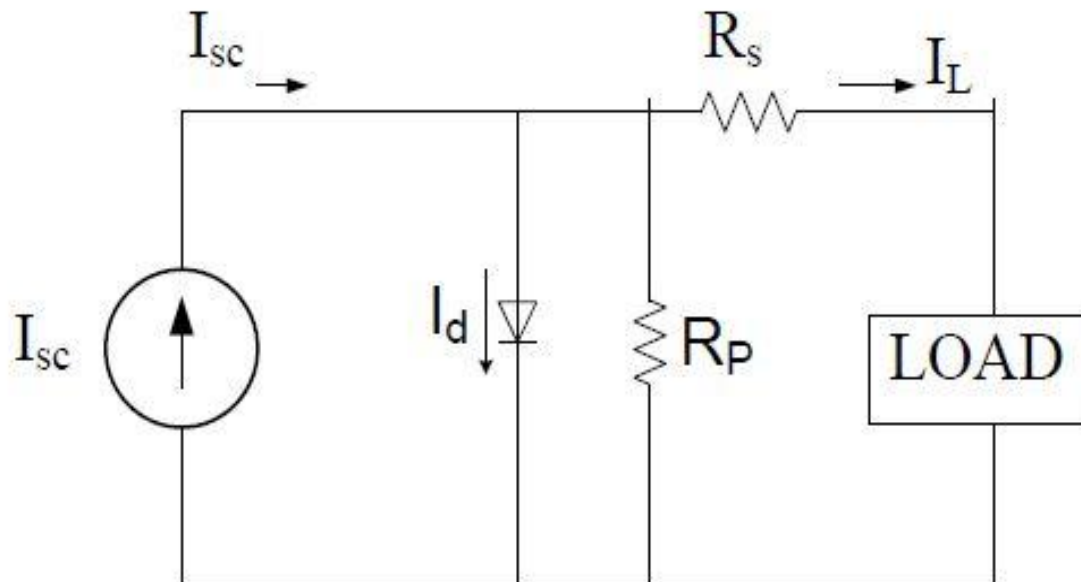


Figure-Orbit along equator

### **2.9 Difference between mono-crystalline and poly-crystalline silicon solar cell:**

When we compare mono-crystalline and poly-crystalline silicon solar cell, mono crystalline panel have a higher efficiency and are more available than poly silicon solar cells. Mono crystalline solar cells are covers less space than poly-crystalline for which they are space-efficient therefore they produces highest power output and takes least amount of space than the polycrystalline. Mono-crystalline panels are more expensive than polycrystalline and also have a higher heat tolerance. Mono crystalline panels have a longer life span when comparing with all other types of solar cells.

### 2.10 Electrical equivalent circuit:



**Figure-8**

The electrical equivalent circuit (Figure-8) of a solar panel. Where,

$I_{sc}$  = short circuit current

$I_o$  = reverse saturation current

$R_s$  = series resistance of the panel

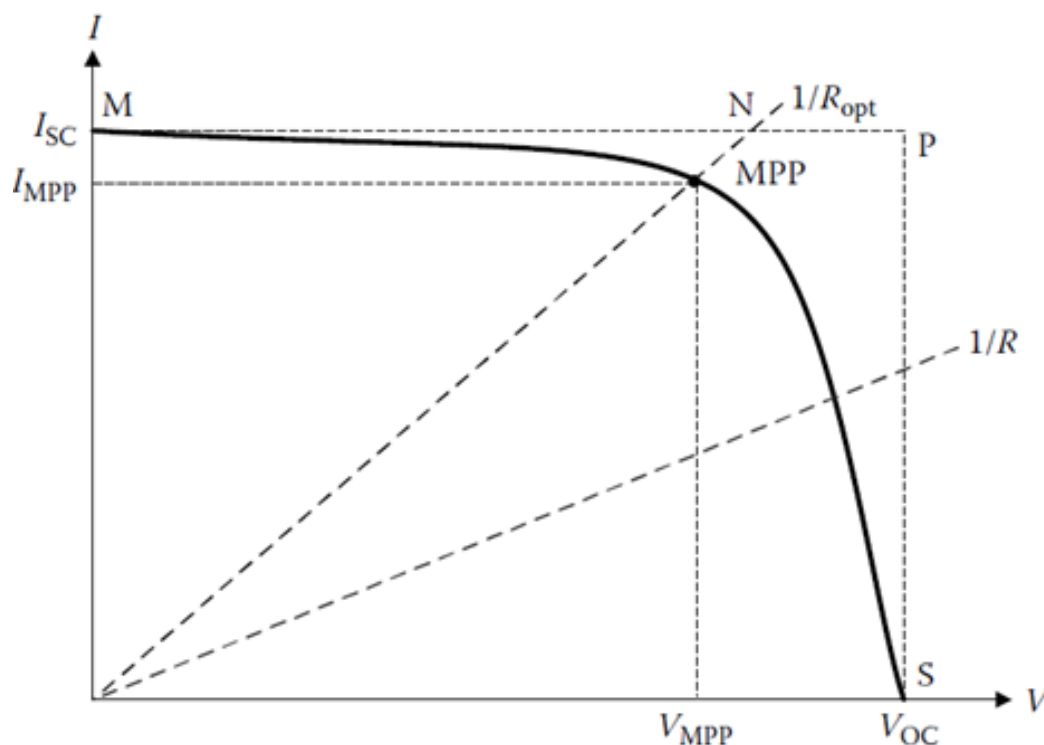
$R_p$  = parallel resistance of the panel

$V_t$  = thermal voltage       $I_d$  = Diode current =  $I_s(e^{qV_d/NKT} - 1)$

$n$  = ideality factor

$I_L$  = load current

## 2.11 I-V Characteristics



**Figure-9**

Current–voltage (I–V) curves are obtained by exposing the cell to a constant level of light, while maintaining a constant cell temperature, varying the resistance of the load, and measuring the produced current. The I–V curve typically passes through two points:

- **Short-circuit current ( $I_{SC}$ ):**  $I_{SC}$  is the current produced when the positive and negative terminals of the cell are short-circuited, and the voltage between the terminals is zero, which corresponds to zero load resistance.
- **Open-circuit voltage ( $V_{OC}$ ):**  $V_{OC}$  is the voltage across the positive and negative terminals under open-circuit conditions, when the current is zero, which corresponds to infinite load resistance.

The cell may be operated over a wide range of voltages and currents. By varying the load resistance from zero (a short circuit) to infinity (an open circuit), the MPP of the cell can be determined. On the I–V curve, the maximum power point (P<sub>m</sub>) occurs when the product of current and voltage is maximum. No power is produced at the short-circuit current with no voltage, or at the open-circuit voltage with no current. Therefore, MPP is somewhere between

these two points. Maximum power is generated at about the “knee” of the curve. This point represents the maximum efficiency of the solar device in converting sunlight into electricity.

If the cell’s terminals are connected to a variable resistance  $R$ , the operating point is determined by the intersection of the I–V characteristic of the solar cell and the load I–V characteristic curves. For a resistive load, the load characteristic is a straight line with a slope of  $I/V = 1/R$ . It should be pointed out that the power delivered to the load depends on the resistance value of the load. However, if the load resistance is small, the cell operates in the MN region of the curve, where the cell behaves as a constant current source, almost equal to the short-circuit current. On the other hand, if the load resistance is large, the cell operates on the PS region of the curve, where the cell behaves more similar to a constant voltage source, which is almost equal to the open-circuit voltage.

Fill Factor,  $FF = \frac{P_{max}}{V_{oc}I_{sc}}$

This factor is a measure of the real I–V characteristics. It is higher than 0.7 for cells in good condition. This factor decreases as the cell temperature increases.

Maximum efficiency is the ratio between the maximum power (MPP) and the incident light power:

$$\eta = \frac{P_{max} (= I_{MPP}V_{MPP})}{P_{in} (= GaA)}$$

where  $G_a$  is ambient irradiation ( $\text{kW/m}^2$ ) and  $A$  is cell area ( $\text{m}^2$ ).

## **2.12 Effect of temperature:**

### **2.12.1 Effect of temperature on short circuit current (Isc):**

While carrying out our experiment in indoor condition we observed certain changes on short circuit current (Isc) due to the effect of temperature. The relationship that we obtained from the experiment in indoor condition for mono-crystalline silicon solar panel is  $I_{sc} = 0.0011 * T + 0.084$  therefore the temperature coefficient is 0.0011A/K. correspondingly polycrystalline it is  $I_{sc} = 0.00096 * T + 0.12$  so the temperature coefficient for polycrystalline silicon solar cell is 0.00096A/K.

### **2.12.2 Effect of temperature on the open circuit voltage (Voc)**

The open circuit voltage decreases with temperature and which has been justified that  $V_{oc} = - 0.0018 * T + 1.1$  for one cell of mono-crystalline solar cell and  $V_{oc} = - 0.0017 * T + 0.12$  for one cell of poly crystalline-silicon solar cell. It had been justified while carrying out indoor experiment but theoretically we have seen that that the Voc it is different for both mono-crystalline silicon solar and poly-crystalline that 2mV/°C for both of them but our indoor analysis came out with different values that the temperature coefficient is 1.8mV/°C for mono crystalline and 1.7mV/°C poly-crystalline.

## **CHAPTER 3**

### **EXPERIMENTAL RESULT AND ANALYSIS**

#### **3.1 Introduction**

Our objective is to analyze the characteristics of silicon solar cells under different conditions. The output voltage and current of a solar cell is affected by many factors. To understand the change of output current and voltage of a silicon solar module we first conducted indoor experiments. Our initial aim was to understand how the current and voltage change with the change of load, for which we studied the i-v curve of a solar panel. Under direct sunlight in outdoor environment there are many parameters due to which the results of experiments change. So to avoid that we started with indoor experiment where we can observe the behavior of a solar panel in a controlled environment and adjust both the temperature and the illumination of light according to our needs. For our thesis we considered two different types of solar panels. Polycrystalline and monocrystalline. There are different parameters to judge the performance of a solar panel. Such parameters are open circuit voltage-Voc, short circuit current-Isc, series resistance of a photovoltaic cell-Rs, maximum power output point- Pmax. The temperature coefficients of these parameters are very essential to know the behavior of the panel, then we can figure it out how it is changing with temperature, and affecting on the output power of the panel, and how much of energy these can provide.

#### **3.2 Indoor experiments**

By using a box designed to simulate sun we experimented with both monocrystalline and polycrystalline panels. To find the voltage and current reading we used a variable load. By changing the load from maximum to zero we achieved the desired values of current and voltage. At first we kept the temperature fixed and for a fixed temperature measured the changing current and voltage by varying the load.

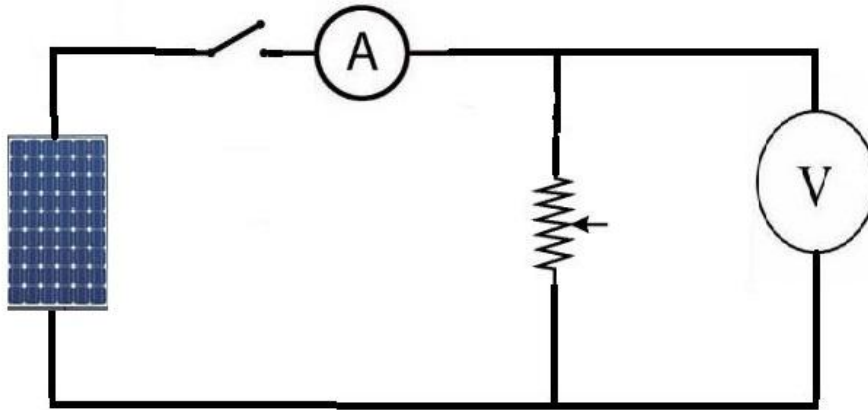


Figure- Circuit diagram of the experimental setup

We used different numbers of bulbs to simulate sunlight at different time points of the day. To emulate the radiation at midday when illumination is at the highest we used light from ten 100watt bulbs. We decreased the number of bulbs gradually to get multiple readings under different illumination conditions. Then we conducted the same routine for different temperature each time keeping the temperature constant.

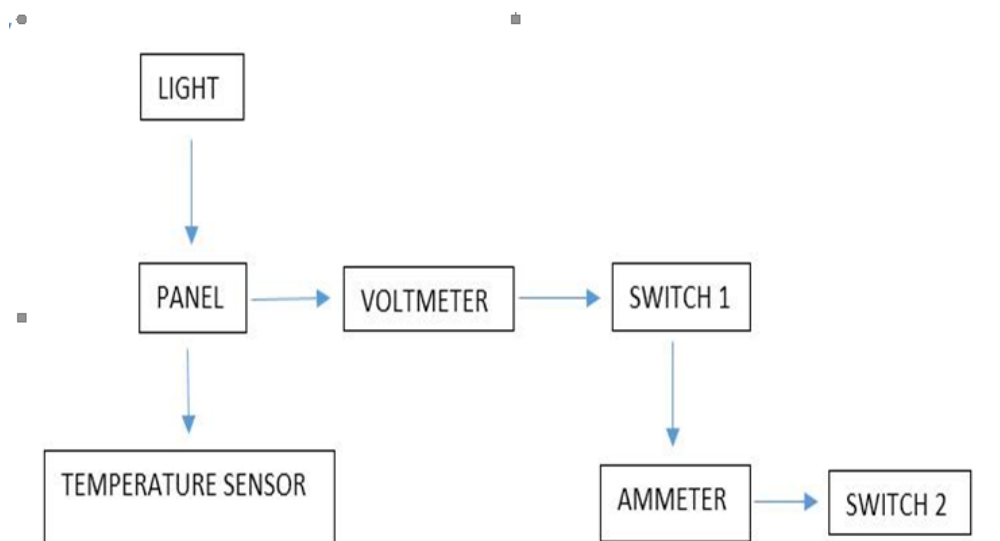


Figure- Block diagram of the circuit used for indoor experiment.



The result of this experiments was corresponding voltage and current readings for load change. By plotting this values we got the i-v characteristics curve for both mono and polycrystalline solar panel. The curves obtained through this experiment are given in the upcoming pages. Here we kept the temperature constant and varied the illumination by conducting the experiment under 2lights, 4lights, 6lights, 8lights, 10lights.

### **3.3 Effect of illumination on solar panels**

The intensity of Illumination greatly affects the output of solar panel. It is perhaps the most significant parameter for power generation of a solar module. To understand the effect of illumination we need to observe the change in voltage and current due to change in illumination at a fixed temperature.

#### **3.3.1 I-v curve of monocrystalline solar panel at different light conditions**

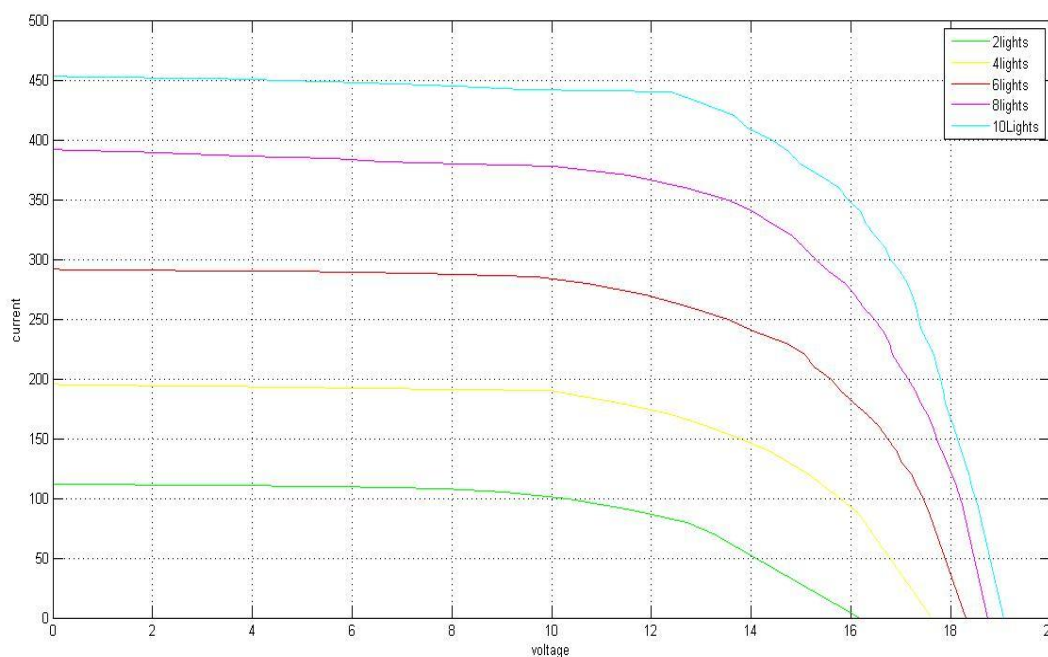


Figure- curve of monocrystalline at 45°C in different light conditions.

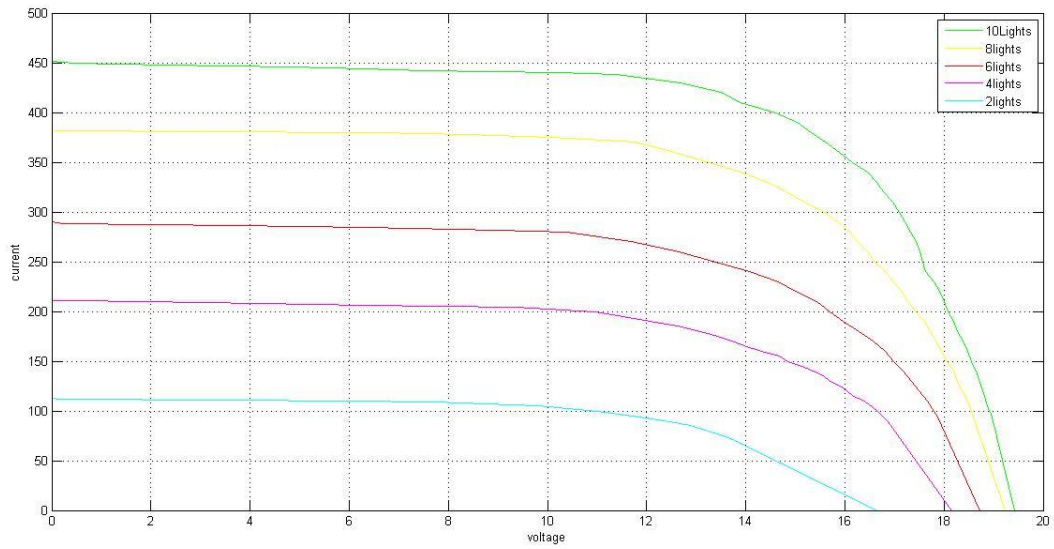


Figure- curve of monocrystalline at 40°C in different light conditions.

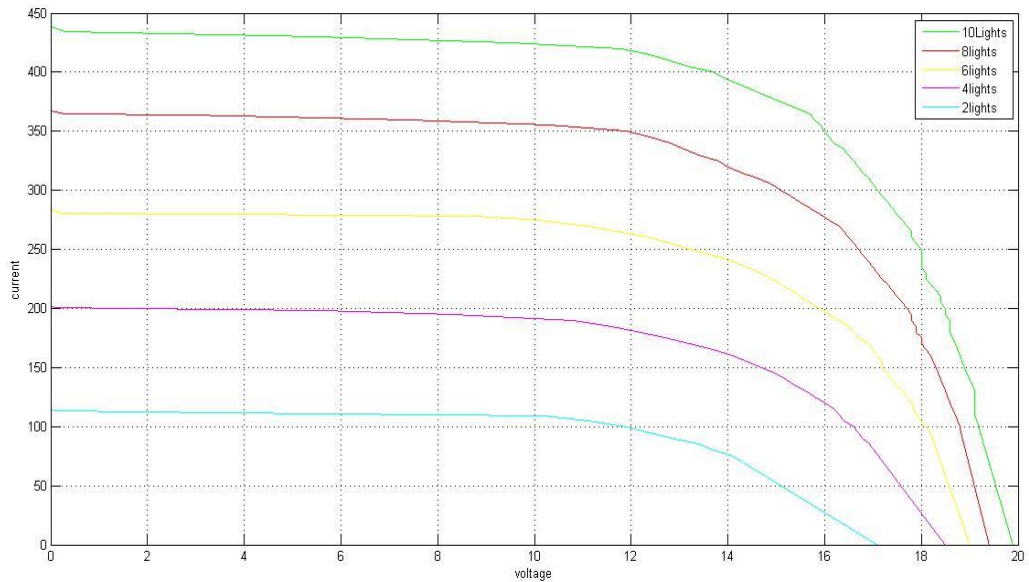


Figure- curve of monocrystalline at 35°C in different light conditions.

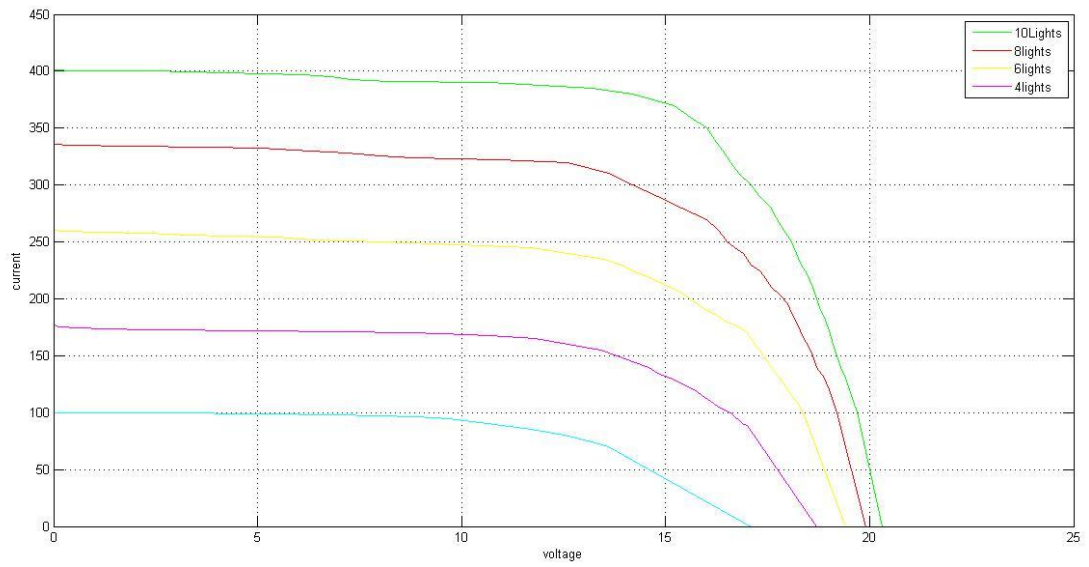


Figure- curve of monocrystalline at 30°C in different light conditions.

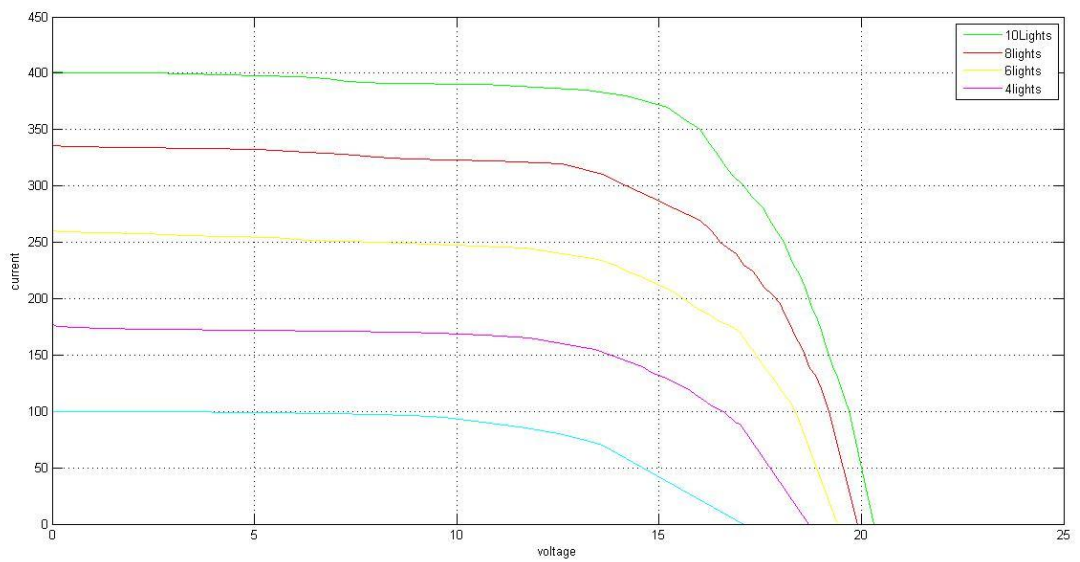


Figure- curve of monocrystalline at 25°C in different light conditions.

From the curves above we can clearly see that the change in illumination has a great change in the i-v curve. The slope for high intensity of illumination is greater which means that the rate of current dropping with changing load is greater at the maximum power point. As the illumination decrease the rate of drop in current with increasing load decrease.

A significant point of this experiment was to observe the change in maximum voltage and current due to change of illumination. From the data we generated we can clearly observe that the effect of illumination is greater on current output of the solar panel then on the voltage that is generated. On the other hand the voltage change is quite settle with the change of illumination.

### **3.3.2 I-v curve of polycrystalline solar panel at different light conditions:**

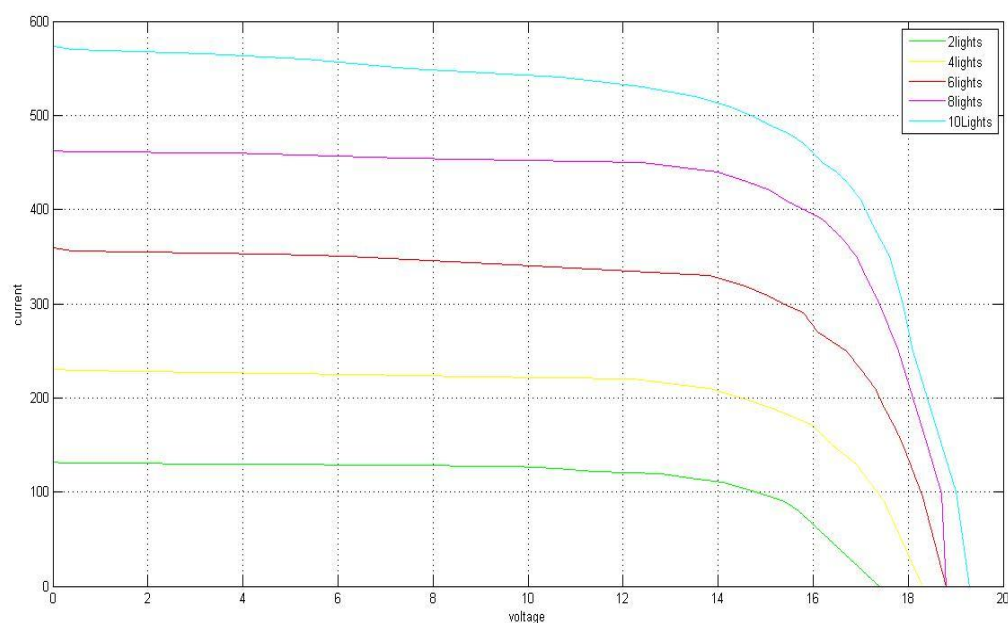


Figure i-v curve for polycrystalline at 45°C in different light condition

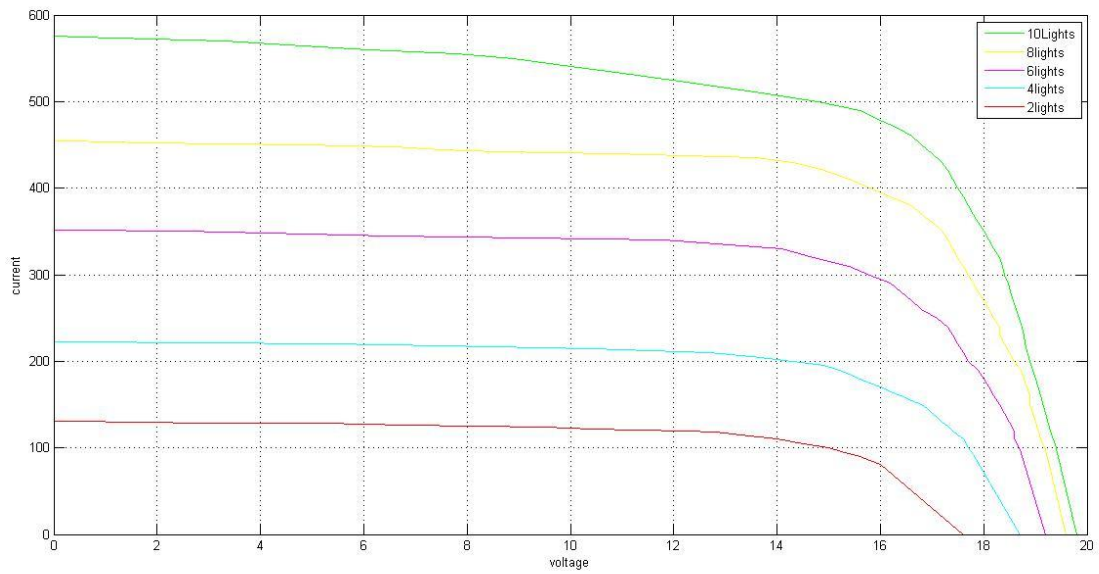


Figure i-v curve for polycrystalline at 40°C in different light condition

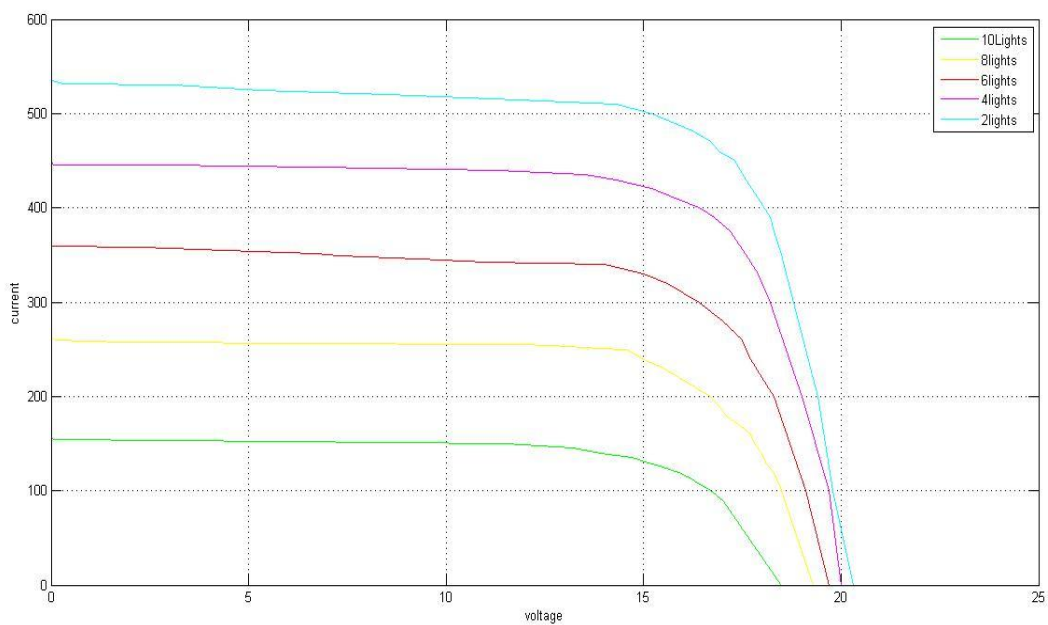


Figure i-v curve for polycrystalline at 35°C in different light condition

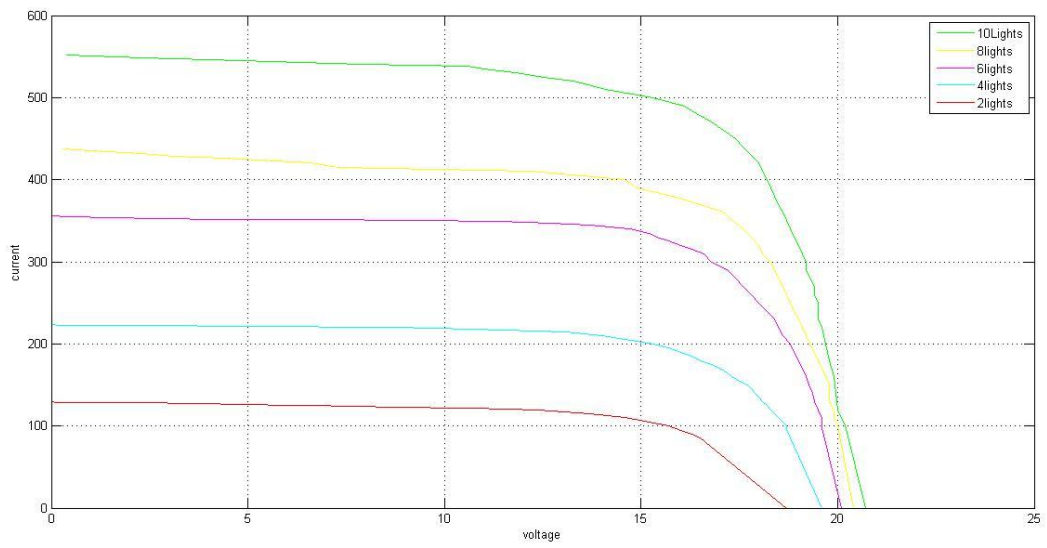


Figure i-v curve for polycrystalline at 30°C in different light condition

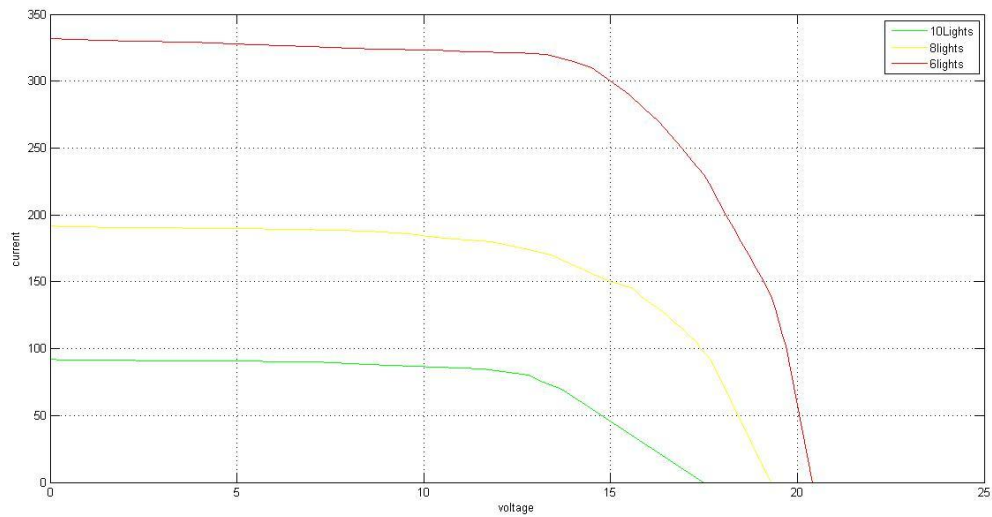


Figure i-v curve for polycrystalline at 25°C in different light condition

For polycrystalline we can observe the same kind of behavior. Current drop after maximum power point is greater at high illumination condition than in low light environments.

Also the change of current in polycrystalline is greater for change in illumination than voltage. Voltage has little change for the change of illumination. But the rise of current is much more for a fixed temperature.

### **3.4 Effect of Temperature on solar panel:**

With the change of temperature the output current and voltage changes due to the characteristics of the solar panel. The panel has silicon diode cells that are connected with metal conductors. As a result the panel displays some unique characteristics. To observe the change of  $V_{oc}$ ,  $I_{sc}$ , and series resistance we need to conduct an experiment where we can achieve the i-v curves at different temperatures in a fixed illumination. To achieve that we again used the sun simulator. Data from the experiments are plotted to analyze the results.

#### **3.4.1 I-v curve of monocrystalline solar panel at different temperatures:**

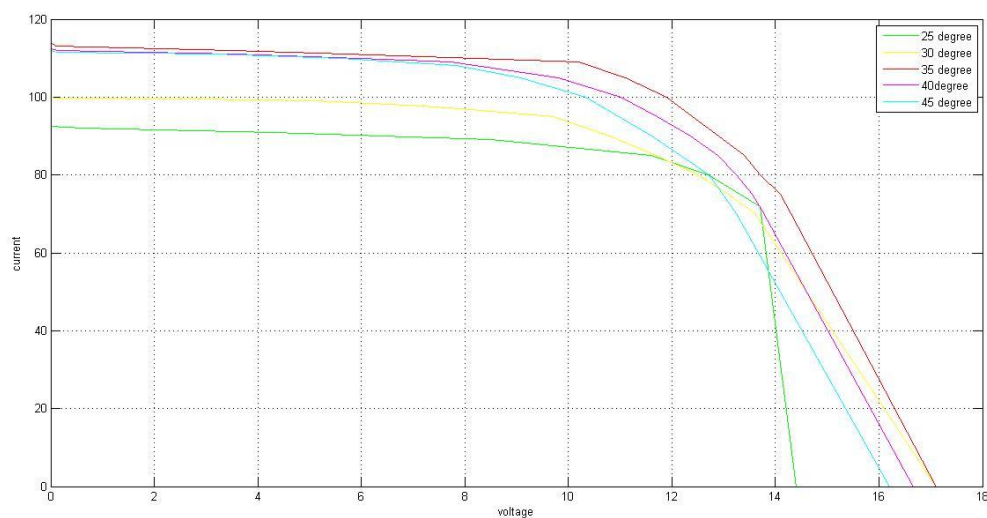


Figure i-v curve for monocrystalline under two filament bulbs



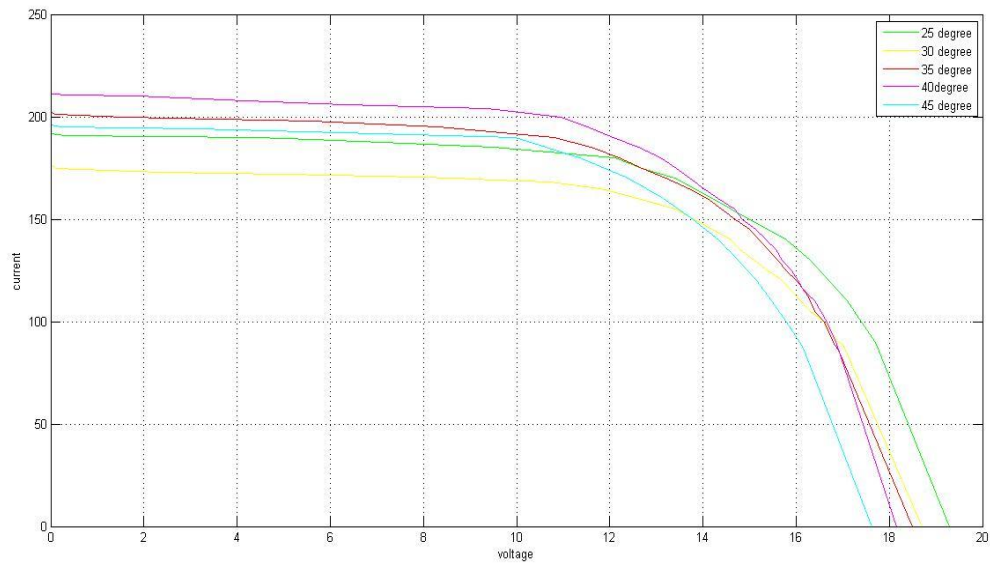


Figure i-v curve for monocrystalline under four filament bulbs

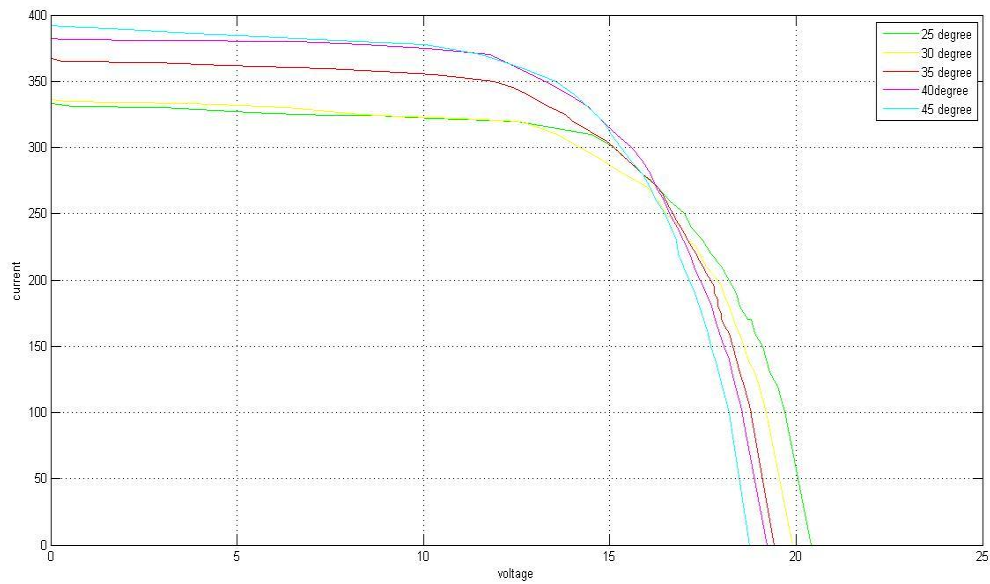


Figure i-v curve for monocrystalline under six filament bulbs

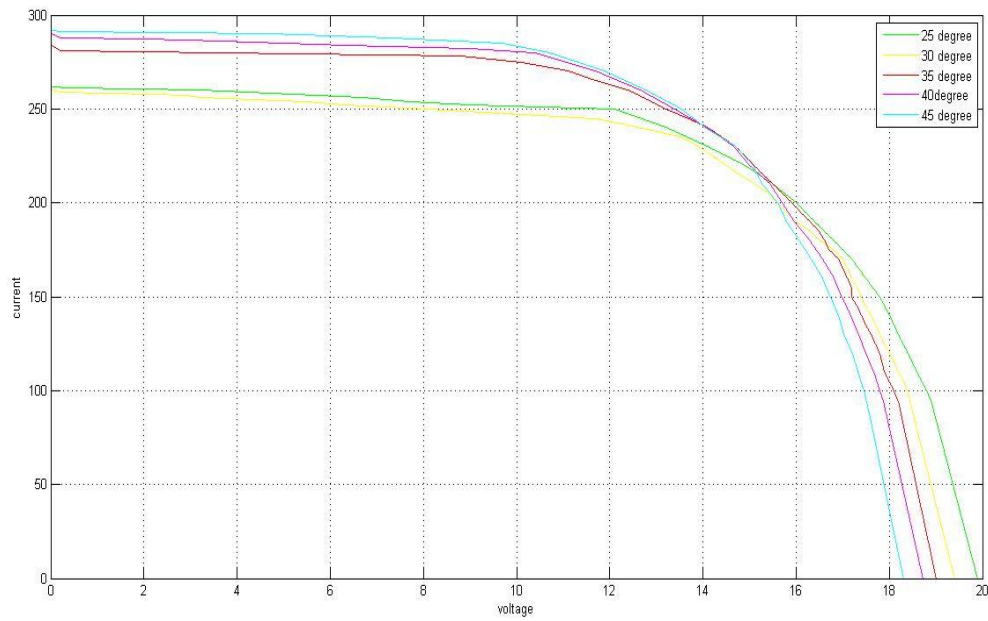


Figure i-v curve for monocrystalline under eight filament bulbs

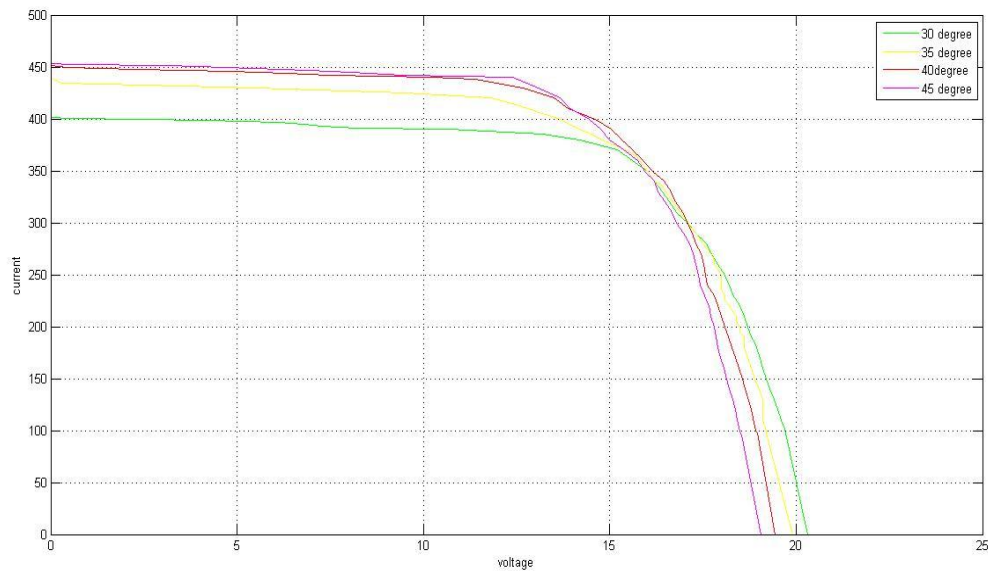


Figure i-v curve for monocrystalline under ten filament bulbs

From the plots above we can observe that under fixed amount of illumination, as the temperature of the panel is increased the open circuit voltage of the panel decreased and the short circuit current increases. This is because like all other semiconductor devices, silicon solar cells are sensitive to temperature. Increases in temperature reduce the band gap of a semiconductor, thereby affecting most of the semiconductor material parameters. The decrease in the band gap of a semiconductor with increasing temperature can be viewed as increasing the energy of the electrons in the material. Lower energy is therefore needed to break the bond. In the bond model of a semiconductor band gap, reduction in the bond energy also reduces the band gap. Therefore increasing the temperature reduces the band gap. In a solar cell, the parameter most affected by an increase in temperature is the open-circuit voltage. The impact of increasing temperature clearly evident in the resulting curves of our experiments. The open-circuit voltage decreases with temperature because of the temperature dependence of  $I_0$ .

### **3.4.2 I-v curve of polycrystalline solar panel at different temperatures:**

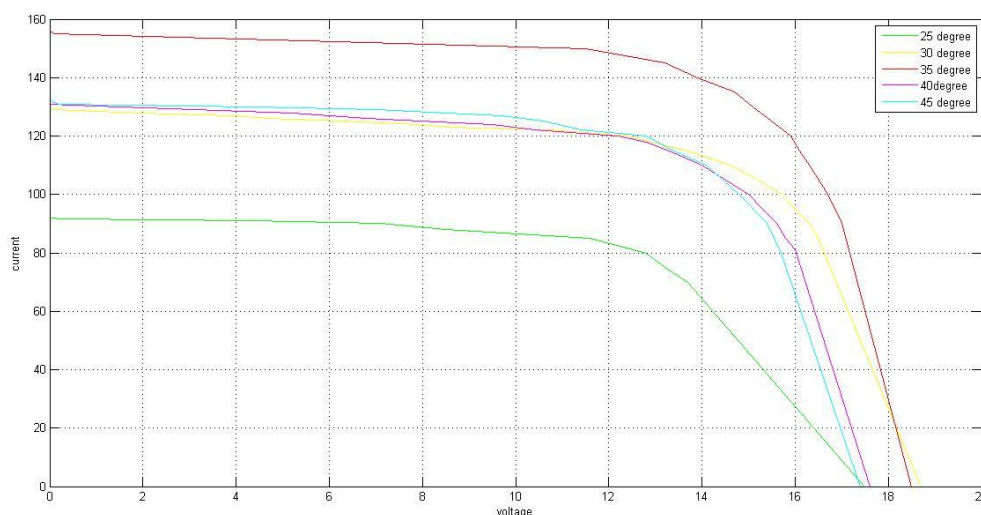


Figure i-v curve for monocrystalline under tow filament bulbs

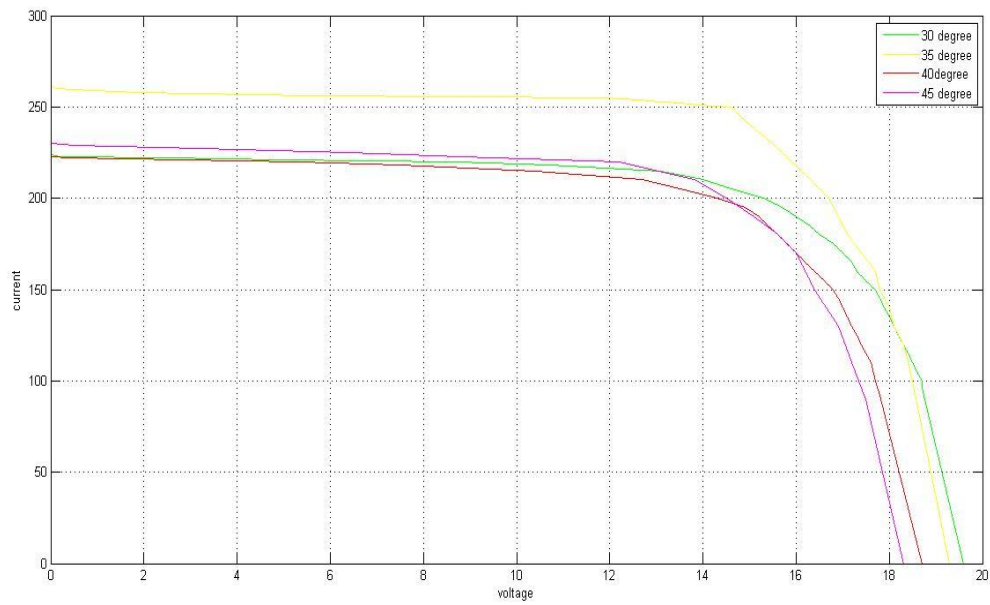


Figure i-v curve for monocrystalline under four filament bulbs

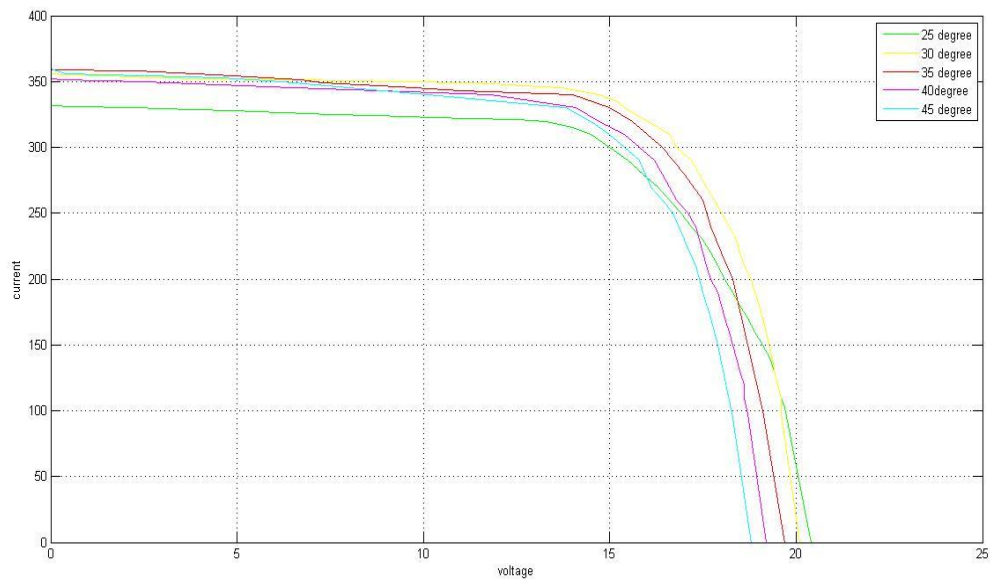


Figure i-v curve for monocrystalline under six filament bulbs

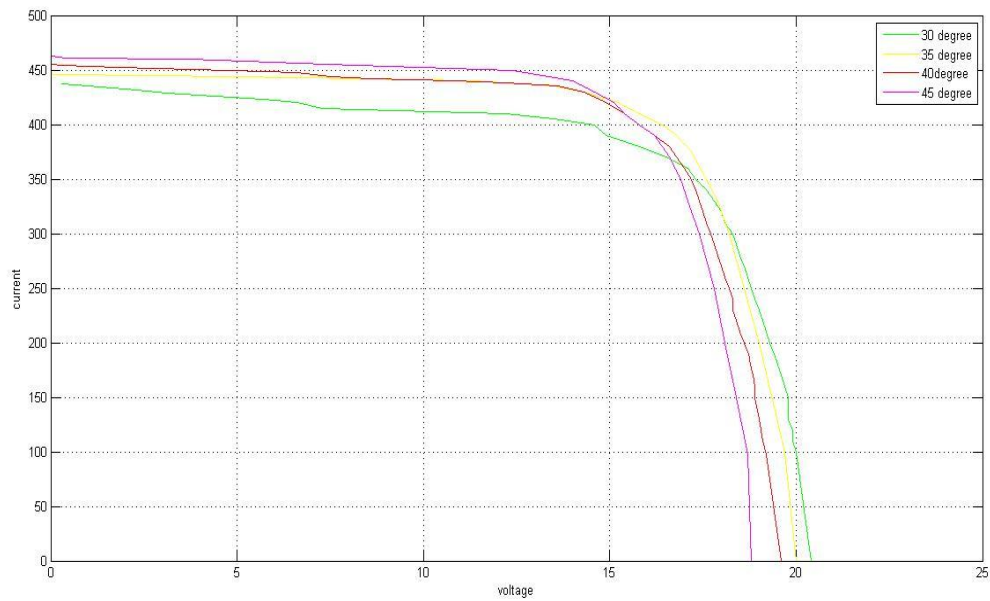


Figure i-v curve for monocrystalline under eight filament bulbs

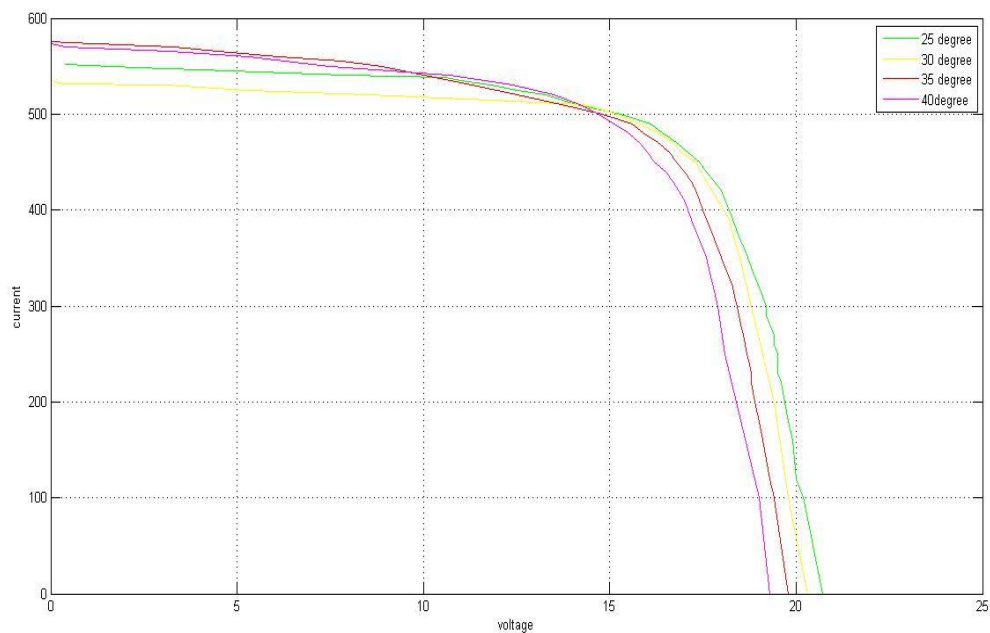


Figure i-v curve for monocrystalline under ten filament bulbs

As we explained for monocrystalline, the same behavior is observed from polycrystalline at different temperatures. The open circuit voltage decreases due to increase in temperature and the short circuit current increases for the same reasons. But at low level of illumination the behavior is less evident for both polycrystalline and monocrystalline.

### **3.5 Sensitivity due to change in temperature**

Sensitivity due to temperature change is defined by the change in short circuit current because of 1 kelvin change in temperature.

Sensitivity calculation:

$$\text{Sensitivity} = \frac{\text{change in current, } \Delta I_{sc}}{\text{change in temperature, } \Delta T_{oc}}$$

#### **3.5.1 Monocrystalline sensitivity due to change in temperature**

For temperature 25°C to 30°C , in under 8 bulbs (346-333)/5=2.6mA/K

For temperature 30°C to 35°C , in under 8 bulbs (357-346)/5=2.2mA/K

For temperature 35°C to 40°C , in under 8 bulbs (362-355)/5=1.4mA/K

For temperature 45°C to 50°C , in under 8 bulbs (368-362)/5=1.2mA/K

For temperature 25°C to 30°C , in under 4 bulbs (192-177)/5=3mA/K

For temperature 30°C to 35°C , in under 4 bulbs (202-192)/5=2mA/K

For temperature 35°C to 40°C , in under 4 bulbs (211-202)/5=1.8mA/K

For temperature 45°C to 50°C , in under 4 bulbs (218-211)/5=1.4mA/K

### **3.5.2 Polycrystalline sensitivity due to change in temperature**

For temperature 25°C to 30°C , in under 8 bulbs  $(437-422)/5=3\text{mA/K}$

For temperature 30°C to 35°C , in under 8 bulbs  $(450-437)/5=2.6\text{mA/K}$

For temperature 40°C to 45°C , in under 8 bulbs  $(455-450)/5=1\text{mA/K}$

For temperature 45°C to 50°C , in under 8 bulbs  $(458-455)/5=0.6\text{mA/K}$

For temperature 25°C to 30°C , in under 4 bulbs  $(224-192)/5=6.4\text{mA/K}$

For temperature 35°C to 40°C , in under 4 bulbs  $(262-240)/5=4.4\text{mA/K}$

For temperature 40°C to 45°C , in under 4 bulbs  $(280-262)/5=3.6\text{mA/K}$

For temperature 45°C to 50°C , in under 4 bulbs  $(292-280)/5=2.4\text{mA/K}$

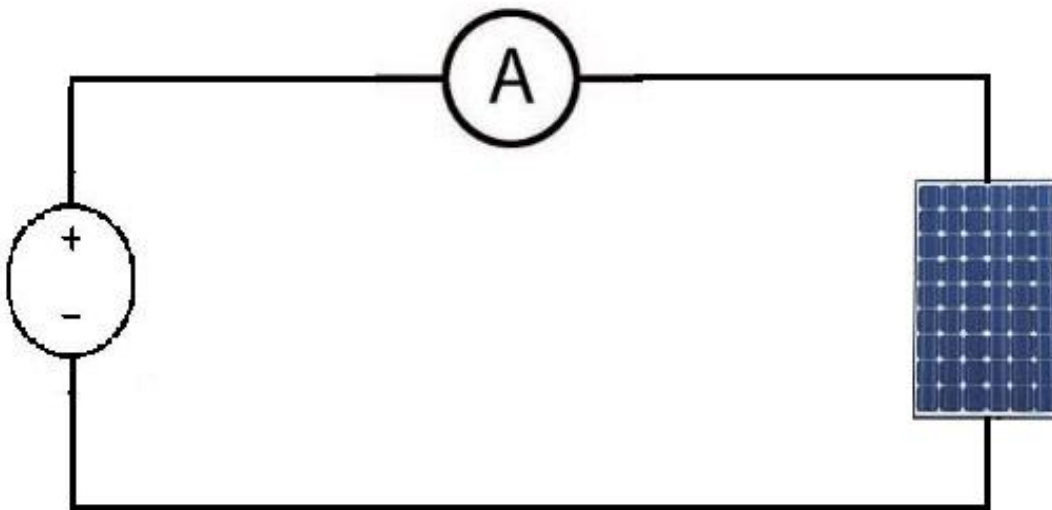
From the above calculations we can conclude that the sensitivity of the solar panel changes with temperature. At higher temperature the sensitivity gradually decreases. SO at a very high temperature the solar module will be less sensitive to farther change in temperature.

Also at high illumination the sensitivity for both polycrystalline and monocrystalline is less than sensitivity at low level of illumination. SO we can say that if illumination increases the sensitivity decreases. And at higher temperature the sensitivity is less than at low temperature.



### **3.6 Dark Condition**

The experiment in dark condition was done in lab environment. We used the sun simulator as a closed box to create the dark conditions required to conduct the experiment. Our objective with this experiment was to find out the reverse current. To find the reverse current a voltage had to be passed through the solar panel. We used a DC source to generate this voltage. Using the DC generator we varied the voltage through the panel and measured the current passing. This current is the reverse current flowing through the panel due to voltage difference provided externally. Our aim was to calculate the series resistance of the panel and also observe the effect of temperature on the series resistance ( $R_s$ ).



Circuit for dark condition experiment.

### 3.6.1 Calculation of Series Resistance (Rs) for polycrystalline

Using the plot generated by the

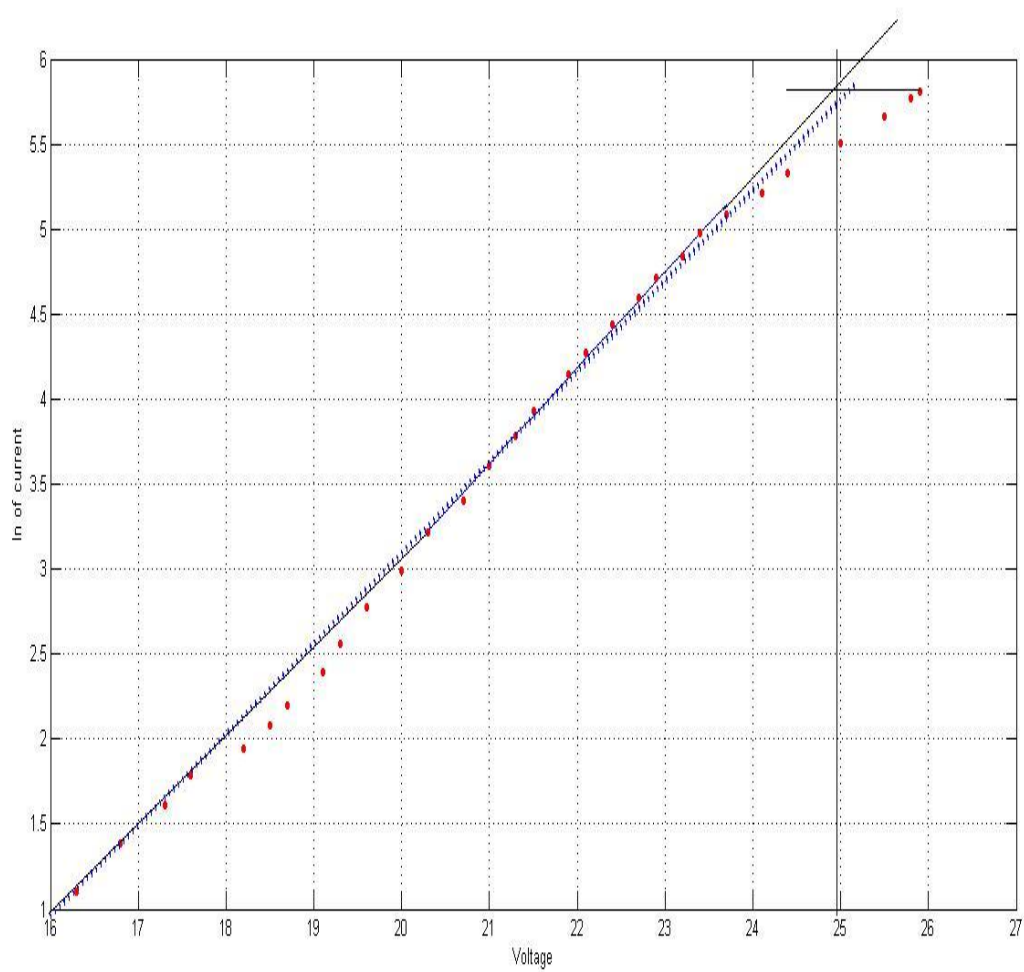


Figure: Series resistance measuring curve at 25°C

For 25 degree Celsius, Series resistance (Rs) =  $\frac{25.9 - 25.4}{0.330} = 1.467 \Omega$

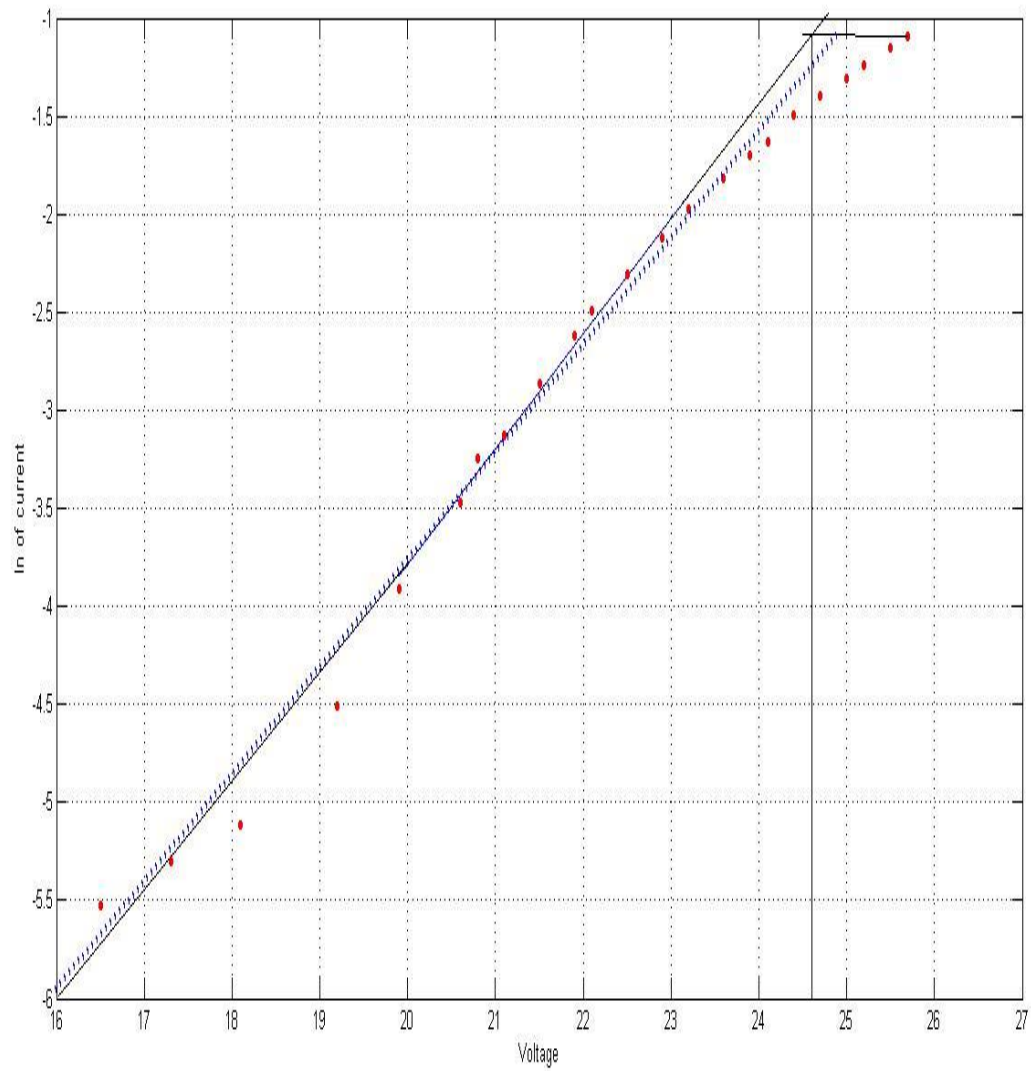


Figure: Series resistance measuring curve at 30°C

For 30 degree Celsius, Series resistance ( $R_s$ ) =  $\frac{25.7-25.2}{0.334} = 1.497 \Omega$

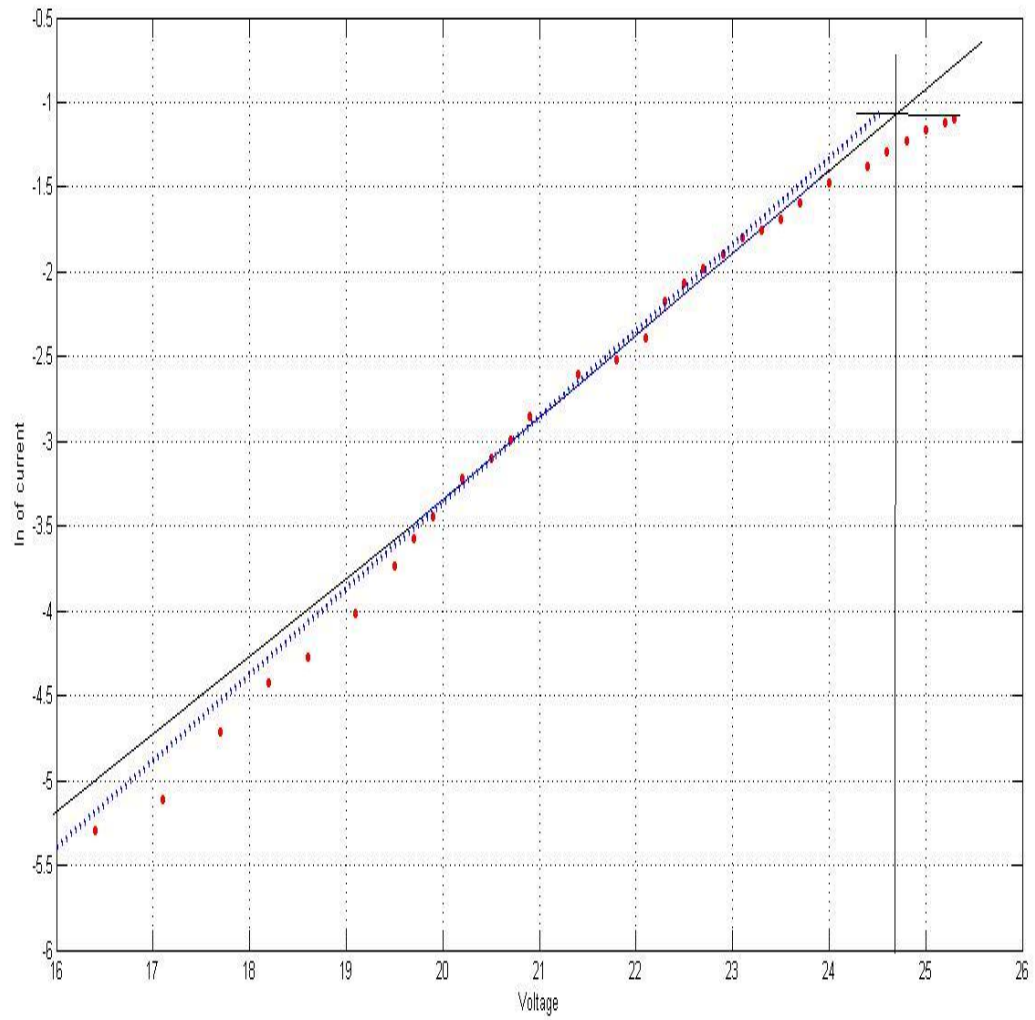


Figure: Series resistance measuring curve at 35°C

For 35 degree Celsius, Series resistance ( $R_s$ ) =  $\frac{25.3-24.7}{0.334} = 1.796 \Omega$

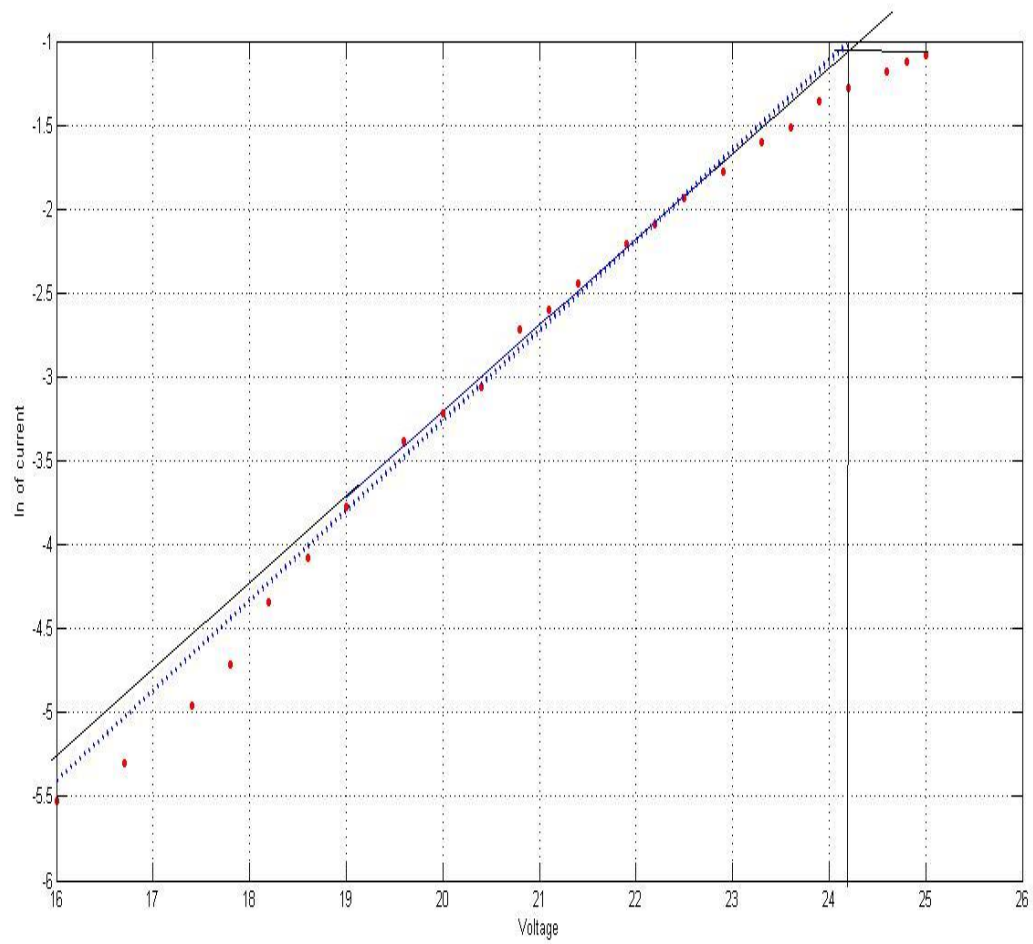


Figure: Series resistance measuring curve at 40°C

For 40 Degree Celsius, Series resistance ( $R_s$ ) =  $\frac{25.24.2}{0.337} = 2.37 \Omega$

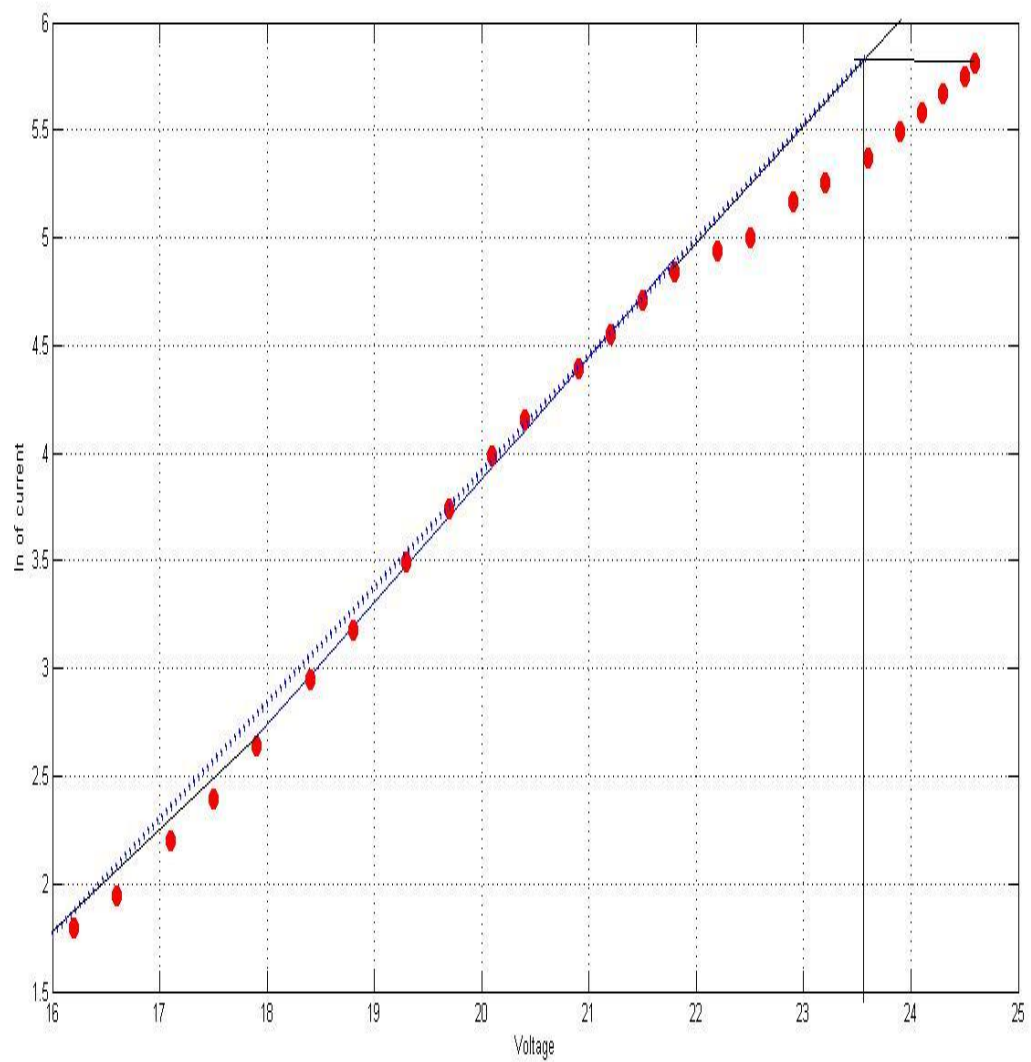


Figure: Series resistance measuring curve at 45°C

For 45 degree Celsius, Series resistance ( $R_s$ ) =  $\frac{24.6-23.6}{0.333} = 3 \Omega$

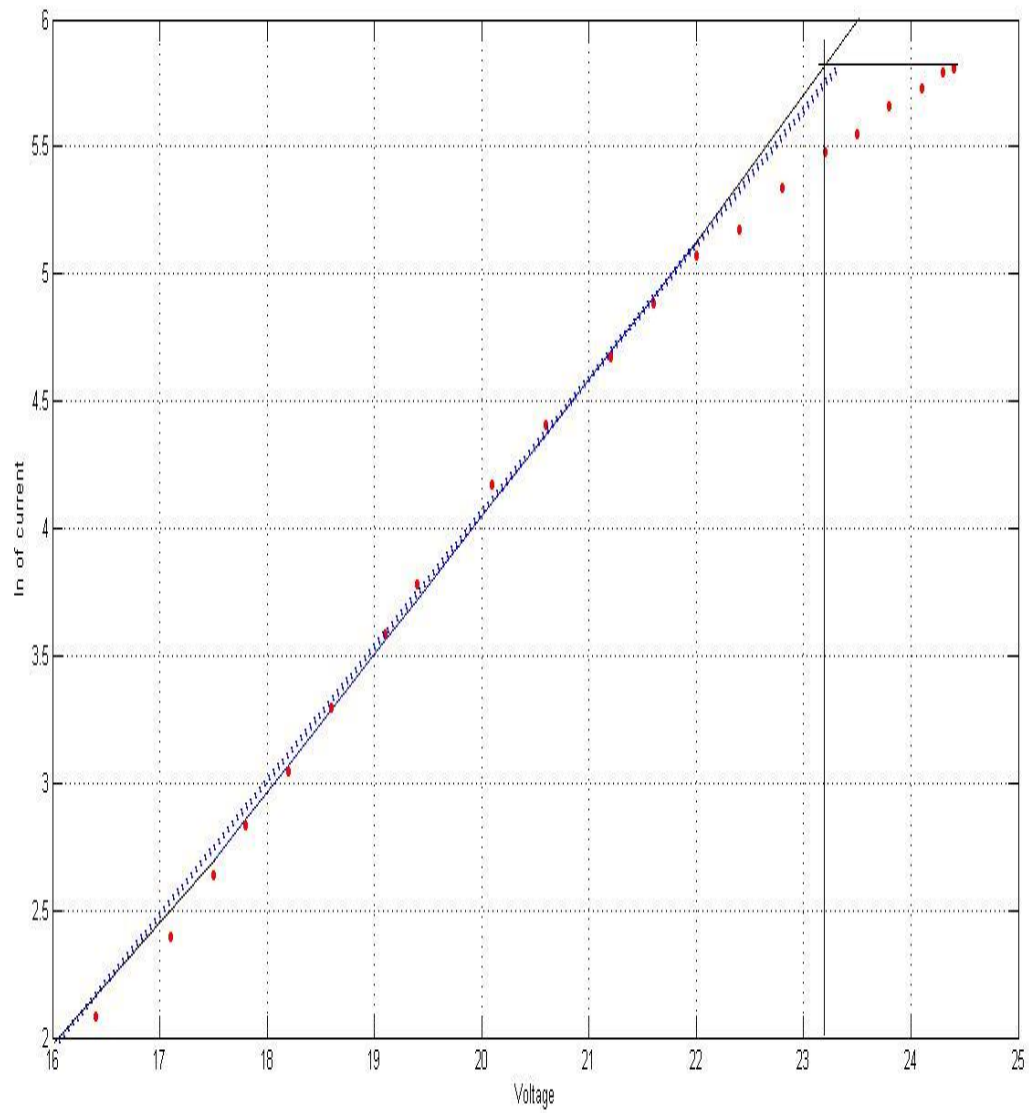


Figure: Series resistance measuring curve at 50°C

For 50 Degree Celsius, Series resistance ( $R_s$ ) =  $\frac{24.4-23.3}{0.333} = 3.3\Omega$

### 3.6.2 Calculation of Series Resistance (Rs) for monocrystalline

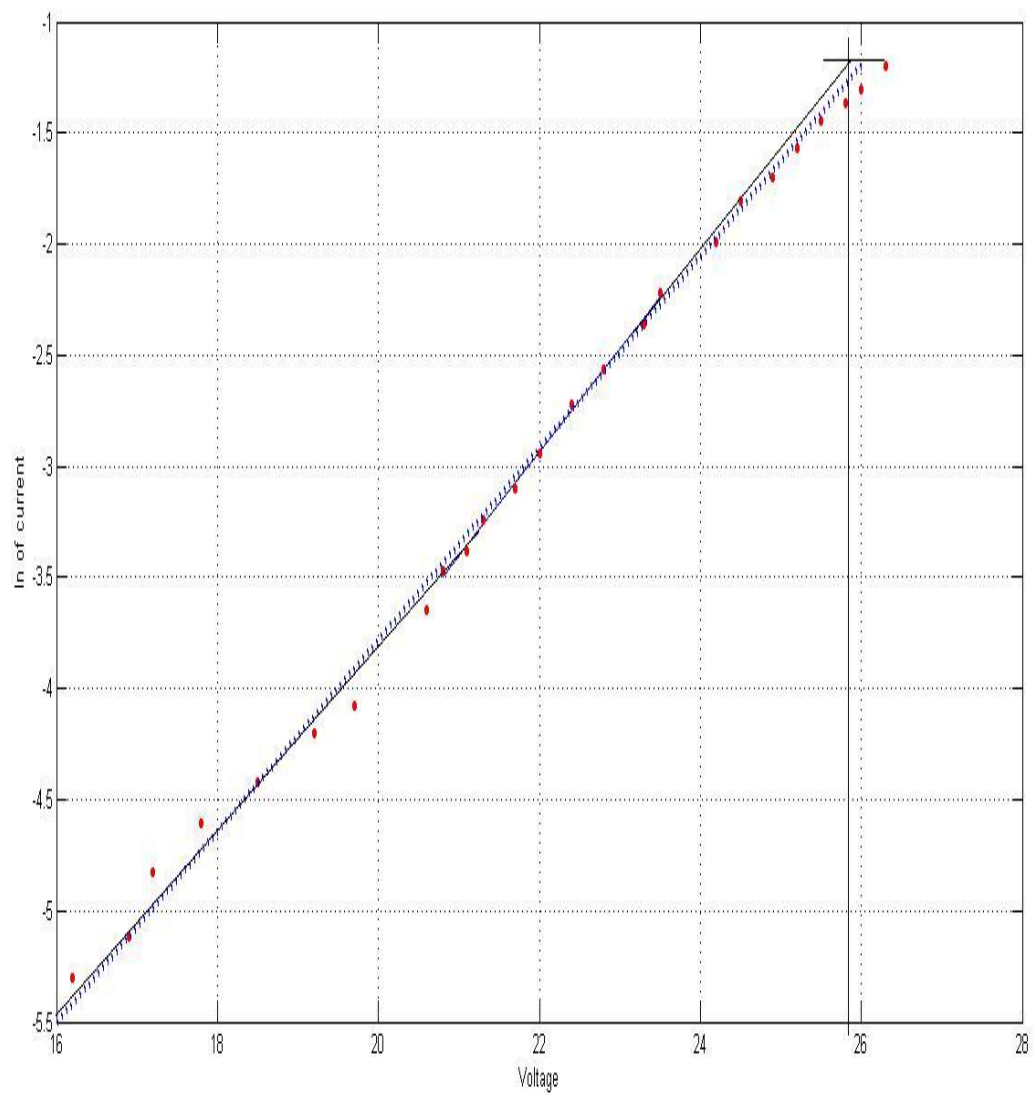


Figure: Series resistance measuring curve at 25°C

$$\text{For 25 Degree Celsius, Series Resistance (Rs)} = \frac{26.6-26}{0.303} = 0.99$$



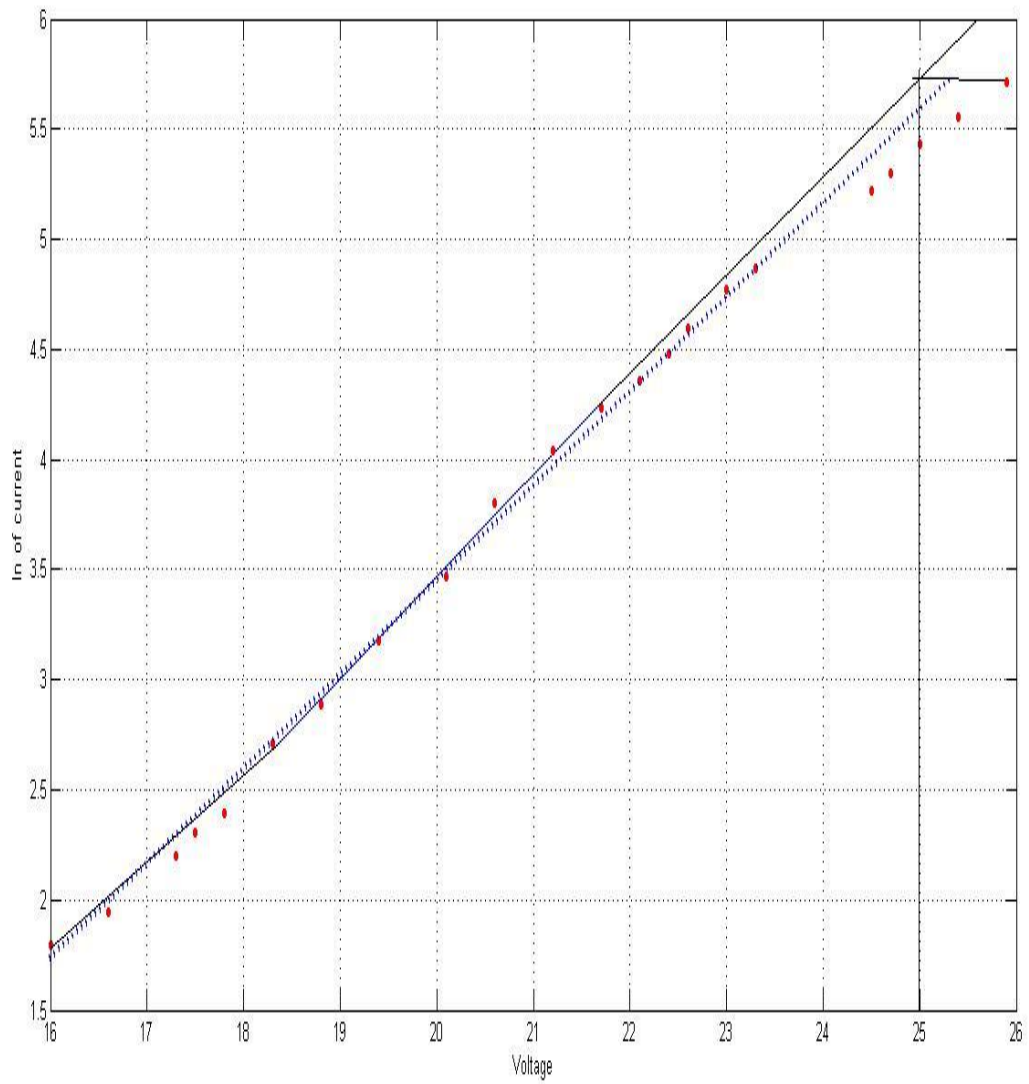


Figure: Series resistance measuring curve at 30°C

For 30 Degree Celsius, Series resistance ( $R_s$ ) =  $\frac{25.9-25.5}{0.303} = 1.32$

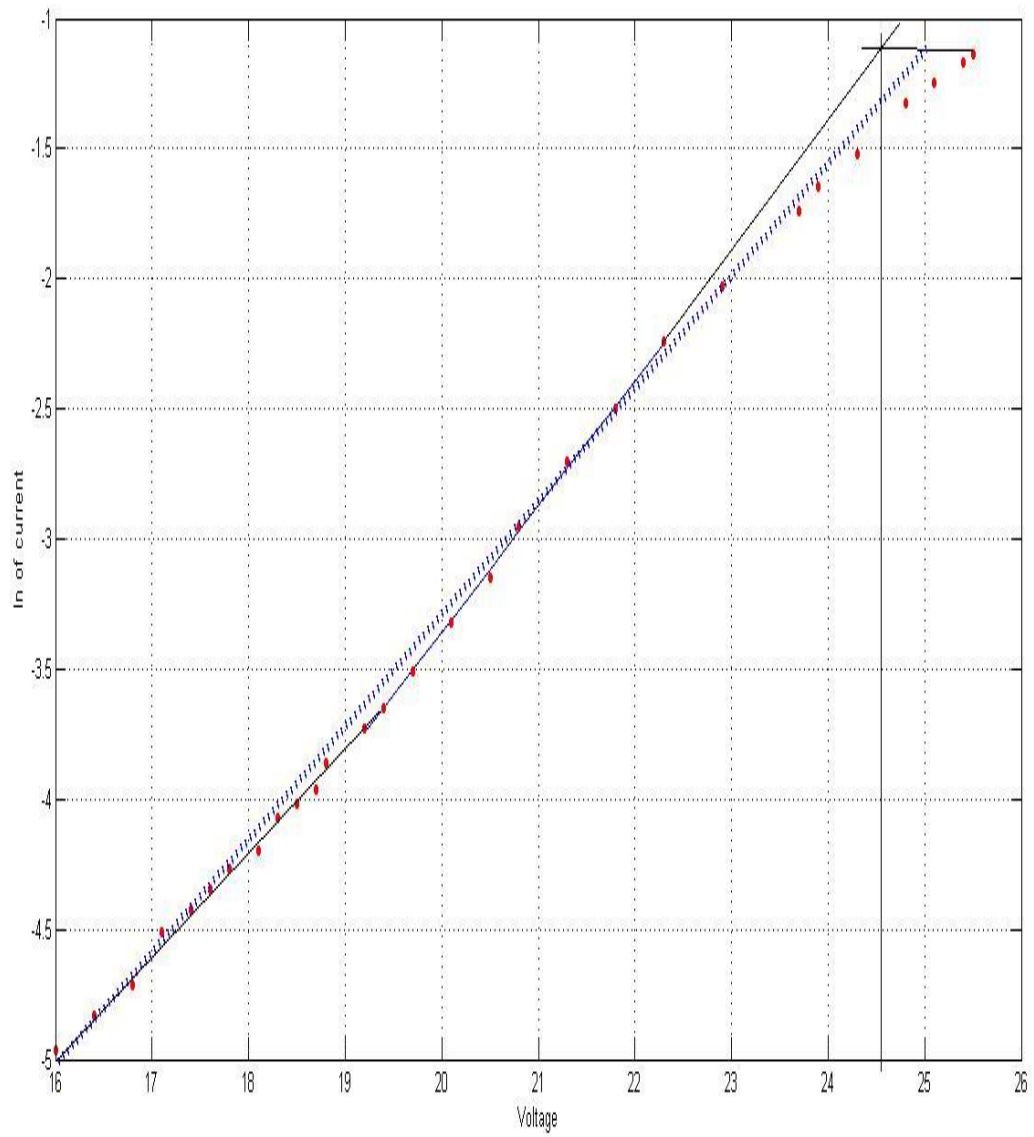


Figure: Series resistance measuring curve at 35°C

$$\text{For 35 Degree Celsius, Series resistance (Rs)} = \frac{25.5 - 25}{0.322} = 1.55$$

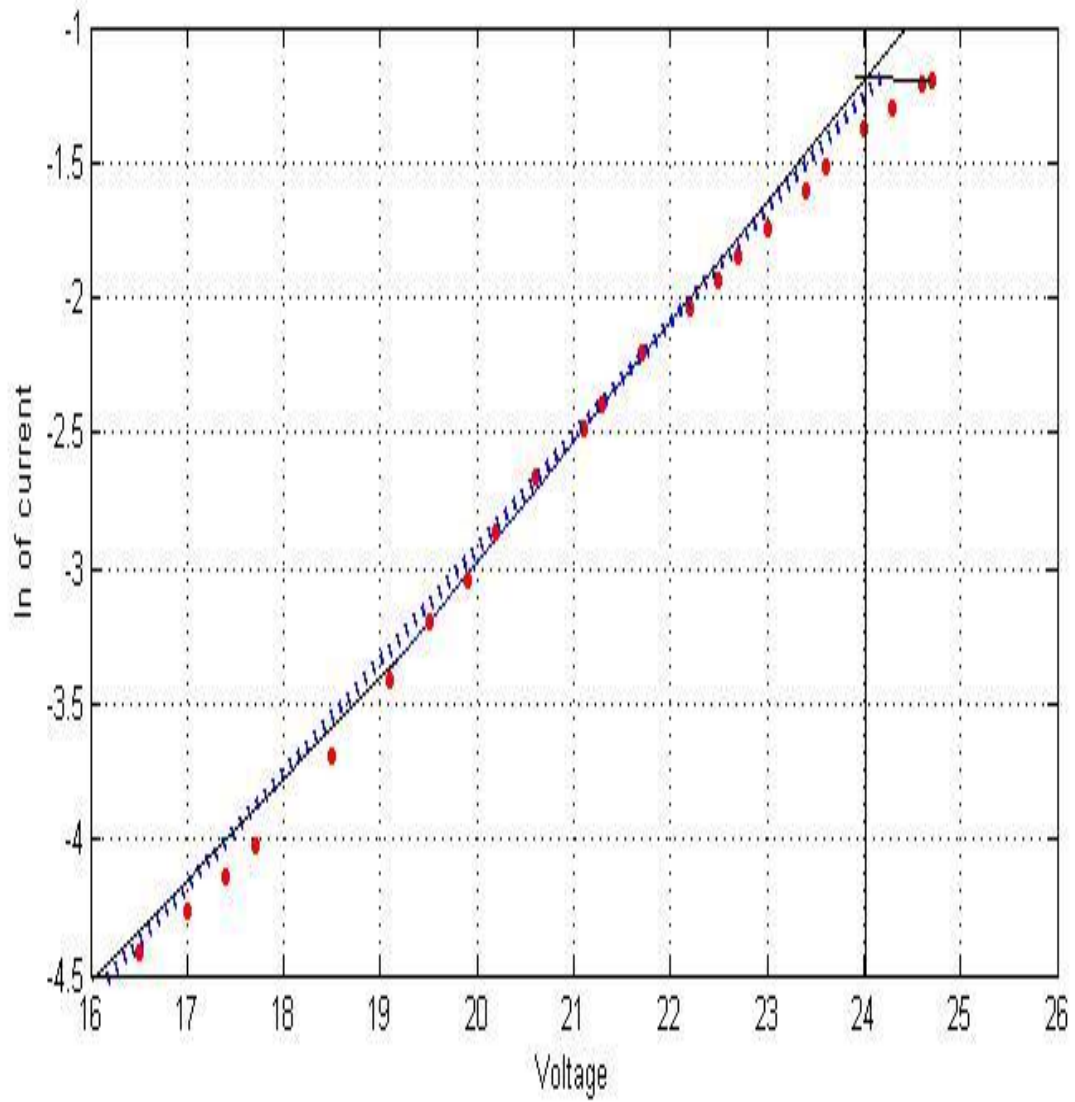


Figure: Series resistance measuring curve at 40°C

For 40 Degree Celsius, Series resistance ( $R_s$ ) =  $\frac{25.2-24.72}{0.322} = 1.58$

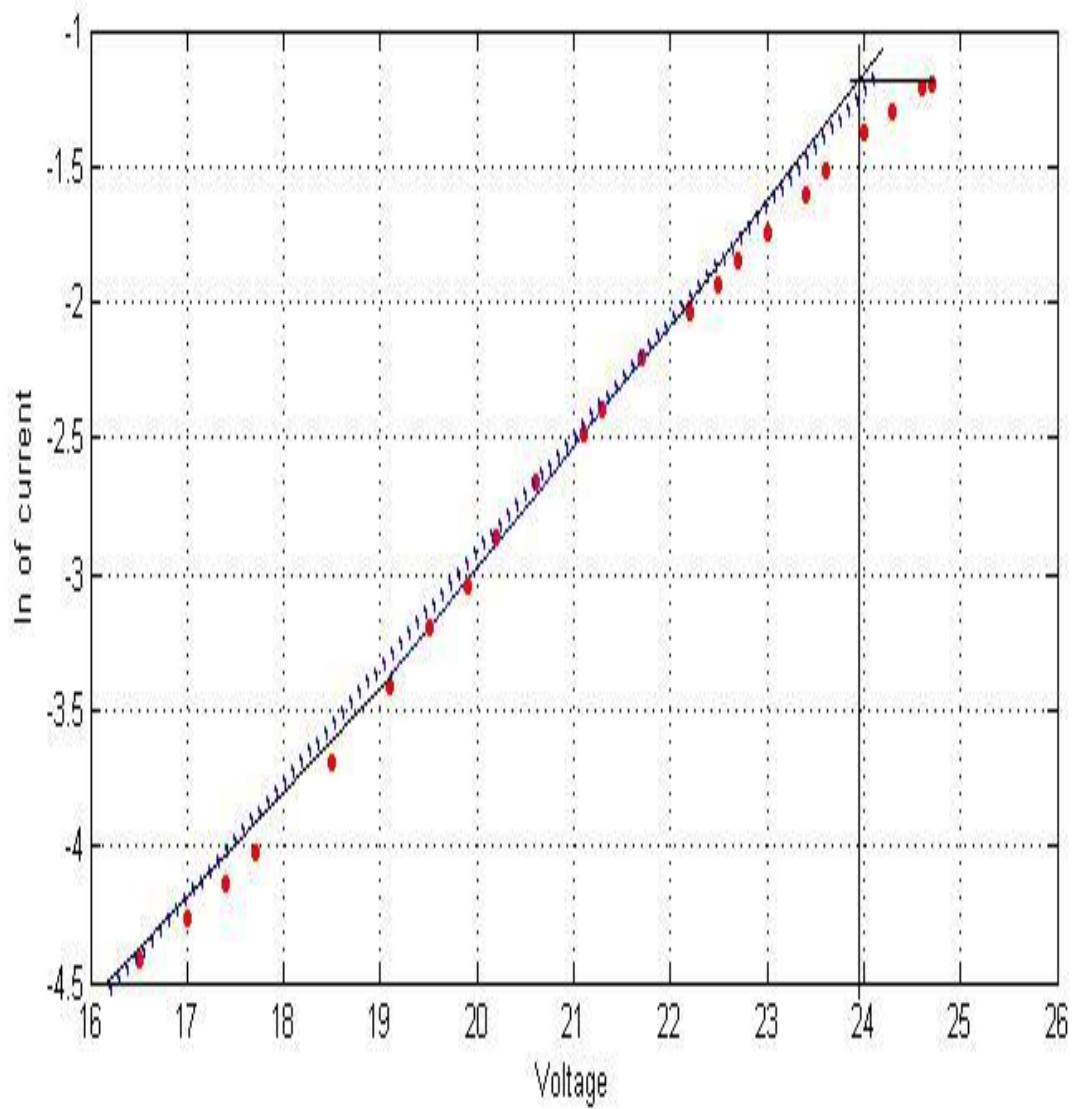


Figure: Series resistance measuring curve at 45°C

For 45 Degree Celsius, Series resistance ( $R_s$ ) =  $\frac{24.7-24.2}{0.322} = 1.65$

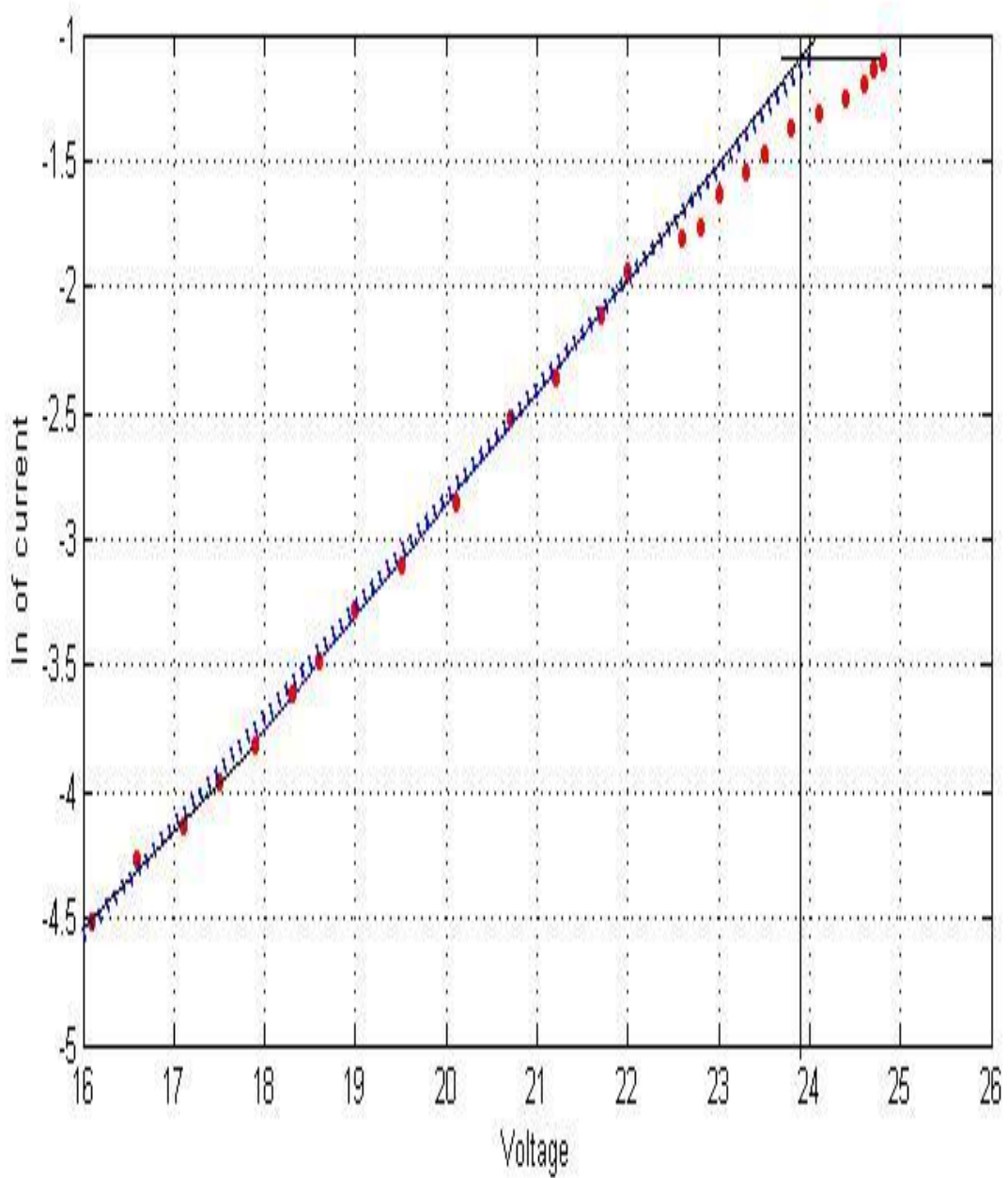


Figure: Series resistance measuring curve at 50°C

For 50 Degree Celsius, Series resistance ( $R_s$ ) =  $\frac{24.8-24}{0.332} = 2.4\Omega$

### 3.6.3 Analysis of series resistance (Rs) for monocrystalline and polycrystalline

Series resistance for monocrystalline at different temperatures:

T	25	30	35	40	45	50
Rs	0.99Ω	1.32Ω	1.55Ω	1.58Ω	1.65Ω	2.4Ω

Series resistance for polycrystalline at different temperatures:

T	25	30	35	40	45	50
Rs	1.467Ω	1.497Ω	1.796Ω	2.37Ω	3Ω	3.3Ω

Materials that are classed as conductors such as metal tend to increase their resistance with an increase in temperature. However insulators are liable to decrease their resistance with an increase in temperature. In terms of silicon the convention is that the resistance decrease with the increase of temperature. But as the temperature is increased the resistance of the solar panel is increasing as we can observe from the calculation showed above. This characteristics is due to the metallic connection of cells. As the temperature is increased the series resistance (Rs) increases as the resistance in the metal connectors increases. This is the reason behind the decrease in power output in high temperature.

Fill factor: fill factor is an important parameter in determining the quality of a solar panel. It is the ratio of maximum power and the theoretical power. The equation for fill factor is,

$$FF = \frac{P_{max}}{v_{oc} I_{sc}}$$

Fill factor for monocrystalline in indoor=0.825

Fill factor for polycrystalline in indoor=0.834.

Fill factor for monocrystalline in outdoor=0.846

Fill factor for polycrystalline in outdoor=0.808

### 3.7 Outdoor experiments:

For our outdoor experiments we used the same solar panels that we used for our indoor experiments. We collected data throughout the day at 30 minutes intervals. We measured the surface temperature of the panels with all our readings. By varying load from  $250\Omega$  load to  $0\Omega$  we took the reading of the current and voltage along with the open circuit voltage and short circuit current values. By plotting this values in MATLAB we got i-v characteristics curves in practical situations.

#### i-v characteristics curves for monocrystalline on various days:

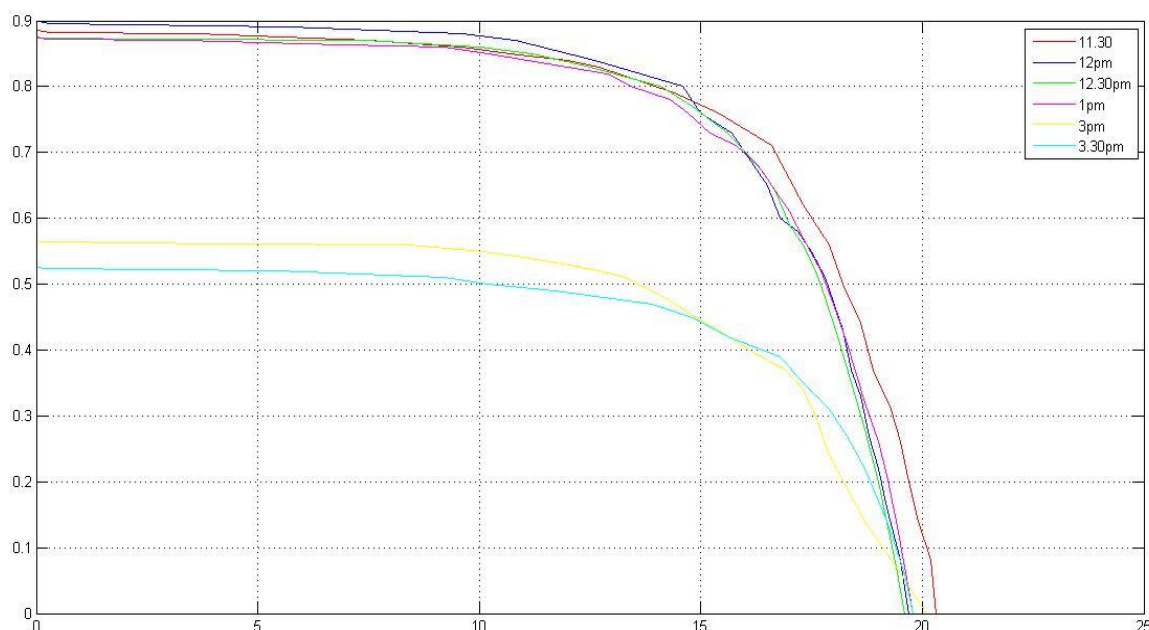


Figure: i-v curve of monocrystalline on 2<sup>nd</sup> June

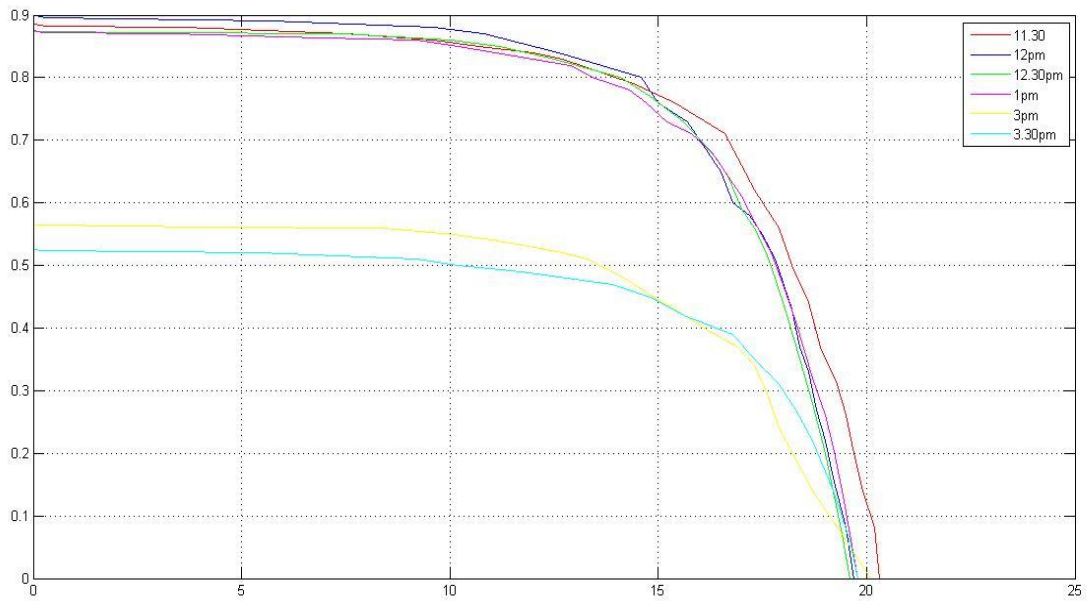


Figure: i-v curve of monocrystalline on 4th June

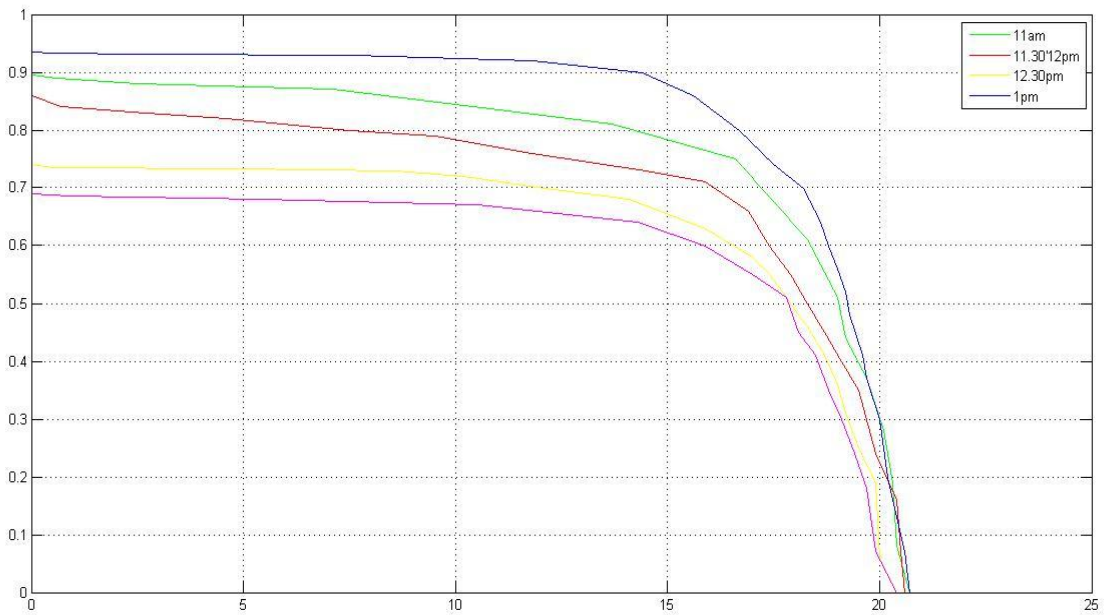


Figure: i-v curve of monocrystalline on 8<sup>th</sup> June



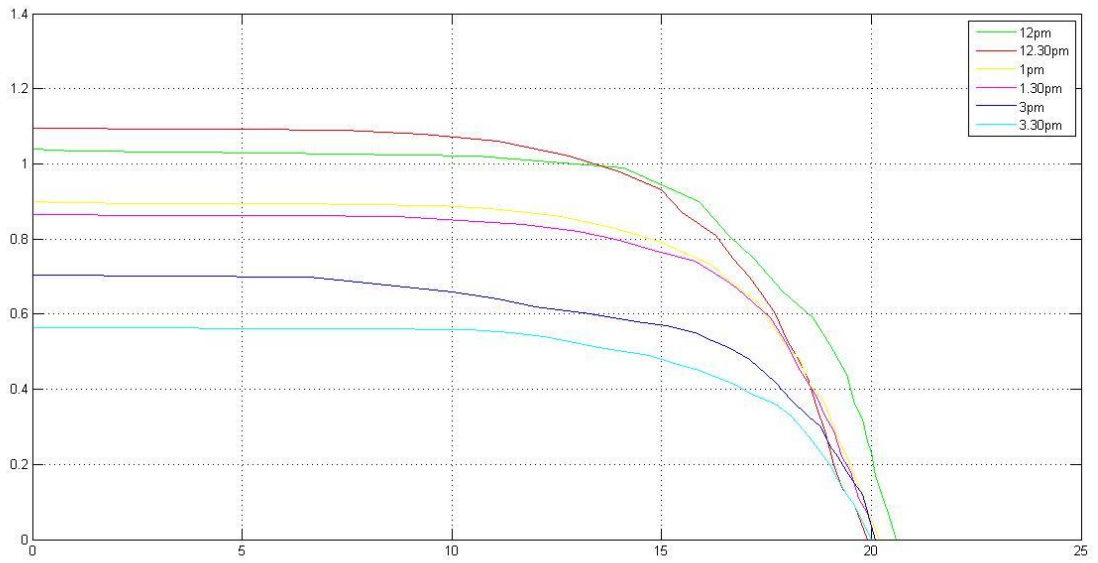


Figure: i-v curve of monocrystalline on 21<sup>st</sup> June

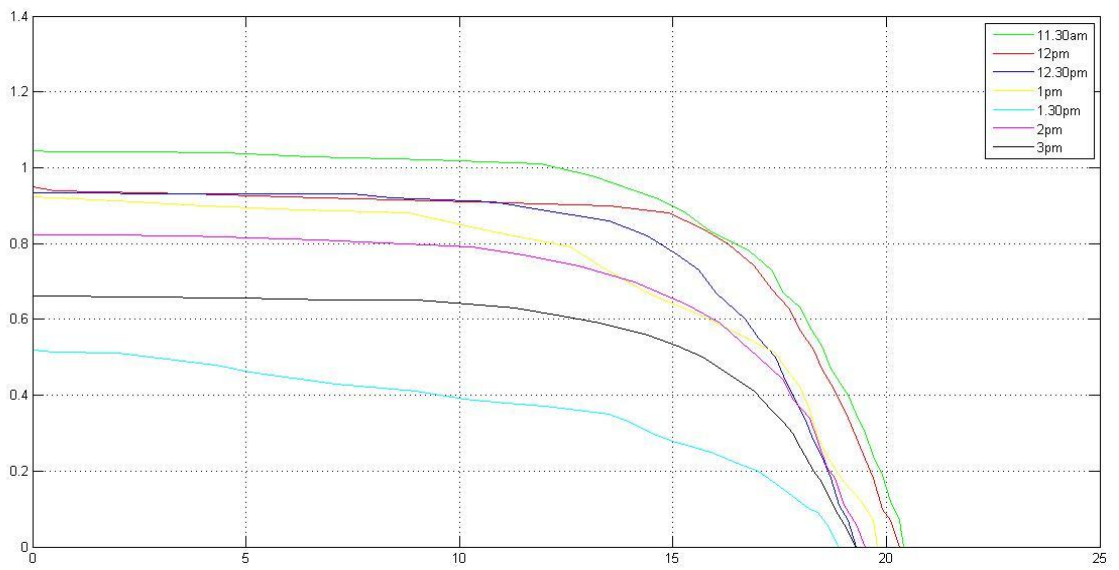


Figure: i-v curve of monocrystalline on 11th July

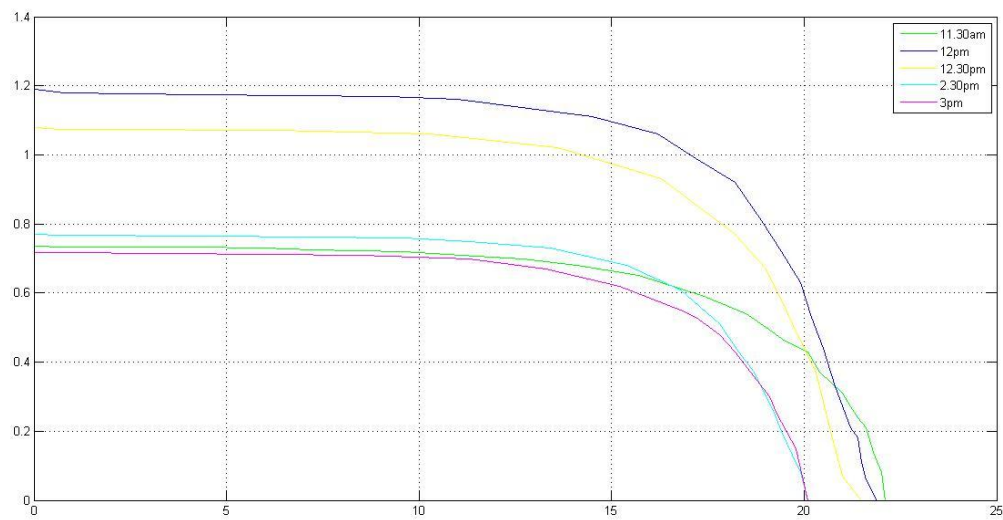


Figure: i-v curve of monocrystalline on 17th July

**i-v characteristics curves for polycrystalline on various days:**

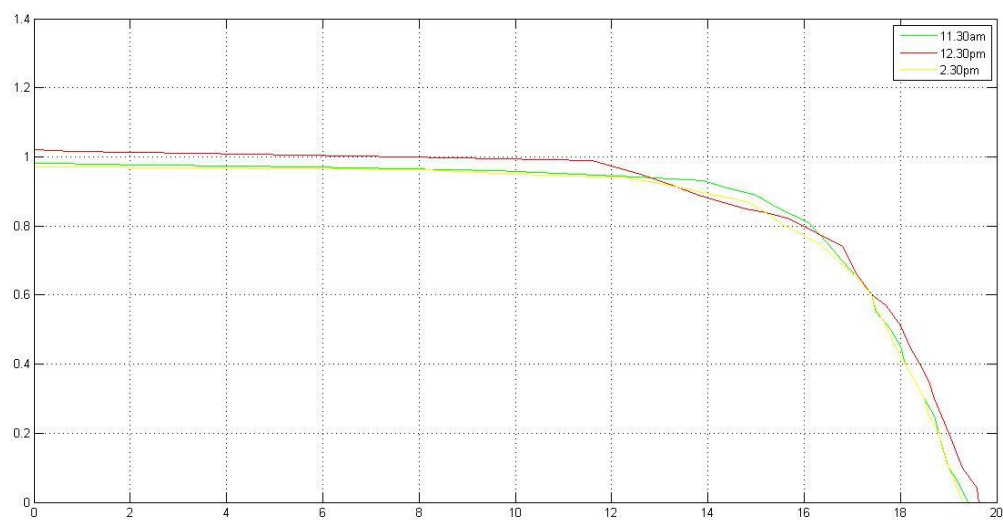


Figure: i-v characteristics curves for polycrystalline on 2<sup>nd</sup> June

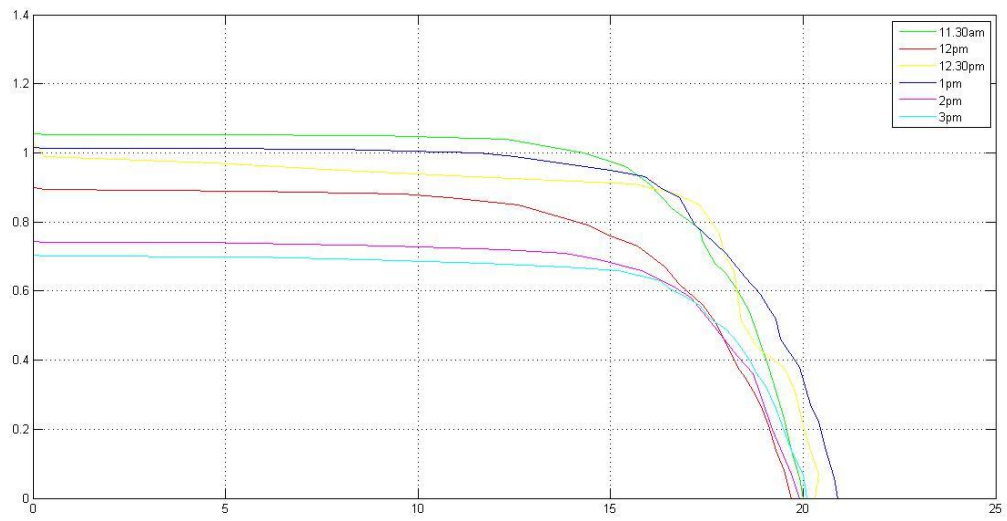


Figure: i-v characteristics curves for polycrystalline on 4<sup>th</sup> June

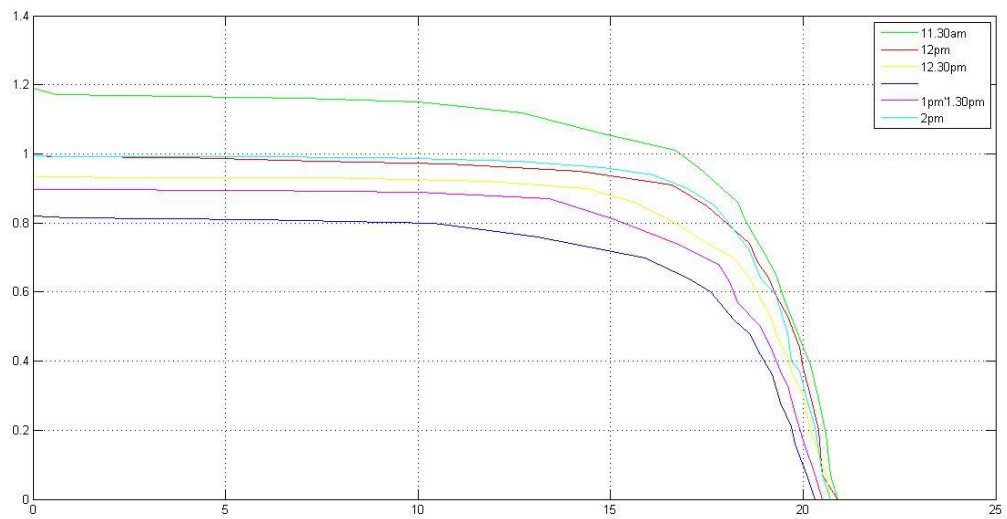


Figure: i-v characteristics curves for polycrystalline on 8<sup>th</sup> June

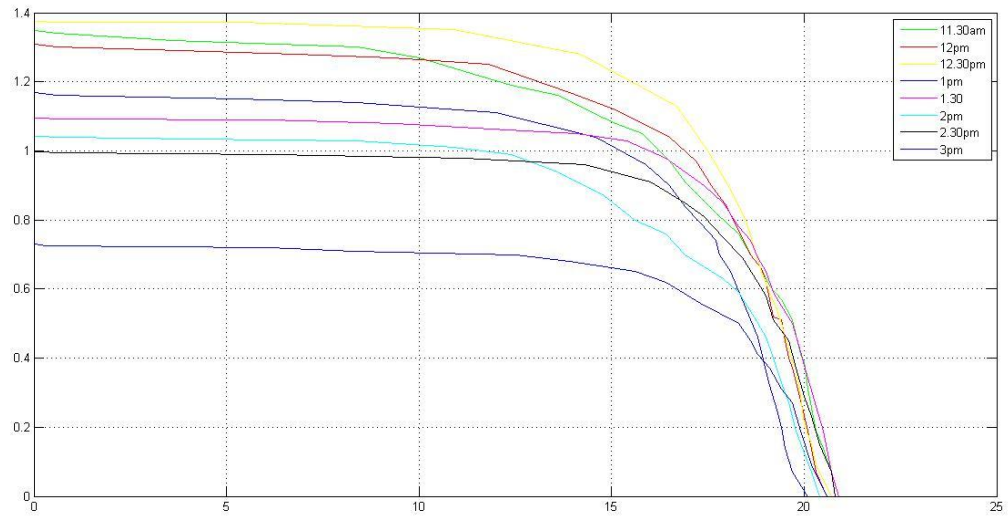


Figure: i-v characteristics curves for polycrystalline on 19<sup>th</sup>June

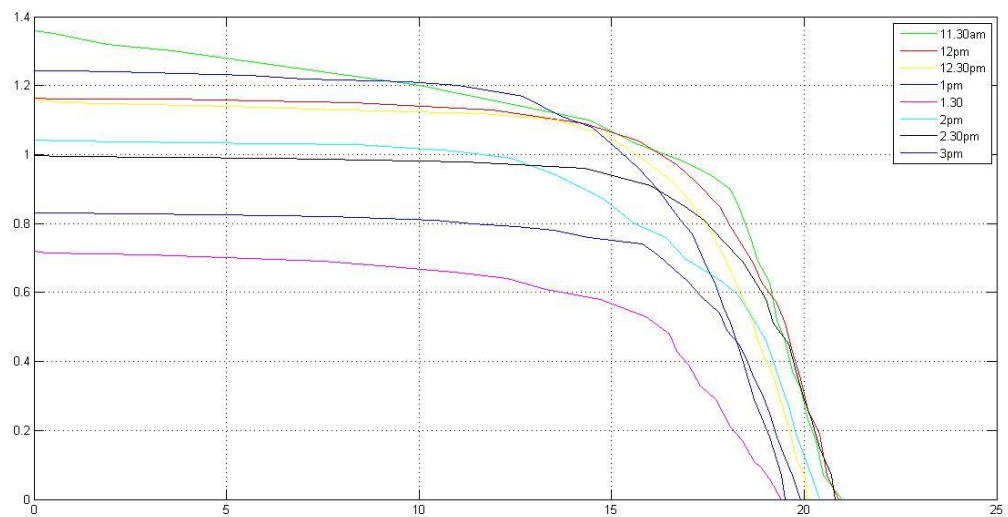


Figure: i-v characteristics curves for polycrystalline on 11thJuly

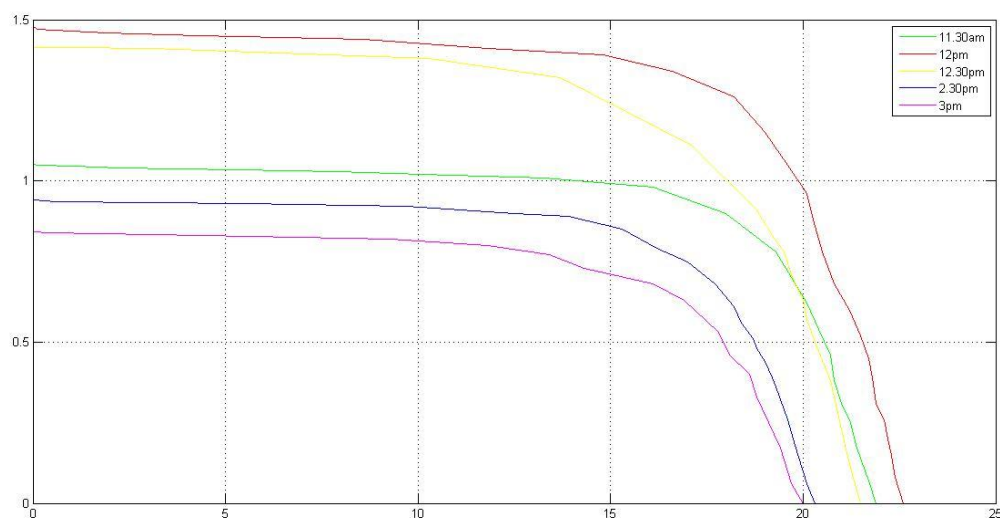


Figure: i-v characteristic curves for polycrystalline on 17<sup>th</sup> July.

In terms of outdoor experiments it is difficult to get data at a constant time interval due to the interference of clouds. Sunlight passing through clouds don't have the proper intensity of illumination to provide a strong current and voltage reading.

### **3.8 Energy Calculation:**

For calculating energy, the maximum power for every time interval was summed up and the result was multiplied with the constant time interval. In our experiment, the time interval was 30 minutes.

The equation for calculating energy =  $(P_{max1} + P_{max2} + \dots + P_{maxn}) \Delta t$

In 8<sup>th</sup> June for monocrystalline the energy =  $(11.79 + 11.7 + 11.4 + 11.28 + 6.82 + 6.66) * 0.5$

= 30 watt hour

In 8<sup>th</sup> June for monocrystalline the energy =  $(14.7 + 11.46 + 14.70 + 14.79 + 10.032 + 10.43) * 0.5$

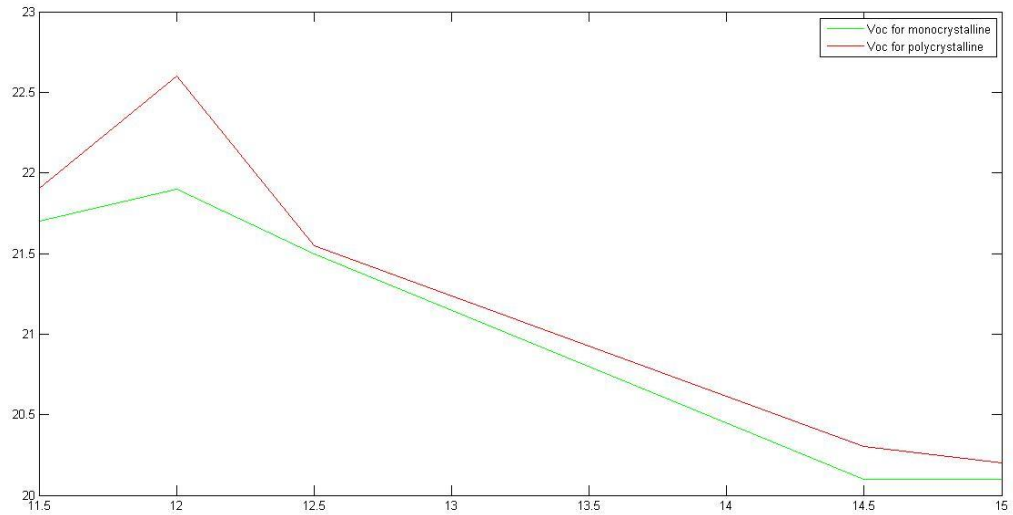
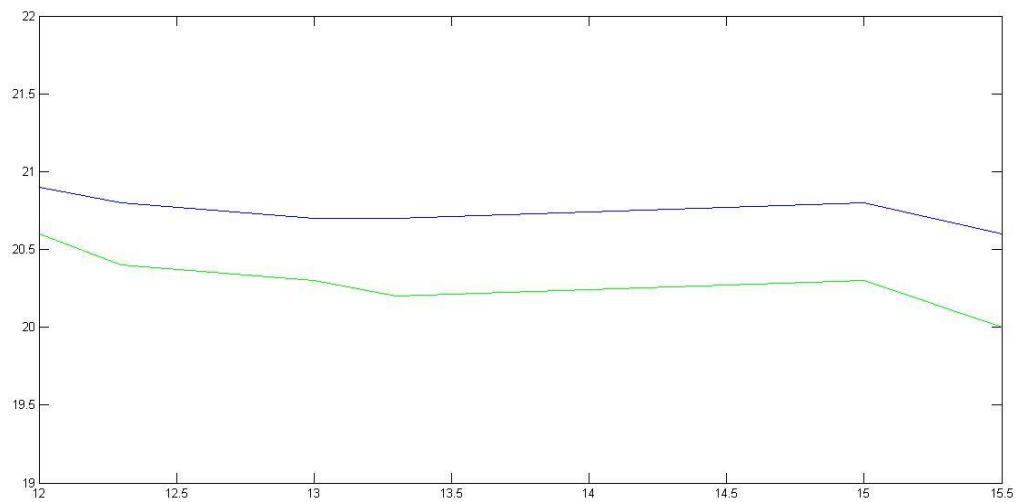
= 39 watt hour



**Figure: Outdoor Experiment Setup**

### **3.9.Comparison between polycrystalline and monocrystalline:**

By gathering data of both polycrystalline and mono crystalline at the same time of the day under similar conditions we can easily differentiate between them. To clearly analyze the difference we are going to plot the open circuit voltage  $V_{oc}$ , short circuit current  $I_{sc}$  and maximum power points of various times on 30 minutes interval of two different days of two different months days.

**Time against open circuit voltage:**Figure: time against Voc for 19<sup>th</sup> JuneFigure: time against Voc for 11<sup>th</sup> July

**Time against short circuit current:**

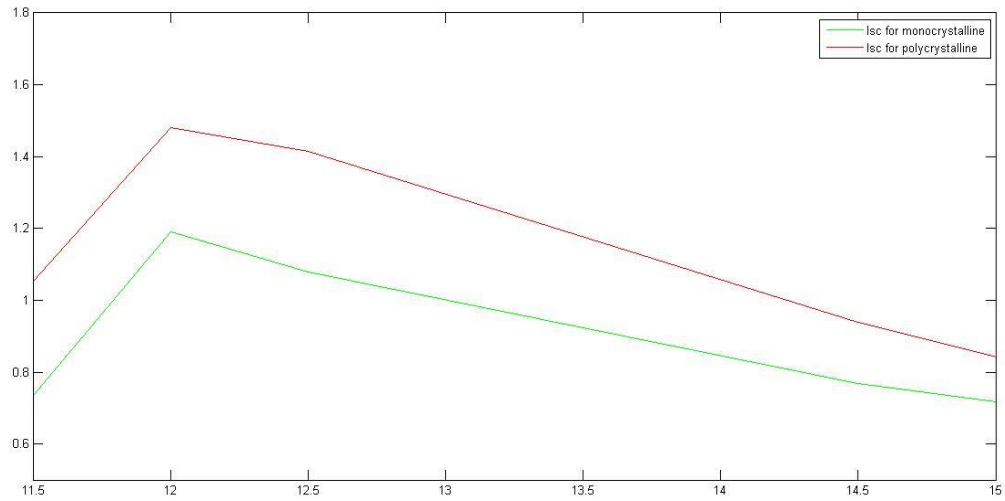


Figure: time against Isc for 19<sup>th</sup> June

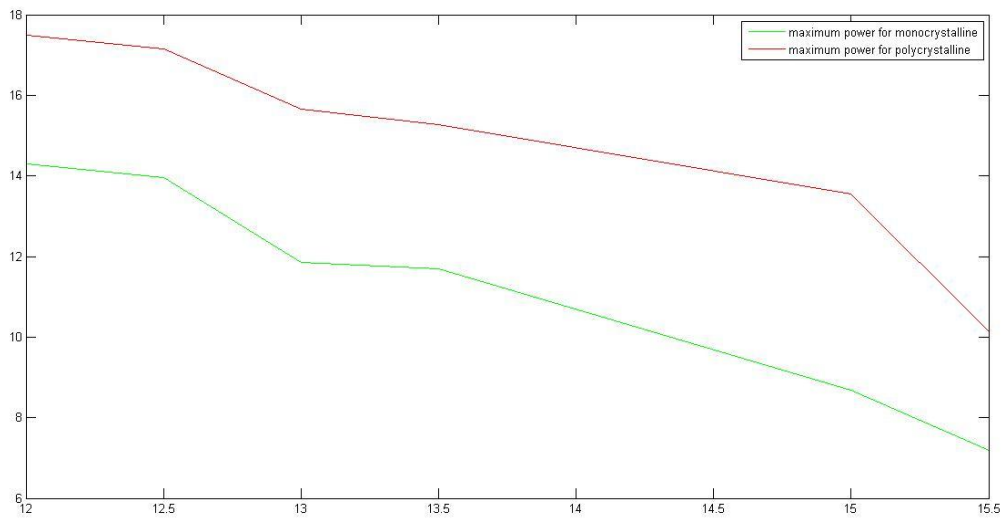


Figure: Time against Isc for 11<sup>th</sup> July



### Time against Maximum power:

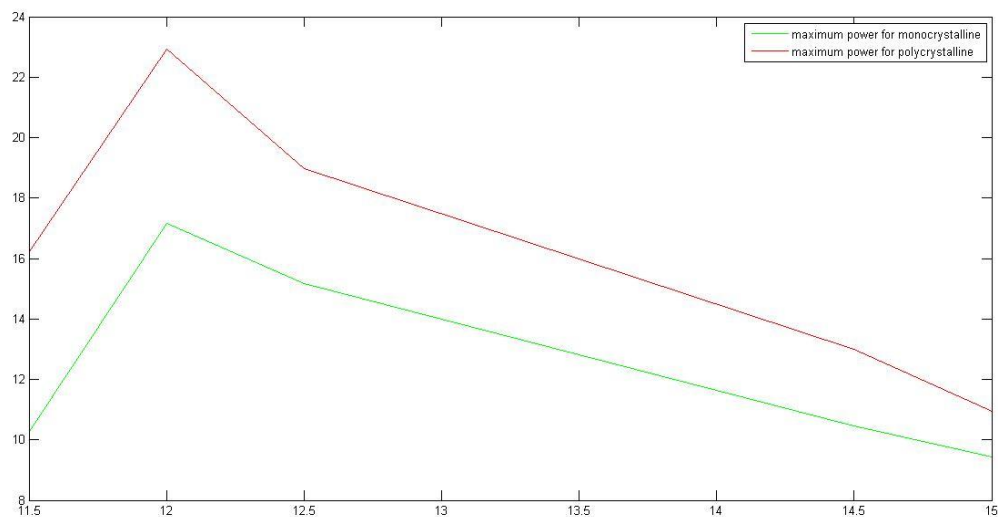


Figure : time against Pmax for 19th June.

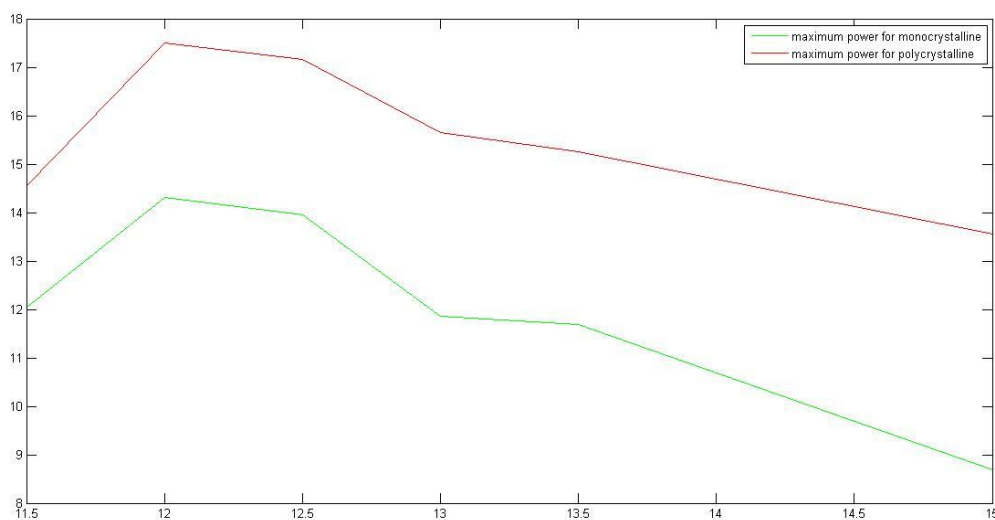


Figure: Time against Pmax for 11 July.

From the comparison curves we can clearly state that the 20Watt polycrystalline maintains a higher  $V_{oc}$  and a higher maximum power throughout the day. But the output of a polycrystalline module is less stable than a monocrystalline which provides a stable change of data for most parameter changes.

## **CHAPTER 4**

### **Economics and Future**

#### **4.1 Economic Importance**

Bangladesh is a developing country of the third world. However the development of our country is slower than expectation. The main reason behind this phenomenon is the growth of population. With the increase of population the demand for every element is increasing. Specialists in various fields are working on technologies through which they can meet the demands. The same goes for electricity. The demand for electricity is increasing day by day. In order to meet that, the grids are not sufficient. Energies from other fields are required to fulfill their needs. Solar energy can serve this purpose greatly. As it is a huge source and the energy is never ending, people can use the energy. Solar cells convert the sunlight to electrical energy and supply to various devices. However due to comparatively low efficiency people do not prefer solar cells for their regular use. If we think of the cost of solar panels, then we can say that they are comparatively more efficient in the long run. Because solar panels have warranty over 20 years and they cost only once which is a little high. On the other hand bills are paid every month for AC electricity. The bill is not fixed in every month. The amount varies according to the use. If we accumulate the bills of 20 years of a specific institution, we can see that solar panels are much cheaper than AC electricity. They last long and serve constantly in every purpose. Though the efficiency is slightly on the lower side, the cost can match up with that problem saving a lot of money which can be used in other fields to develop the overall condition of the country. Also in rural areas there are a lot of load shedding for which people have to suffer but still they have to pay bills for electricity. If they use solar panels, they will get constant supply of electricity and will not have to worry about load shedding.

## **4.2 Future works**

Currently, Bangladesh is going through a major electricity crisis. Government is taking various projects on implementing solar panels to provide a secondary method to provide electricity. But for the time being, all the projects are collecting solar energy and storing them to a DC battery instead of using the energy to support a locality through grid. In many developed countries, solar arrays are connected to grids and from there; the energy is distributed to the neighborhood. This technology is yet to come to our country.

These results can provide a further analysis for how to deal with the parameters in order to implement in the projects in larger scale. With the consideration of cost and sustainability, solar energy has a very huge role to play in this field.

## **CHAPTER 5**

### **Conclusion**

We have presented detailed solar photovoltaic power system data's starting with the solar cell device physics and its principle of operation, to solar cell efficiency. The experiments that we carried out to calculate the parameters affecting the solar cells, after finding the parameters theoretically we see that there are other factors affecting as well. The energy calculations for indoor is quite relevant but for outdoor it is a little bit higher than the theoretical value which is due to errors due to external factors other than temperature and illumination. We have selected this project to know about solar power generation systems, the working principles of power generation and inversion, how each and every equipment works and we have done that with success but with some environmental errors which cannot be altered humanly. The primary goal of this thesis is achieved. But we have faced some problems too. Some of the goals we had targeted are not achieved.

One of the factors that affect most while carrying out outdoor experiment is shading. Ideally solar panels should be located such that there will never be shadows on them because a shadow on even a small part of the panel can have a surprisingly large effect on the output. The cells within a panel are normally all wired in series and the shaded cells affect the current flow of the whole panel. But there can be situations where it cannot be avoided, and thus the effects of partial shading should be considered while carrying out experiments.

## CHAPTER 6

### REFERENCES

1. Green, Martin A. Solar Cells; Operating Principles, Technology, and System Applications, Prentice-Hall Inc, 1982 pp xii and pp 62-184
2. Roger A. Messenger and Jerry Ventre, "The Sun", Photovoltaic Systems Engineering, second edition, CRC Press , Boca Raton, Florida, 2003, pp.21-30
3. **Energy Harvesting: Solar, Wind, and Ocean Energy Conversion Systems**  
AlirezaKhaligh, Omer C. Onar
4. IMPROVING THE EFFICIENCY OF SOLAR POTOVOLTAIC POWER SYSTEM  
Henry A. Aribisala, 2013
5. An analytical method to extract the physical parameters of solar cell  
H.Saleem, IEEE electron deivce letters (volume 30, issue 4), March 2009.
6. Solar Electricity Handbook-2014 Edition: a simple Practical Guide to Solar Energy,  
MichealBoxwell.
7. Solar Electricity Basics, Dan Chiras
8. Photovoltaic Desigh and Installation,Ryan Mayfield.
9. PV Modules With variable Ideality Factors,GeorgieHristovYordanov.IEEE,june 2012,page 2362-2367.

## CHAPTER 7

### APPENDIX

#### Indoor Experiments:

#### For Fixed Light:

#### Monocrystalline 2 lights:

```
v25=[14.4 13.7 12.7 11.6 8.5 4.3 0.6 0]
```

```
i25=[0 72 80 85 89 91 92 92.5]
```

```
plot(v25,i25,'g');hold on;
```

```
v30=[17.1 13.6 13.1 12.5 11.7 10.8 9.7 8.9 7.9 6.9 5.1 2.8 0.1 0];
```

```
i30=[0 70 75 80 85 90 95 96 97 98 99 99.5 99.8 100];
```

```
plot(v30,i30,'y');
```

```
V35=[17.1 14.3 14.1 13.7 13.4 12.9 12.4 11.9 11.1 10.2 5.7 3.5 0.1 0];
```

```
I35=[0 70 75 80 85 90 95 100 105 109 111 112 113 114];
```

```
plot(V35,I35,'r');
```

```
v40=[16.66 13.74 13.55 13.24 12.88 12.36 11.71 11.01 9.81 7.73 5.97 3.55 0.13 0];
```

```
i40=[0 71 75 80 85 90 95 100 105 109 110 111 112 112.5];
```

```
plot(v40,i40,'m');grid on;
```

```
v45=[16.20 13.24 12.72 11.61 10.34 9.07 7.84 5.60 3.15 0.12 0];
```

```
i45=[0 70 80 90 100 105 108 110 111 111.5 112];
```

```
plot(v45,i45,'c');hold on;grid on;xlabel('voltage'),ylabel('current');
```

```
legend('25 degree','30 degree','35 degree','40degree','45 degree');
```

**Monocrystalline 4 lights:**

```
v25=[19.3 17.7 17.4 17.1 16.7 16.3 15.8 15.0 14.2 13.4 12.7 12.1 9.5 7.6 5.6 4.4 0.3 0];  
i25=[0 90 100 110 120 130 140 150 160 170 175 180 185 187 189 190 191 192];  
plot(v25,i25,'g');hold on;
```

```
v30=[18.7 17.0 16.9 16.6 16.3 16.1 15.9 15.7 15.4 15.1 14.8 14.6 14.2 13.8 13.4 12.6 11.8  
10.7 9.5 8.7 7.0 5.0 2.4 1.2 0.1 0 ];  
i30=[0 89 90 100 105 110 115 120 125 130 135 140 145 150 155 160 165 168 169 170 171  
172 173 174 175 177];  
plot(v30,i30,'y')
```

```
V35=[18.5 16.9 16.8 16.6 16.4 16.3 16.2 16.0 15.8 15.6 15.4 15.2 15.0 14.7 14.4 14.1 13.7  
13.2 12.7 12.2 11.6 10.8 8.3 5.6 1.6 0.1 0];  
I35=[0 86 90 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185  
190 195 198 200 201 202];  
plot(V35,I35,'r');hold on;
```

```
v40=[18.16 16.87 16.66 16.39 16.17 16.04 15.90 15.70 15.57 15.35 15.13 14.85 14.67 14.32  
14.02 13.72 13.43 13.09 12.62 12.07 11.52 10.95 9.36 6.30 4.18 1.86 0.39 0];  
i40=[0 89 100 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195  
200 204 206 208 210 210.5 211];  
plot(v40,i40,'m');hold on;
```

```
v45=[17.63 16.15 16.07 15.79 15.48 15.16 14.75 14.34 13.79 13.15 12.39 11.36 9.97 6.23  
3.13 0.22 0];  
i45=[0 87 90 100 110 120 130 140 150 160 170 180 190 192 194 195 196];  
plot(v45,i45,'c');grid on;xlabel('voltage'),ylabel('current');  
legend('25 degree','30 degree','35 degree','40degree','45 degree');
```

**Monocrystalline 6 lights:**

```
v25=[19.9 18.9 18.8 18.6 18.4 18.2 18.0 17.8 17.5 17.2 16.8 16.4 16.0 15.5 14.9 14.1 13.2  
12.1 9.0 7.7 6.7 5.2 3.2 0.4 0]
```

```
i25=[0 95 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 252 254 256  
258 260 261 262]
```

```
plot(v25,i25,'g');hold on;
```

```
v30=[19.4 18.4 18.3 18.2 18.1 18.0 17.9 17.8 17.7 17.6 17.5 17.4 17.3 17.2 17.1 17.0 16.8  
16.5 16.3 16.0 15.8 15.6 15.4 15.1 14.8 14.5 14.2 13.9 13.5 12.6 11.7 8.1 6.3 5.5 3.2 2.9 2.2  
0.2 0];
```

```
i30=[0 98 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195  
200 205 210 215 220 225 230 235 240 245 250 252 254 256 257 258 259 260];
```

```
plot(v30,i30,'y');
```

```
V35=[19.0 18.2 18.1 17.9 17.8 17.7 17.6 17.5 17.4 17.3 17.2 17.2 17.1 17.0 16.9 16.7 16.6  
16.5 16.3 16.1 15.9 15.7 15.5 15.3 15.1 14.9 14.7 14.4 14.1 13.7 13.2 12.8 12.4 11.7 11.1  
10.1 8.8 3.6 0.2 0];
```

```
I35=[0 94 100 110 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195 200  
205 210 215 220 225 230 235 240 245 250 255 260 265 270 275 278 280 281 284];
```

```
plot(V35,I35,'r');hold on;
```

```
v40=[18.72 17.87 17.80 17.66 17.49 17.35 17.17 16.99 16.81 16.57 16.29 15.97 15.69 15.43  
15.00 14.66 14.08 13.40 12.65 11.69 10.39 8.98 6.34 3.68 2.03 0.22 0];
```

```
i40=[0 94 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280  
282 284 286 287 288 290];
```

```
plot(v40,i40,'m');hold on;
```

```
v45=[18.31 17.56 17.46 17.32 17.21 17.03 16.90 16.74 16.56 16.32 16.05 15.80 15.61 15.27  
15.08 14.70 14.04 13.54 12.76 11.88 10.70 9.68 7.32 4.67 0.23 0];
```



```
i45=[0 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280
285 288 290 291 292];
plot(v45,i45,'c');grid on;xlabel('voltage'),ylabel('current');
legend('25 degree','30 degree','35 degree','40degree','45 degree');
```

### Monocrystalline 8 lights:

```
v25=[20.4 19.7 19.6 19.5 19.3 19.2 19.1 18.9 18.8 18.7 18.5 18.4 18.2 18.0 17.7 17.5 17.2
17.0 16.6 16.3 15.9 15.5 15.1 14.5 12.5 10.3 8.7 7.5 5.9 4.4 3.0 0.6 0]
i25=[0 101 110 120 130 140 150 160 170 170 180 190 200 210 220 230 240 250 260 270
280 290 300 310 320 322 324 324 326 328 330 331 333]
plot(v25,i25,'g');hold on;
```

```
v30=[19.9 19.2 19.1 19.0 18.9 18.7 18.6 18.5 18.4 18.3 18.2 18.1 18.0 17.8 17.6 17.5 17.4
17.3 17.1 16.9 16.7 16.5 16.4 16.3 16.0 15.4 14.8 14.2 13.6 12.6 10.9 8.8 8.0 7.2 6.3 5.1 3.7
1.9 0.4 0];
i30=[0 100 110 120 130 140 150 159 164 172 180 187 196 203 210 215 220 225 230 240
245 250 255 260 270 280 290 300 310 320 322 324 326 328 330 332 333 334 335 336];
plot(v30,i30,'y')
```

```
V35=[19.4 18.8 18.8 18.7 18.6 18.5 18.4 18.3 18.2 18.1 18.0 18.0 17.9 17.9 17.8 17.8 17.7
17.6 17.5 17.4 17.3 17.2 17.1 17.0 16.9 16.8 16.7 16.6 16.5 16.4 16.3 16.1 15.9 15.7 15.5
15.3 15.1 14.9 14.6 14.3 14.0 13.8 13.4 13.1 12.8 12.4 11.9 10.3 7.4 4.7 2.8 0.3 0];
I35=[0 98 100 110 120 130 140 150 160 165 170 175 180 185 190 195 200 205 210 215 220
225 230 235 240 245 250 255 260 265 270 275 280 285 290 295 300 305 310 315 320 325
330 335 340 345 350 355 360 362 364 365 367];
plot(V35,I35,'r');hold on;
```

```
v40=[19.23 18.59 18.55 18.47 18.37 18.27 18.20 18.07 17.94 17.83 17.73 17.60 17.43 17.26
17.14 16.98 16.81 16.61 16.45 16.24 16.11 15.86 15.59 15.19 14.81 14.44 13.91 13.27 12.56
11.77 10.08 8.37 6.59 2.90 0.34 0];
```

```
i40=[0 94 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280  
290 300 310 320 330 340 350 360 370 375 378 380 381 381.5 382];
```

```
plot(v40,i40,'m');hold on;
```

```
v45=[18.75 18.23 18.20 18.11 18.02 17.93 17.82 17.72 17.64 17.53 17.40 17.29 17.15 16.98  
16.84 16.78 16.65 16.48 16.24 16.08 15.89 15.55 15.30 15.05 14.82 14.42 14.04 13.54 12.68  
11.55 10.04 8.23 6.61 5.61 3.81 1.56 0.36 0]
```

```
i45=[0 95 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280  
290 300 310 320 330 340 350 360 370 378 380 382 384 386 390 391 392]
```

```
plot(v45,i45,'c');grid on;xlabel('voltage'),ylabel('current');
```

```
legend('25 degree','30 degree','35 degree','40degree','45 degree');
```

### **Monocrystalline 10 lights:**

```
v30=[20.3 19.7 19.6 19.5 19.4 19.3 19.2 19.1 19.0 18.9 18.8 18.7 18.6 18.5 18.3 18.2 18.1  
17.9 17.7 17.6 17.3 17.1 16.8 16.6 16.4 16.2 16.0 15.6 15.2 14.2 13.2 10.7 8.2 7.3 6.8 6.1 4.2  
2.4 0.5 0];
```

```
i30=[0 101 110 120 130 140 150 160 172 184 190 200 210 220 231 240 250 260 271 280  
290 300 310 320 330 340 350 360 370 380 385 390 391 393 395 397 399 400 400.5 401];
```

```
plot(v30,i30,'g');hold on;
```

```
V35= [19.9 19.2 19.2 19.1 19.1 19.1 19.0 18.9 18.8 18.7 18.6 18.6 18.6 18.5 18.5 18.4 18.4  
18.3 18.2 18.1 18.1 18.0 18.0 18.0 17.9 17.8 17.8 17.7 17.6 17.5 17.4 17.3 17.2 17.1 17.0  
16.9 16.8 16.7 16.6 16.5 16.4 16.2 16.1 16.0 15.9 15.8 15.7 15.4 15.1 14.8 14.5 14.2 13.9  
13.7 13.2 12.8 12.4 11.8 9.5 5.5 3.5 0.3 0];
```

```
I35=[0 98 100 110 120 130 140 150 160 170 180 185 190 195 200 205 210 215 220 225 230  
235 240 250 255 260 265 270 275 280 285 290 295 300 305 310 315 320 325 330 335 340  
345 350 355 360 365 370 375 380 385 390 395 400 405 410 415 420 425 430 432 434 439];
```

```
plot(V35,I35,'y');hold on;
```

```
v40=[19.43 18.96 18.92 18.79 18.64 18.56 18.47 18.38 18.27 18.19 18.09 18.00 17.91 17.80
17.62 17.57 17.52 17.44 17.32 17.22 17.10 16.96 16.77 16.65 16.45 16.15 15.88 15.60 15.33
15.04 14.61 13.89 13.51 12.67 11.38 10.22 7.49 6.31 4.83 2.29 0.44 0];
i40=[0 98 100 120 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300
310 320 330 340 350 360 370 380 390 400 410 420 430 438 440 442 444 446 448 450 451];
plot(v40,i40,'r');hold on;
```

```
v45=[19.06 18.53 18.49 18.43 18.37 18.29 18.21 18.14 18.07 17.96 17.90 17.86 17.80 17.72
17.66 17.55 17.42 17.37 17.30 17.23 17.14 16.98 16.80 16.68 16.48 16.30 16.19 15.94 15.75
15.37 14.99 14.75 14.44 13.93 13.66 13.08 12.40 9.44 8.08 6.90 5.45 3.13 0.53 0];
i45=[0 96 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280
290 300 310 320 330 340 350 360 370 380 390 400 410 420 430 440 442 445 447 449 451
452 453];
plot(v45,i45,'m');grid on;xlabel('voltage'),ylabel('current');
legend('30 degree','35 degree','40degree','45 degree');
```

### **Polycrystalline 2 lights:**

```
v25=[17.5 13.7 13.2 12.8 11.6 8.5 7.1 4.3 0.3 0];
i25=[0 70 75 80 85 88 90 91 91.5 92];
plot(v25,i25,'g');hold on;
```

```
v30=[18.7 16.5 16.3 16.0 15.7 15.2 14.6 13.7 12.4 10.7 8.6 7.9 6.3 4.7 3.9 2.0 0.10 0];
i30=[0 85 90 95 100 105 110 115 120 122 123 124 125 126 127 128 129 129.5];
plot(v30,i30,'y');hold on;
```

```
v35=[18.5 17.0 16.7 16.3 16.1 15.9 15.5 15.1 14.7 13.9 13.2 11.5 0.09 0]
i35=[0 90 100 110 115 120 125 130 135 140 145 150 155 156]
plot(v35,i35,'r');hold on;
```

```
v40=[17.6 16.0 15.8 15.6 15.3 15.0 14.5 14.0 13.3 12.8 12.2 10.4 9.5 6.8 5.2 3.1 1.5 0.5 0];
i40=[0 81 85 90 95 100 105 110 115 118 120 122 124 126 128 129 130 130.5 131];
```

```
plot(v40,i40,'m');grid on;
```

```
v45=[17.4 15.7 15.4 14.8 14.1 13.4 12.8 11.4 10.6 9.7 7.0 4.4 0.2 0]
```

```
i45=[0 80 90 100 110 115 120 122 125 127 129 130 131 132]
```

```
plot(v45,i45,'c');grid on;xlabel('voltage'),ylabel('current');
```

```
legend('25 degree','30 degree','35 degree','40degree','45 degree');
```

### **Polycrystalline 4 lights:**

```
v30=[19.6 18.7 18.7 18.6 18.5 18.4 18.3 18.2 18.1 18.0 17.9 17.8 17.7 17.5 17.3 17.2 17.0  
16.8 16.5 16.3 16.0 15.7 15.3 14.6 14.0 13.1 10.7 8.7 4.9 2.5 0.2 0];
```

```
i30=[0 96 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190  
195 200 205 210 215 218 220 221 222 223 224];
```

```
plot(v30,i30,'g');hold on;
```

```
v35=[19.3 18.5 18.4 18.3 18.1 18.0 17.8 17.7 17.4 17.1 16.9 16.7 16.3 15.9 15.5 15.0 14.6  
13.9 13.5 13.1 12.6 11.9 5.6 3.1 1.9 0.9 0.1 0]
```

```
i35=[0 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 251 252 253  
254 255 256 257 258 259 260 262]
```

```
plot(v35,i35,'y');hold on
```

```
v40=[18.7 17.8 17.7 17.6 17.5 17.4 17.3 17.2 17.1 17.0 16.9 16.8 16.6 16.4 16.2 16.0 15.8  
15.6 15.4 15.2 14.9 14.3 13.5 12.7 10.4 7.5 5.3 2.8 0.4 0];
```

```
i40=[0 92 100 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195  
200 205 210 215 218 220 221 222 223];
```

```
plot(v40,i40,'r');hold on;
```

```
v45=[18.3 17.5 17.2 16.9 16.4 16.0 15.6 15.1 14.5 13.8 12.2 8.8 6.4 3.2 0.5 0]
```

```
i45=[0 90 110 130 150 170 180 190 200 210 220 223 225 227 229 230]
```

```
plot(v45,i45,'m');hold on;gridon;xlabel('voltage'),ylabel('current');
```

```
legend('30 degree','35 degree','40degree','45 degree');
```

**Polycrystalline 6 lights:**

```
v25=[20.4 19.7 19.6 19.5 19.4 19.3 19.1 18.9 18.7 18.5 18.3 18.1 17.9 17.7 17.5 17.2 16.9  
16.6 16.3 15.9 15.5 15.0 14.5 14.0 13.3 12.5 11.2 10.3 8.7 7.5 6.9 5.5 4.9 3.8 2.2 0.6 0];  
i25=[0 102 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280  
290 300 310 315 320 321 322 323 324 325 326 327 328 329 330 331 332];  
plot(v25,i25,'g');hold on;grid on;
```

```
v30=[20.1 19.6 19.6 19.6 19.5 19.4 19.36 19.28 19.20 19.1 19.0 18.9 18.8 18.6 18.5 18.4  
18.2 18.0 17.8 17.6 17.4 17.2 16.8 16.6 16.3 16.0 15.7 15.4 15.2 14.7 13.7 12.7 11.4 9.3 6.6  
4.4 2.6 1.6 0.4 0];  
i30=[0 98 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280  
290 300 310 315 320 325 330 335 340 345 347 349 350 351 352 353 354 355 356];  
plot(v30,i30,'y');hold on;
```

```
v35=[19.7 19.1 18.7 18.3 18.0 17.7 17.5 17.0 16.4 15.6 15.0 14.0 11.0 9.3 7.3 6.7 4.4 2.3  
0.02 0]  
i35=[0 0100 150 200 220 240 0260 280 300 320 330 340 343 346 349 351 355 358 359 360]  
plot(v35,i35,'r');hold on;
```

```
v40=[19.2 18.7 18.6 18.6 18.5 18.4 18.3 18.2 18.1 18.0 17.9 17.7 17.6 17.5 17.4 17.3 17.1  
16.8 16.6 16.4 16.2 15.8 15.4 14.7 14.1 11.8 6.5 2.5 0.3 0];  
i40=[0 98 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290  
300 310 320 330 340 345 350 351 352];  
plot(v40,i40,'m');hold on;
```

```
v45=[18.8 18.3 17.9 17.7 17.5 17.3 17.0 16.7 16.4 16.1 15.8 15.4 15.0 14.5 13.8 10.1 6.2 4.6  
0.4 0]  
i45=[0 95 150 170 190 210 230 250 260 270 290 300 310 320 330 340 350 353 356 360]
```

```
length(v45)
length(i45)
plot(v45,i45,'c');hold on;grid on;xlabel('voltage'),ylabel('current');
legend('25 degree','30 degree','35 degree','40degree','45 degree');
```

### **Polycrystalline 8 lights:**

```
v30=[20.4 20.0 19.9 19.9 19.8 19.8 19.8 19.7 19.6 19.5 19.4 19.3 19.2 19.1 19.0 18.9 18.8
18.7 18.6 18.5 18.4 18.3 18.1 18.0 17.8 17.6 17.3 17.1 16.5 15.8 14.9 14.6 13.5 12.2 7.3 6.6
5.7 4.4 3.1 2.3 1.0 0.3];
```

```
i30=[0 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280
290 300 310 320 330 340 350 360 370 380 390 400 405 410 415 420 423 426 429 432 435
437];
```

```
plot(v30,i30,'g');hold on;
```

```
v35=[20.0 19.7 19.0 18.2 17.9 17.6 17.2 16.8 16.4 15.8 15.2 14.3 13.5 11.3 6.7 2.8 0.05 0];
```

```
i35=[0 100 200 300 330 350 375 390 400 410 420 430 435 440 443 445 446 450];
```

```
plot(v35,i35,'y');hold on;
```

```
v40=[19.6 19.2 19.1 19.0 18.9 18.89 18.84 18.78 18.73 18.6 18.5 18.4 18.3 18.3 18.2 18.1
18.0 17.9 17.8 17.7 17.6 17.5 17.4 17.3 17.2 17.0 16.8 16.6 16.2 15.8 15.4 14.9 14.3 13.6
12.2 10.8 8.6 7.5 6.6 4.8 1.8 0.30 0];
```

```
i40=[0 98 110 130 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300 310
320 330 340 350 360 370 380 390 400 410 420 430 435 438 440 442 444 448 450 452 454
455];
```

```
plot(v40,i40,'r');
```

```
v45=[18.8 18.7 18.4 18.1 17.8 17.4 17.1 16.9 16.6 16.2 15.8 15.4 15.1 14.6 14.0 12.4 7.4 5.2
3.7 0.4 0];
```

```
i45=[0 98 150 200 250 300 330 350 370 390 400 410 420 430 440 450 455 458 460 461
463];
plot(v45,i45,'m');grid on;xlabel('voltage'),ylabel('current');
legend('30 degree','35 degree','40degree','45 degree');
```

### Polycrystalline 10 lights:

```
V30=[20.7 20.2 20.1 20.0 19.9 19.8 19.7 19.6 19.5 19.5 19.5 19.4 19.4 19.3 19.2 19.2 19.1
19.0 18.9 18.8 18.7 18.6 18.5 18.4 18.3 18.2 18.1 18.0 17.8 17.6 17.4 17.1 16.8 16.4 16.1
15.3 14.1 13.3 12.5 11.8 11.0 10.6 7.9 4.8 2.3 0.4];
```

```
I30=[0 101 110 120 160 180 200 220 230 240 250 260 270 280 290 300 310 320 330 340
350 360 370 380 390 400 410 420 430 440 450 460 470 480 490 500 510 520 525 530 535
538 541 545 548 552];
```

```
plot(V30,I30,'g');hold on;
```

```
v35=[20.3 19.8 19.4 18.8 18.5 18.3 18.2 17.9 17.6 17.3 16.9 16.7 16.3 15.8 15.2 14.3 11.8
8.5 5.3 3.1 0.3 0];
```

```
i35=[0 100 200 300 350 375 390 410 430 450 460 470 480 490 500 510 515 520 525 530
531 535];
```

```
plot(v35,i35,'y');hold on;
```

```
v40=[19.8 19.4 19.4 19.3 19.2 19.1 19.0 18.9 18.8 18.79 18.74 18.69 18.63 18.58 18.52
18.47 18.41 18.36 18.30 18.2 18.1 18.0 17.9 17.8 17.7 17.6 17.5 17.4 17.3 17.2 17.0 16.8
16.6 16.3 15.9 15.6 14.8 13.7 12.5 11.3 10.0 8.9 7.8 6.1 4.5 3.3 0.5 0];
```

```
i40=[0 99 100 120 140 160 180 200 220 230 240 250 260 270 280 290 300 310 320 330 340
350 360 370 380 390 400 410 420 430 440 450 460 470 480 490 500 510 520 530 540 550
555 560 565 570 575 576];
```

```
plot(v40,i40,'r');hold on;
```

```
v45=[19.3 19.0 18.4 18.1 17.9 17.6 17.4 17.2 17.0 16.7 16.5 16.2 16.0 15.8 15.5 15.1 14.7
14.2 13.5 12.4 10.7 7.5 5.3 3.2 0.4 0]
```

```
i45=[0 100 200 250 300 350 370 390 410 430 440 450 460 470 480 490 500 510 520 530
540 550 560 565 570 574]
plot(v45,i45,'m');grid on;xlabel('voltage'),ylabel('current');
legend('25 degree','30 degree','35 degree','40degree','45 degree');
```

### **For fixed temperature:**

#### **Monocrystalline 25 degree Celsius:**

```
v2=[14.4 13.7 12.7 11.6 8.5 4.3 0.6 0]
i2=[0 72 80 85 89 91 92 92.5]
plot(v2,i2,'g');hold on;
```

```
v4=[19.3 17.7 17.4 17.1 16.7 16.3 15.8 15.0 14.2 13.4 12.7 12.1 9.5 7.6 5.6 4.4 0.3 0]
i4=[0 90 100 110 120 130 140 150 160 170 175 180 185 187 189 190 191 192]
plot(v4,i4,'r');hold on;
```

```
v6=[19.9 18.9 18.8 18.6 18.4 18.2 18.0 17.8 17.5 17.2 16.8 16.4 16.0 15.5 14.9 14.1 13.2
12.1 9.0 7.7 6.7 5.2 3.2 0.4 0]
i6=[0 95 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 252 254 256
258 260 261 262]
plot(v6,i6,'y');hold on;
```

```
v8=[20.4 19.7 19.6 19.5 19.3 19.2 19.1 18.9 18.8 18.7 18.5 18.4 18.2 18.0 17.7 17.5 17.2
17.0 16.6 16.3 15.9 15.5 15.1 14.5 12.5 10.3 8.7 7.5 5.9 4.4 3.0 0.6 0]
i8=[0 101 110 120 130 140 150 160 170 170 180 190 200 210 220 230 240 250 260 270 280
290 300 310 320 322 324 324 326 328 330 331 333]
plot(v8,i8,'m');grid on;gridon;xlabel('voltage'),ylabel('current');
legend('10Lights','8lights','6lights','4lights','2lights');
```



**Monocrystalline 30 degree Celsius:**

```
v1=[20.3 19.7 19.6 19.5 19.4 19.3 19.2 19.1 19.0 18.9 18.8 18.7 18.6 18.5 18.3 18.2 18.1  
17.9 17.7 17.6 17.3 17.1 16.8 16.6 16.4 16.2 16.0 15.6 15.2 14.2 13.2 10.7 8.2 7.3 6.8 6.1 4.2  
2.4 0.5 0];
```

```
i1=[0 101 110 120 130 140 150 160 172 184 190 200 210 220 231 240 250 260 271 280 290  
300 310 320 330 340 350 360 370 380 385 390 391 393 395 397 399 400 400.5 401];
```

```
plot(v1,i1,'g');hold on;
```

```
v2=[19.9 19.2 19.1 19.0 18.9 18.7 18.6 18.5 18.4 18.3 18.2 18.1 18.0 17.8 17.6 17.5 17.4  
17.3 17.1 16.9 16.7 16.5 16.4 16.3 16.0 15.4 14.8 14.2 13.6 12.6 10.9 8.8 8.0 7.2 6.3 5.1 3.7  
1.9 0.4 0];
```

```
i2=[0 100 110 120 130 140 150 159 164 172 180 187 196 203 210 215 220 225 230 240 245  
250 255 260 270 280 290 300 310 320 322 324 326 328 330 332 333 334 335 336];
```

```
plot(v2,i2,'r')
```

```
v3=[19.4 18.4 18.3 18.2 18.1 18.0 17.9 17.8 17.7 17.6 17.5 17.4 17.3 17.2 17.1 17.0 16.8  
16.5 16.3 16.0 15.8 15.6 15.4 15.1 14.8 14.5 14.2 13.9 13.5 12.6 11.7 8.1 6.3 5.5 3.2 2.9 2.2  
0.2 0];
```

```
i3=[0 98 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195  
200 205 210 215 220 225 230 235 240 245 250 252 254 256 257 258 259 260];
```

```
plot(v3,i3,'y')
```

```
v7=[18.7 17.0 16.9 16.6 16.3 16.1 15.9 15.7 15.4 15.1 14.8 14.6 14.2 13.8 13.4 12.6 11.8  
10.7 9.5 8.7 7.0 5.0 2.4 1.2 0.1 0];
```

```
i7=[0 89 90 100 105 110 115 120 125 130 135 140 145 150 155 160 165 168 169 170 171  
172 173 174 175 177];
```

```
plot(v7,i7,'m');grid on;xlabel('voltage'),ylabel('current');
```

```
legend('10Lights','8lights','6lights','4lights','2lights');
```

```
v8=[17.1 13.6 13.1 12.5 11.7 10.8 9.7 8.9 7.9 6.9 5.1 2.8 0.1 0];
```

```
i8=[0 70 75 80 85 90 95 96 97 98 99 99.5 99.8 100];
```

```
plot(v8,i8,'c')
```

```
grid on;
```

### **Monocrystalline 35 degree Celsius:**

```
V10= [19.9 19.2 19.2 19.1 19.1 19.1 19.0 18.9 18.8 18.7 18.6 18.6 18.6 18.5 18.5 18.4 18.4  
18.3 18.2 18.1 18.1 18.0 18.0 18.0 17.9 17.8 17.8 17.7 17.6 17.5 17.4 17.3 17.2 17.1 17.0  
16.9 16.8 16.7 16.6 16.5 16.4 16.2 16.1 16.0 15.9 15.8 15.7 15.4 15.1 14.8 14.5 14.2 13.9  
13.7 13.2 12.8 12.4 11.8 9.5 5.5 3.5 0.3 0];
```

```
I10=[0 98 100 110 120 130 140 150 160 170 180 185 190 195 200 205 210 215 220 225 230  
235 240 250 255 260 265 270 275 280 285 290 295 300 305 310 315 320 325 330 335 340  
345 350 355 360 365 370 375 380 385 390 395 400 405 410 415 420 425 430 432 434 439];
```

```
plot(V10,I10,'g');hold on;
```

```
V8=[19.4 18.8 18.8 18.7 18.6 18.5 18.4 18.3 18.2 18.1 18.0 18.0 17.9 17.9 17.8 17.8 17.7  
17.6 17.5 17.4 17.3 17.2 17.1 17.0 16.9 16.8 16.7 16.6 16.5 16.4 16.3 16.1 15.9 15.7 15.5  
15.3 15.1 14.9 14.6 14.3 14.0 13.8 13.4 13.1 12.8 12.4 11.9 10.3 7.4 4.7 2.8 0.3 0];
```

```
I8=[0 98 100 110 120 130 140 150 160 165 170 175 180 185 190 195 200 205 210 215 220  
225 230 235 240 245 250 255 260 265 270 275 280 285 290 295 300 305 310 315 320 325  
330 335 340 345 350 355 360 362 364 365 367];
```

```
plot(V8,I8,'r');hold on;
```

```
V6=[19.0 18.2 18.1 17.9 17.8 17.7 17.6 17.5 17.4 17.3 17.2 17.2 17.1 17.0 16.9 16.7 16.6  
16.5 16.3 16.1 15.9 15.7 15.5 15.3 15.1 14.9 14.7 14.4 14.1 13.7 13.2 12.8 12.4 11.7 11.1  
10.1 8.8 3.6 0.2 0];
```

```
I6=[0 94 100 110 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195 200  
205 210 215 220 225 230 235 240 245 250 255 260 265 270 275 278 280 281 284];
```

```
plot(V6,I6,'y');hold on;
```

```
V4=[18.5 16.9 16.8 16.6 16.4 16.3 16.2 16.0 15.8 15.6 15.4 15.2 15.0 14.7 14.4 14.1 13.7  
13.2 12.7 12.2 11.6 10.8 8.3 5.6 1.6 0.1 0];
```

```
I4=[0 86 90 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185  
190 195 198 200 201 202];
```

```
plot(V4,I4,'m');hold on;
```

```
V2=[17.1 14.3 14.1 13.7 13.4 12.9 12.4 11.9 11.1 10.2 5.7 3.5 0.1 0];
```

```
I2=[0 70 75 80 85 90 95 100 105 109 111 112 113 114];
```

```
plot(V2,I2,'c');hold on;
```

```
gridon;xlabel('voltage'),ylabel('current');
```

```
legend('10Lights','8lights','6lights','4lights','2lights');
```

### **Monocrystalline 40 degree Celsius:**

```
v10=[19.43 18.96 18.92 18.79 18.64 18.56 18.47 18.38 18.27 18.19 18.09 18.00 17.91 17.80  
17.62 17.57 17.52 17.44 17.32 17.22 17.10 16.96 16.77 16.65 16.45 16.15 15.88 15.60 15.33  
15.04 14.61 13.89 13.51 12.67 11.38 10.22 7.49 6.31 4.83 2.29 0.44 0];
```

```
i10=[0 98 100 120 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300  
310 320 330 340 350 360 370 380 390 400 410 420 430 438 440 442 444 446 448 450 451];
```

```
plot(v10,i10,'g');hold on;
```

```
v8=[19.23 18.59 18.55 18.47 18.37 18.27 18.20 18.07 17.94 17.83 17.73 17.60 17.43 17.26  
17.14 16.98 16.81 16.61 16.45 16.24 16.11 15.86 15.59 15.19 14.81 14.44 13.91 13.27 12.56  
11.77 10.08 8.37 6.59 2.90 0.34 0];
```

```
i8=[0 94 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280  
290 300 310 320 330 340 350 360 370 375 378 380 381 381.5 382];
```

```
plot(v8,i8,'y');hold on;
```

```
v6=[18.72 17.87 17.80 17.66 17.49 17.35 17.17 16.99 16.81 16.57 16.29 15.97 15.69 15.43  
15.00 14.66 14.08 13.40 12.65 11.69 10.39 8.98 6.34 3.68 2.03 0.22 0];
```

```
i6=[0 94 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280  
282 284 286 287 288 290];
```

```
plot(v6,i6,'r');hold on;
```

```
v4=[18.16 16.87 16.66 16.39 16.17 16.04 15.90 15.70 15.57 15.35 15.13 14.85 14.67 14.32  
14.02 13.72 13.43 13.09 12.62 12.07 11.52 10.95 9.36 6.30 4.18 1.86 0.39 0];  
i4=[0 89 100 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195  
200 204 206 208 210 210.5 211];  
plot(v4,i4,'m');hold on;
```

```
v2=[16.66 13.74 13.55 13.24 12.88 12.36 11.71 11.01 9.81 7.73 5.97 3.55 0.13 0];  
i2=[0 71 75 80 85 90 95 100 105 109 110 111 112 112.5];  
plot(v2,i2,'c');grid on;  
xlabel('voltage'),ylabel('current');  
legend('10Lights','8lights','6lights','4lights','2lights');
```

### **Monocrystalline 45 degree Celsius:**

```
v2=[16.20 13.24 12.72 11.61 10.34 9.07 7.84 5.60 3.15 0.12 0];  
i2=[0 70 80 90 100 105 108 110 111 111.5 112];  
plot(v2,i2,'g');hold on;
```

```
v4=[17.63 16.15 16.07 15.79 15.48 15.16 14.75 14.34 13.79 13.15 12.39 11.36 9.97 6.23  
3.13 0.22 0];  
i4=[0 87 90 100 110 120 130 140 150 160 170 180 190 192 194 195 196];  
plot(v4,i4,'y')
```

```
v6=[18.31 17.56 17.46 17.32 17.21 17.03 16.90 16.74 16.56 16.32 16.05 15.80 15.61 15.27  
15.08 14.70 14.04 13.54 12.76 11.88 10.70 9.68 7.32 4.67 0.23 0];  
i6=[0 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280  
285 288 290 291 292];  
plot(v6,i6,'r')
```

```
v8=[18.75 18.23 18.20 18.11 18.02 17.93 17.82 17.72 17.64 17.53 17.40 17.29 17.15 16.98  
16.84 16.78 16.65 16.48 16.24 16.08 15.89 15.55 15.30 15.05 14.82 14.42 14.04 13.54 12.68  
11.55 10.04 8.23 6.61 5.61 3.81 1.56 0.36 0]  
i8=[0 95 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280  
290 300 310 320 330 340 350 360 370 378 380 382 384 386 390 391 392]  
plot(v8,i8,'m')
```

```
v10=[19.06 18.53 18.49 18.43 18.37 18.29 18.21 18.14 18.07 17.96 17.90 17.86 17.80 17.72  
17.66 17.55 17.42 17.37 17.30 17.23 17.14 16.98 16.80 16.68 16.48 16.30 16.19 15.94 15.75  
15.37 14.99 14.75 14.44 13.93 13.66 13.08 12.40 9.44 8.08 6.90 5.45 3.13 0.53 0];  
i10=[0 96 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280  
290 300 310 320 330 340 350 360 370 380 390 400 410 420 430 440 442 445 447 449 451  
452 453];  
plot(v10,i10,'c')  
gridon;xlabel('voltage'),ylabel('current');  
legend('10Lights','8lights','6lights','4lights','2lights');
```

### **Polycrystalline 25 degree Celsius:**

```
v2=[17.5 13.7 13.2 12.8 11.6 8.5 7.1 4.3 0.3 0];  
i2=[0 70 75 80 85 88 90 91 91.5 92];  
plot(v2,i2,'g');hold on;  
  
v4=[19.3 17.7 17.6 17.4 17.3 17.1 16.9 16.7 16.5 16.3 16.0 15.8 15.6 15.0 14.6 14.2 13.8  
13.4 12.7 11.8 10.8 10.1 9.6 8.5 6.6 4.8 2.2 0.3 0];  
i4=[0 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 182  
184 186 188 189 190 190.5 191 192];  
plot(v4,i4,'y');hold on;
```

```
v8=[20.4 19.7 19.6 19.5 19.4 19.3 19.1 18.9 18.7 18.5 18.3 18.1 17.9 17.7 17.5 17.2 16.9
16.6 16.3 15.9 15.5 15.0 14.5 14.0 13.3 12.5 11.2 10.3 8.7 7.5 6.9 5.5 4.9 3.8 2.2 0.6 0];
i8=[0 102 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290
300 310 315 320 321 322 323 324 325 326 327 328 329 330 331 332];
plot(v8,i8,'r');hold on;grid on;xlabel('voltage'),ylabel('current');
legend('10Lights','8lights','6lights','4lights','2lights');
```

### Polycrystalline 30 degree Celsius:

```
V1=[20.7 20.2 20.1 20.0 19.9 19.8 19.7 19.6 19.5 19.5 19.5 19.4 19.4 19.3 19.2 19.2 19.1
19.0 18.9 18.8 18.7 18.6 18.5 18.4 18.3 18.2 18.1 18.0 17.8 17.6 17.4 17.1 16.8 16.4 16.1
15.3 14.1 13.3 12.5 11.8 11.0 10.6 7.9 4.8 2.3 0.4];
I1=[0 101 110 120 160 180 200 220 230 240 250 260 270 280 290 300 310 320 330 340 350
360 370 380 390 400 410 420 430 440 450 460 470 480 490 500 510 520 525 530 535 538
541 545 548 552];
plot(V1,I1,'g');hold on;
```

```
v2=[20.4 20.0 19.9 19.9 19.8 19.8 19.8 19.7 19.6 19.5 19.4 19.3 19.2 19.1 19.0 18.9 18.8
18.7 18.6 18.5 18.4 18.3 18.1 18.0 17.8 17.6 17.3 17.1 16.5 15.8 14.9 14.6 13.5 12.2 7.3 6.6
5.7 4.4 3.1 2.3 1.0 0.3];
i2=[0 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290
300 310 320 330 340 350 360 370 380 390 400 405 410 415 420 423 426 429 432 435 437];
plot(v2,i2,'y');hold on;
```

```
v3=[20.1 19.6 19.6 19.6 19.5 19.4 19.36 19.28 19.20 19.1 19.0 18.9 18.8 18.6 18.5 18.4 18.2
18.0 17.8 17.6 17.4 17.2 16.8 16.6 16.3 16.0 15.7 15.4 15.2 14.7 13.7 12.7 11.4 9.3 6.6 4.4
2.6 1.6 0.4 0];
i3=[0 98 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280
290 300 310 315 320 325 330 335 340 345 347 349 350 351 352 353 354 355 356];
plot(v3,i3,'m');hold on;
```

```
v4=[19.6 18.7 18.7 18.6 18.5 18.4 18.3 18.2 18.1 18.0 17.9 17.8 17.7 17.5 17.3 17.2 17.0
16.8 16.5 16.3 16.0 15.7 15.3 14.6 14.0 13.1 10.7 8.7 4.9 2.5 0.2 0];
i4=[0 96 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190
195 200 205 210 215 218 220 221 222 223 224];
plot(v4,i4,'c');hold on;
```

```
v5=[18.7 16.5 16.3 16.0 15.7 15.2 14.6 13.7 12.4 10.7 8.6 7.9 6.3 4.7 3.9 2.0 0.10 0];
i5=[0 85 90 95 100 105 110 115 120 122 123 124 125 126 127 128 129 129.5];
plot(v5,i5,'r');hold on;
gridon;xlabel('voltage'),ylabel('current');
legend('10Lights','8lights','6lights','4lights','2lights');
```

### Polycrystalline 35 degree Celsius:

```
v2=[18.5 17.0 16.7 16.3 16.1 15.9 15.5 15.1 14.7 13.9 13.2 11.5 0.09 0]
i2=[0 90 100 110 115 120 125 130 135 140 145 150 155 156]
plot(v2,i2,'g');hold on;
```

```
v4=[19.3 18.5 18.4 18.3 18.1 18.0 17.8 17.7 17.4 17.1 16.9 16.7 16.3 15.9 15.5 15.0 14.6
13.9 13.5 13.1 12.6 11.9 5.6 3.1 1.9 0.9 0.1 0]
i4=[0 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 251 252 253 254
255 256 257 258 259 260 262]
plot(v4,i4,'y');hold on;
```

```
v6=[19.7 19.1 18.7 18.3 18.0 17.7 17.5 17.0 16.4 15.6 15.0 14.0 11.0 9.3 7.3 6.7 4.4 2.3 0.02
0]
i6=[0 0100 150 200 220 240 0260 280 300 320 330 340 343 346 349 351 355 358 359 360]
plot(v6,i6,'r');hold on;
```

```
v8=[20.0 19.7 19.0 18.2 17.9 17.6 17.2 16.8 16.4 15.8 15.2 14.3 13.5 11.3 6.7 2.8 0.05 0]
i8=[0 100 200 300 330 350 375 390 400 410 420 430 435 440 443 445 446 450]
plot(v8,i8,'m');hold on;
```

```
v10=[20.3 19.8 19.4 18.8 18.5 18.3 18.2 17.9 17.6 17.3 16.9 16.7 16.3 15.8 15.2 14.3 11.8
8.5 5.3 3.1 0.3 0];
i10=[0 100 200 300 350 375 390 410 430 450 460 470 480 490 500 510 515 520 525 530
531 535];
plot(v10,i10,'c');hold on;grid on;xlabel('voltage'),ylabel('current');
legend('10Lights','8lights','6lights','4lights','2lights');
```

### Polycrystalline 40 degree Celsius:

```
v10=[19.8 19.4 19.4 19.3 19.2 19.1 19.0 18.9 18.8 18.79 18.74 18.69 18.63 18.58 18.52
18.47 18.41 18.36 18.30 18.2 18.1 18.0 17.9 17.8 17.7 17.6 17.5 17.4 17.3 17.2 17.0 16.8
16.6 16.3 15.9 15.6 14.8 13.7 12.5 11.3 10.0 8.9 7.8 6.1 4.5 3.3 0.5 0];
i10=[0 99 100 120 140 160 180 200 220 230 240 250 260 270 280 290 300 310 320 330 340
350 360 370 380 390 400 410 420 430 440 450 460 470 480 490 500 510 520 530 540 550
555 560 565 570 575 576];
plot(v10,i10,'g');hold on;
```

```
v8=[19.6 19.2 19.1 19.0 18.9 18.89 18.84 18.78 18.73 18.6 18.5 18.4 18.3 18.3 18.2 18.1
18.0 17.9 17.8 17.7 17.6 17.5 17.4 17.3 17.2 17.0 16.8 16.6 16.2 15.8 15.4 14.9 14.3 13.6
12.2 10.8 8.6 7.5 6.6 4.8 1.8 0.30 0];
i8=[0 98 110 130 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300 310
320 330 340 350 360 370 380 390 400 410 420 430 435 438 440 442 444 448 450 452 454
455];
plot(v8,i8,'y');hold on;
```

```
v6=[19.2 18.7 18.6 18.6 18.5 18.4 18.3 18.2 18.1 18.0 17.9 17.7 17.6 17.5 17.4 17.3 17.1
16.8 16.6 16.4 16.2 15.8 15.4 14.7 14.1 11.8 6.5 2.5 0.3 0];
i6=[0 98 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290
300 310 320 330 340 345 350 351 352];
plot(v6,i6,'m');hold on;
```



```
v4=[18.7 17.8 17.7 17.6 17.5 17.4 17.3 17.2 17.1 17.0 16.9 16.8 16.6 16.4 16.2 16.0 15.8  
15.6 15.4 15.2 14.9 14.3 13.5 12.7 10.4 7.5 5.3 2.8 0.4 0];  
i4=[0 92 100 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195  
200 205 210 215 218 220 221 222 223];  
plot(v4,i4,'c');hold on;
```

```
v2=[17.6 16.0 15.8 15.6 15.3 15.0 14.5 14.0 13.3 12.8 12.2 10.4 9.5 6.8 5.2 3.1 1.5 0.5 0];  
i2=[0 81 85 90 95 100 105 110 115 118 120 122 124 126 128 129 130 130.5 131];  
plot(v2,i2,'r');grid on;xlabel('voltage'),ylabel('current');  
legend('10Lights','8lights','6lights','4lights','2lights');
```

### **Polycrystalline 45 degree Celsius:**

```
v2=[17.4 15.7 15.4 14.8 14.1 13.4 12.8 11.4 10.6 9.7 7.0 4.4 0.2 0]  
i2=[0 80 90 100 110 115 120 122 125 127 129 130 131 132]  
length(v2)  
length(i2)  
plot(v2,i2,'g');grid on;hold on;
```

```
v4=[18.3 17.5 17.2 16.9 16.4 16.0 15.6 15.1 14.5 13.8 12.2 8.8 6.4 3.2 0.5 0]  
i4=[0 90 110 130 150 170 180 190 200 210 220 223 225 227 229 230]  
length(v4)  
length(i4)  
plot(v4,i4,'y');grid on;hold on;
```

```
v6=[18.8 18.3 17.9 17.7 17.5 17.3 17.0 16.7 16.4 16.1 15.8 15.4 15.0 14.5 13.8 10.1 6.2 4.6  
0.4 0]  
i6=[0 95 150 170 190 210 230 250 260 270 290 300 310 320 330 340 350 353 356 360]  
length(v6)  
length(i6)
```

```
plot(v6,i6,'r');grid on;hold on;
```

```
v8=[18.8 18.7 18.4 18.1 17.8 17.4 17.1 16.9 16.6 16.2 15.8 15.4 15.1 14.6 14.0 12.4 7.4 5.2  
3.7 0.4 0]
```

```
i8=[0 98 150 200 250 300 330 350 370 390 400 410 420 430 440 450 455 458 460 461 463]
```

```
length(v8)
```

```
length(i8)
```

```
plot(v8,i8,'m'); grid on;hold on;
```

```
v10=[19.3 19.0 18.4 18.1 17.9 17.6 17.4 17.2 17.0 16.7 16.5 16.2 16.0 15.8 15.5 15.1 14.7  
14.2 13.5 12.4 10.7 7.5 5.3 3.2 0.4 0]
```

```
i10=[0 100 200 250 300 350 370 390 410 430 440 450 460 470 480 490 500 510 520 530  
540 550 560 565 570 574]
```

```
length(v10)
```

```
length(i10)
```

```
plot(v10,i10,'c');grid on;hold on;xlabel('voltage'),ylabel('current');
```

```
legend('10Lights','8lights','6lights','4lights','2lights');
```

## Outdoor Experiments:

### Monocrystalline:

```
%day 2, june 6th, MONO, temp=34
V1130=[20.3 20.2 19.9 19.7 19.5 19.3 18.9 18.6 18.2 17.9 17.3 16.6
15.4 14.4 12.7 12.0 10.7 9.6 7.5 3.6 0.3 0];
I1130=[0 0.08 0.14 0.20 0.26 0.31 0.37 0.44 0.50 0.56 0.62 0.71 0.76
0.79 0.83 0.84 0.85 0.86 0.87 0.88 0.882 0.885];
plot(V1130,I1130,'r');hold on;
grid on;
p1130=times(V1130,I1130)
```

```
%day 2, june 6th, MONO, temp=37
V1200=[19.7 19.5 19.2 19.0 18.8 18.6 18.4 18.2 17.8 17.5 17.2 16.8
16.5 15.7 15.0 14.6 12.6 10.8 9.6 5.7 0.3 0];
I1200=[0 0.08 0.16 0.22 0.27 0.33 0.37 0.43 0.51 0.55 0.58 0.60 0.65
0.73 0.76 0.80 0.84 0.87 0.88 0.89 0.895 0.90];
plot(V1200,I1200,'b');
```

```
p1200=times(V1130,I1130)
```

```
%day 2, june 6th, MONO, temp=39
V1230=[19.6 19.4 19.0 18.7 18.4 18.1 17.8 17.6 17.3 17.0 16.7 16.4
16.0 15.6 14.8 14.1 13.5 12.5 11.2 10.0 7.4 2.9 0.1 0];
I1230=[0 0.07 0.20 0.28 0.35 0.42 0.48 0.52 0.56 0.59 0.64 0.67 0.70
0.73 0.77 0.80 0.81 0.83 0.85 0.86 0.87 0.872 0.873 0.874];
plot(V1230,I1230,'g');
```

```
p1230=times(V1230,I1230)
```

```
%day 2, june 6th, MONO, temp=34
V0100=[19.8 19.6 19.4 19.2 19.0 18.7 18.3 18.0 17.7 17.3 17.0 16.3
15.8 15.2 14.7 14.3 13.4 12.9 11.1 10.2 9.2 6.9 3.3 0.2 0];
I0100=[0 0.07 0.14 0.21 0.26 0.32 0.41 0.47 0.52 0.57 0.61 0.68 0.71
0.73 0.76 0.78 0.80 0.82 0.84 0.85 0.86 0.864 0.870 0.872 0.875];
plot(V0100,I0100,'m');
```

```
p0100=times(V0100,I0100)
```

```
%day 2, june 6th, MONO, temp=37
V0200=[20.1 19.4 18.7 17.9 17.6 17.3 16.9 16.1 15.4 14.9 14.2 13.3
12.7 11.9 11.0 10.1 8.4 4.1 0.3 0];
I0200=[0 0.07 .14 0.24 0.30 0.34 0.37 0.40 0.43 0.45 0.48 0.51 0.52
0.53 0.54 0.55 0.56 0.562 0.564 0.565];
plot(V0200,I0200,'y');
```

```
p0200=times(V0200,I0200)
```

```
%day 2, june 6th, MONO, temp=  
V0300=[19.8 19.6 19.2 18.7 18.3 17.9 17.3 16.8 15.6 14.8 13.9 11.7  
10.2 9.2 5.4 0.2 0];  
I0300=[0 0.06 0.14 0.22 0.27 0.31 0.35 0.39 0.42 0.45 0.47 0.49 0.50  
0.51 0.52 0.524 0.525];  
plot(V0300,I0300,'c');  
p0300=times(V0300,I0300)  
gridon;legend('11.30','12pm','12.30pm','1pm','3pm','3.30pm');
```

```
%day 6,mono,temp=38  
v1200=[20.6 20.4 20.3 20.1 20.0 19.9 19.8 19.6 19.4 19.0 18.6 17.9  
17.2 16.6 15.9 14.1 10.6 5.7 1.0 0]  
i1200=[0 0.07 0.10 0.17 0.23 0.26 0.32 0.36 0.44 0.52 0.59 0.66 0.75  
0.81 0.90 0.99 1.02 1.03 1.035 1.04]  
plot(v1200,i1200,'g');  
gridon;hold on;
```

```
%day 6,mono,temp=46  
v1230=[19.9 19.6 19.3 19.1 18.9 18.7 18.5 18.2 18.0 17.7 17.4 17.1  
16.7 16.3 15.5 15.0 14.0 12.8 11.1 9.3 7.4 4.8 3.0 0.6 0]  
i1230=[0 0.09 0.14 0.20 0.29 0.35 0.43 0.49 0.53 0.60 0.65 0.70 0.75  
0.81 0.87 0.93 0.98 1.02 1.06 1.08 1.090 1.092 1.093 1.094 1.095]  
plot(v1230,i1230,'r');
```

```
%day 6,mono,temp=41  
v0100=[20.2 19.8 19.6 19.4 19.2 18.9 18.7 18.5 18.3 18.0 17.6 17.3  
16.7 16.2 15.0 13.8 12.6 11.8 10.9 9.7 7.7 6.4 4.3 2.8 0.7 0]  
i0100=[0 0.11 0.17 0.22 0.27 0.36 0.39 0.42 0.48 0.51 0.58 0.63 0.68  
0.73 0.79 0.83 0.86 0.87 0.88 0.890 0.892 0.893 0.894 0.895 0.897  
0.9]  
plot(v0100,i0100,'y');
```

```
%day 6,mono,temp=39  
v0130=[20.1 19.9 19.7 19.5 19.3 19.1 18.9 18.7 18.3 18.0 17.6 16.8  
16.4 15.8 14.8 13.9 13.0 11.7 8.7 6.2 2.6 0.5 0]  
i0130=[0 0.07 0.11 0.18 0.22 0.29 0.33 0.38 0.45 0.52 0.59 0.67 0.70  
0.74 0.77 0.80 0.82 0.84 0.860 0.862 0.863 0.864 0.865]  
plot(v0130,i0130,'m')
```

```
%day 6,mono,temp=37  
v0300=[20.1 19.8 19.6 19.4 19.2 19.0 18.8 18.5 18.1 17.7 17.1 16.6  
16.2 15.8 15.1 14.4 13.3 12.0 11.1 10.0 8.2 6.6 3.1 0.3 0]  
i0300=[0 0.12 0.15 0.18 0.22 0.25 0.30 0.33 0.37 0.42 0.48 0.51 0.53  
0.55 0.57 0.58 0.60 0.62 0.64 0.66 0.68 0.70 0.702 0.703 0.705]  
plot(v0300,i0300,'b');grid on
```

```
%day 6,mono,temp=38  
v0330=[20.0 19.6 19.4 19.2 19.0 18.8 18.6 18.4 18.1 17.7 17.1 16.8  
15.9 15.3 14.7 13.5 12.2 11.4 10.4 7.8 5.3 2.6 0.4 0]
```

```
i0330=[0 0.09 0.12 0.16 0.20 0.23 0.26 0.29 0.33 0.36 0.39 0.41 0.45  
0.47 0.49 0.51 0.54 0.55 0.560 0.561 0.562 0.563 0.564 0.565]  
plot(v0330,i0330,'c');grid on;  
legend('12pm','12.30pm','1pm','1.30pm','3pm','3.30pm');
```

```
%day 7,mono, temp=41  
v1130=[20.4 20.3 20.1 19.9 19.7 19.5 19.3 19.1 18.7 18.5 18.2 18.0  
17.6 17.3 16.8 15.9 15.3 14.6 13.1 11.9 9.3 6.5 4.5 2.3 0.5 0]  
i1130=[0 0.07 0.12 0.19 0.24 0.30 0.35 0.40 0.47 0.53 0.58 0.63 0.67  
0.73 0.78 0.83 0.88 0.92 0.98 1.01 1.02 1.03 1.040 1.042 1.043  
1.045]  
plot(v1130,i1130,'g');hold on;  
%day 7,mono, temp=45.  
v1200=[20.3 20.1 19.9 19.7 19.5 19.3 19.1 18.9 18.7 18.5 18.3 18.0  
17.7 17.3 16.9 16.3 15.7 14.9 13.5 10.3 6.7 3.7 0.5 0]  
i1200=[0 0.07 0.10 0.18 0.23 0.29 0.34 0.39 0.43 0.47 0.52 0.57 0.63  
0.68 0.74 0.80 0.84 0.88 0.90 0.91 0.92 0.93 0.94 0.95]  
plot(v1200,i1200,'r');grid on
```

```
%day 7,mono, temp=56.  
v1230=[19.3 19.1 18.9 18.7 18.5 18.3 18.1 17.8 17.6 17.4 17.0 16.7  
16.0 15.6 15.1 14.4 13.5 11.9 10.8 8.4 7.5 3.5 0.6 0]  
i1230=[0 0.07 0.11 0.18 0.24 0.28 0.34 0.40 0.45 0.50 0.55 0.60 0.67  
0.73 0.77 0.82 0.86 0.89 0.91 0.92 0.930 0.932 0.933 0.935]  
plot(v1230,i1230,'b');grid on
```

```
%day 7,mono, temp=49.  
v0100=[19.8 19.7 19.4 19.0 18.6 18.4 18.2 18.0 17.6 17.4 16.9 15.7  
14.4 13.3 12.6 10.8 8.8 6.3 4.0 2.4 0.5 0]  
i0100=[0 0.07 0.12 0.17 0.24 0.29 0.36 0.42 0.48 0.51 0.54 0.61 0.67  
0.74 0.79 0.83 0.88 0.89 0.90 0.91 0.920 0.922]  
plot(v0100,i0100,'y');grid on
```

```
%day 7,mono, temp=49.  
v0130=[18.9 18.6 18.4 18.2 17.5 17.0 16.5 15.9 15.0 14.5 14.0 13.5  
12.0 11.1 10.1 9.0 7.1 5.1 4.3 2.0 0.5 0]  
i0130=[0 0.06 0.09 0.10 0.16 0.20 0.22 0.25 0.28 0.30 0.33 0.35 0.37  
0.38 0.39 0.41 0.43 0.46 0.48 0.510 0.515 0.52]  
plot(v0130,i0130,'c');grid on
```

```
%day 7,mono, temp=47.  
v0200=[19.5 19.3 19.0 18.8 18.6 18.2 17.8 17.6 17.0 16.6 16.1 15.3  
14.1 12.8 11.5 10.3 8.7 6.7 3.6 1.5 0.3 0]  
i0200=[0 0.06 0.11 0.18 0.21 0.34 0.39 0.44 0.50 0.54 0.59 0.64 0.70  
0.74 0.77 0.79 0.80 0.81 0.820 0.822 0.823 0.824]  
plot(v0200,i0200,'m');grid on
```

```
%day 7, mono, temp=47  
v0300=[19.3 19.0 18.8 18.5 18.3 18.0 17.8 17.6 17.3 16.9 15.7 15.1  
14.4 13.3 12.4 11.3 10.2 9.0 7.0 4.8 2.2 0.5 0]
```

```
i0300=[0 0.06 0.10 0.17 0.20 0.26 0.30 0.33 0.36 0.41 0.50 0.53 0.56
0.59 0.61 0.63 0.64 0.650 0.652 0.656 0.660 0.662 0.663]
plot(v0300,i0300,'k');grid on
legend('11.30am','12pm','12.30pm','1pm','1.30pm','2pm','3pm');
```

```
%11th july, mono, temp=37
v1130=[22.1 22.0 21.8 21.6 21.4 21.2 21.0 20.4 20.1 19.5 19.0 18.5
17.4 15.7 14.1 12.7 11.1 9.6 7.2 6.0 4.0 0.8 0]
i1130=[0 0.08 0.14 0.21 0.24 0.27 0.31 0.37 0.43 0.46 0.50 0.54 0.59
0.65 0.68 0.70 0.71 0.720 0.725 0.730 0.733 0.734 0.735]
plot(v1130,i1130,'g');hold on;
```

```
%11th,mono,temp=35
v1200=[21.9 21.6 21.5 21.4 21.2 20.8 20.5 20.2 19.9 19.4 18.9 18.2
17.2 16.2 14.5 11.0 9.2 4.3 0.8 0]
i1200=[0 0.06 0.11 0.18 0.21 0.33 0.44 0.53 0.63 0.72 0.81 0.92 0.99
1.06 1.11 1.16 1.17 1.175 1.18 1.19]
plot(v1200,i1200,'b'),
```

```
%11th, mono,temp=39
v1230=[21.5 21.0 20.7 20.3 20.0 19.7 19.4 19.0 18.2 16.3 13.6 10.3
6.3 1.6 0.7 0]
i1230=[0 0.07 0.19 0.37 0.44 0.51 0.58 0.67 0.77 0.93 1.02 1.06 1.07
1.074 1.075 1.08]
plot(v1230,i1230,'y');
```

```
%11th, mono,temp=40
v0230=[20.1 19.9 19.7 19.4 19.2 18.7 18.3 17.8 16.8 15.4 13.4 11.3
9.6 4.6 0.7 0]
i0230=[0 0.08 0.13 0.20 0.26 0.37 0.43 0.51 0.61 0.68 0.73 0.75
0.760 0.765 0.768 0.769]
plot(v0230,i0230,'c');
```

```
%11th, mono,temp=39
v0300=[20.1 19.9 19.8 19.3 19.1 18.6 18.2 17.8 17.2 16.8 15.2 13.3
11.3 8.5 3.5 0.5 0]
i0300=[0 0.09 0.15 0.25 0.30 0.37 0.43 0.48 0.53 0.55 0.62 0.67 0.70
0.71 0.715 0.717 0.718]
plot(v0300,i0300,'m');grid on
legend('11.30am','12pm','12.30pm','2.30pm','3pm');
```

**Polycrystalline:**

```
%day 2,4th june,POLY, temp=34
V1130=[20.0 19.9 19.7 19.5 19.3 19.1 18.8 18.6 18.3 18.0 17.7 17.4
17.3 16.6 16.0 15.4 14.3 12.3 9.0 4.5 0.4 0]
I1130=[0 0.06 0.14 0.23 0.31 0.38 0.48 0.54 0.60 0.65 0.68 0.74 0.78
0.84 0.91 0.96 1.00 1.04 1.05 1.052 1.053 1.055]
plot(V1130,I1130,'g');
grid on;hold on
p1130=times(V1130,I1130)
```

```
%day 2, june 4th, POLY, temp=38
V1200=[19.7 19.5 19.3 19.1 18.9 18.7 18.5 18.3 18.0 17.7 17.4 17.2
16.8 16.4 15.7 15.0 14.4 12.6 10.8 9.6 5.7 0.3 0];
I1200=[0 0.08 0.14 0.21 0.27 0.31 0.35 0.38 0.45 0.51 0.56 0.58 0.62
0.67 0.73 0.76 0.79 0.85 0.87 0.88 0.89 0.895 0.90];
plot(V1200,I1200,'r');
grid on;
p1200=times(V1200,I1200)
```

```
%day 2, june 4th, POLY, temp=40, the cloud interfered throughout
this
%experiment
V1230=[20.3 20.4 20.2 20.0 19.8 19.5 19.0 18.8 18.4 18.2 18.0 17.8
17.3 16.7 15.6 11.4 8.0 4.7 0.3 0];
I1230=[0 0.07 0.14 0.21 0.31 0.38 0.42 0.44 0.51 0.66 0.70 0.77 0.85
0.88 0.91 0.93 0.95 0.97 0.99 1.03];
plot(V1230,I1230,'y');
grid on;
p1230=times(V1230,I1230)
```

```
%day 2, june 4th, POLY, temp=41
V0100=[20.9 20.8 20.6 20.4 20.2 19.9 19.4 19.3 19.1 18.9 18.5 18.0
17.2 16.8 16.3 15.9 15.0 12.5 11.6 7.9 4.1 0.3 0];
I0100=[0 0.06 0.14 0.22 0.27 0.38 0.46 0.52 0.55 0.59 0.64 0.71 0.79
0.87 0.90 0.93 0.95 0.99 1.00 1.01 1.012 1.013 1.015];
plot(V0100,I0100,'b');
grid on;
p0100=times(V0100,I0100)
```

```
%day 2, june 4th, POLY, temp=39
V0200=[19.9 19.7 19.2 18.9 18.7 18.3 17.6 17.1 16.7 15.8 14.7 13.8
12.2 9.3 4.4 0.3 0];
I0200=[0 0.07 0.20 0.30 0.36 0.41 0.51 0.58 0.61 0.66 0.69 0.71 0.72
0.73 0.74 0.742 0.744];
plot(V0200,I0200,'m');
grid on;
p0200=times(V0200,I0200)
```

```
%day 2, june 4th, POLY, temp=35
V0300=[20.1 20.0 19.7 19.3 19.0 18.8 18.6 18.3 18.0 17.6 17.3 17.0
16.5 16.3 15.2 13.8 11.7 8.7 5.7 0.3 0];
I0300=[0 0.07 0.14 0.26 0.33 0.36 0.40 0.45 0.49 0.52 0.56 0.58 0.61
0.63 0.66 0.67 0.68 0.69 0.70 0.702 0.704];
plot(V0300,I0300,'c');
grid on;
p0300=times(V0300,I0300)
```

```
%day4 ,8thjune.
%temperature=36, POLY
V1130=[20.9 20.7 20.6 20.4 20.2 20.0 19.8 19.5 19.3 19.0 18.8 18.5
18.3 17.9 17.4 16.7 14.7 12.7 10.0 7.00 2.30 0.600 0];
I1130=[0 0.07 0.19 0.29 0.39 0.44 0.50 0.58 0.65 0.71 0.75 0.81 0.86
0.90 0.95 1.01 1.06 1.12 1.15 1.16 1.17 1.172 1.19];
grid on;
plot(V1130,I1130,'g');hold on;
p1130=times(V1130,I1130)
```

```
%day4 ,8thjune.
%temperature=40 POLY
V1200=[20.9 20.5 20.4 20.2 20.0 19.9 19.6 19.3 19.1 18.8 18.6 17.5
16.6 14.2 10.8 7.40 3.90 0.700 0];
I1200=[0 0.07 0.20 0.30 0.38 0.44 0.53 0.59 0.64 0.69 0.74 0.85 0.91
0.95 0.97 0.98 0.99 0.992 0.995];
plot(V1200,I1200,'r');
grid on;
p1200=times(V1200,I1200)
```

```
%day4 ,8thjune.
%temp=38 POLY
V1230=[20.7 20.6 20.2 20.0 19.7 19.6 19.3 19.2 19.0 18.8 18.6 18.2
17.5 16.7 15.6 14.4 11.8 7.6 2.6 0.5 0];
I1230=[0 0.07 0.20 0.30 0.37 0.41 0.48 0.52 0.56 0.60 0.64 0.70 0.74
0.80 0.86 0.90 0.92 0.93 0.932 0.933 0.935];
plot(V1230,I1230,'y');
grid on;
p1230=times(V1230,I1230)
```

```
%day4 ,8thjune.
%temp=42 POLY
V0100=[20.3 20.1 19.8 19.7 19.4 19.2 18.9 18.6 18.2 17.6 17.0 15.9
13.1 10.4 5.8 0.9 0];
I0100=[0 0.07 0.16 0.21 0.28 0.36 0.42 0.48 0.52 0.60 0.64 0.70 0.76
0.80 0.81 0.815 0.82];
plot(V0100,I0100,'b');
grid on;
p0100=times(V0100,I0100)
```



```
%day4 ,8thjune.
%temp=38 POLY
V0130=[20.5 20.3 20.0 19.8 19.6 19.4 19.2 18.9 18.3 18.1 17.8 16.7
15.1 13.4 10.0 5.7 0.7 0];
I0130=[0 0.07 0.17 0.25 0.33 0.37 0.43 0.50 0.57 0.63 0.68 0.74 0.81
0.87 0.89 0.895 0.896 0.898];
plot(V0130,I0130,'m');
grid on;
p0130=times(V0130,I0130)
```

```
%day4 ,8thjune.
%temp=38 poly
V0200=[20.7 20.5 20.3 20.1 19.9 19.7 19.6 19.3 18.9 18.6 18.2 17.7
17.0 16.1 14.8 12.6 9.0 5.2 0.9 0];
I0200=[0 0.07 0.21 0.29 0.37 0.40 0.48 0.59 0.64 0.72 0.78 0.85 0.90
0.94 0.96 0.98 0.99 0.991 0.993 0.995];
plot(V0200,I0200,'c');
grid on;
p0200=times(V0200,I0200)
```

```
%june 19th,poly, temp=39
v1130=[20.9 20.7 20.5 20.3 20.1 20.0 19.9 19.7 19.4 19.1 18.9 18.6
18.3 17.7 16.9 16.5 15.8 15.1 14.5 13.6 12.4 11.2 10.0 8.4 3.6 2.1
0.6 0]
i1130=[0 0.07 0.14 0.19 0.31 0.39 0.41 0.51 0.57 0.61 0.66 0.70 0.76
0.82 0.91 0.97 1.05 1.08 1.11 1.16 1.19 1.23 1.27 1.30 1.32 1.33
1.34 1.35]
plot(v1130,i1130,'g');hold on;
grid on
p1130=times(v1130,i1130)
```

```
%19th june, poly,temp=41
v1200=[20.6 20.3 20.1 19.9 19.7 19.6 19.5 19.4 19.2 19.0 18.9 18.6
18.3 18.0 17.6 17.2 16.5 15.1 13.9 11.8 9.3 6.8 3.8 0.6 0]
i1200=[0 0.07 0.19 0.28 0.37 0.40 0.45 0.51 0.52 0.62 0.66 0.70 0.77
0.84 0.90 0.97 1.04 1.12 1.17 1.25 1.27 1.28 1.29 1.30 1.31]
plot(v1200,i1200,'r');
grid on
p1200=times(v1200,i1200)
```

```
%19th june, poly,temp=43
v1230=[20.7 20.3 20.2 20.0 19.9 19.8 19.7 19.6 19.5 19.4 19.3 19.1
18.9 18.7 18.5 18.1 17.5 16.7 14.2 10.9 5.4 0.6 0]
i1230=[0 0.09 0.15 0.21 0.29 0.37 0.39 0.43 0.46 0.50 0.54 0.59 0.65
0.72 0.80 0.89 1.00 1.13 1.28 1.35 1.371 1.372 1.375]
plot(v1230,i1230,'y');
grid on
p1230=times(v1230,i1230)
```

```
%19th june, poly,temp=40
v0100=[20.1 19.7 19.5 19.4 19.3 19.1 19.0 18.9 18.8 18.6 18.2 18.1
17.8 17.7 17.3 16.9 16.5 15.9 14.6 12.0 8.4 5.3 0.6 0]
i0100=[0 0.07 0.14 0.20 0.25 0.32 0.36 0.42 0.46 0.51 0.62 0.65 0.70
0.74 0.79 0.84 0.90 0.96 1.04 1.11 1.14 1.15 1.16 1.17]
plot(v0100,i0100,'b');
grid on
p0100=times(v0100,i0100)
```

```
%19th june, poly,temp=36
v0130=[20.9 20.7 20.5 20.3 20.0 19.9 19.7 19.4 19.2 19.0 18.8 18.6
18.3 17.9 17.4 16.4 15.4 14.1 12.3 9.4 6.1 0.8 0]
i0130=[0 0.07 0.19 0.26 0.38 0.42 0.50 0.55 0.59 0.65 0.69 0.74 0.78
0.85 0.90 0.98 1.03 1.05 1.06 1.08 1.09 1.092 1.095]
plot(v0130,i0130,'m');
grid on
p0130=times(v0130,i0130)
```

```
%19th june,poly, temp=42,slight cloud interruption.
v0200=[20.4 20.2 19.8 19.6 19.4 19.2 19.0 18.7 18.3 17.9 16.9 16.4
15.6 14.8 13.6 12.4 10.9 8.4 4.1 0.8 0];
i0200=[0 0.07 0.19 0.27 0.33 0.40 0.46 0.52 0.59 0.63 0.70 0.76 0.80
0.87 0.94 0.99 1.01 1.03 1.035 1.04 1.042];
plot(v0200,i0200,'c');
grid on
p0200=times(v0200,i0200)
```

```
%19th june,poly, temp=36
v0230=[20.8 20.7 20.4 20.2 20.0 19.8 19.6 19.2 19.0 18.8 18.4 17.9
17.4 16.9 16.0 14.3 11.2 6.20 0.80 0]
i0230=[0 0.07 0.15 0.23 0.29 0.37 0.45 0.51 0.58 0.62 0.69 0.75 0.81
0.85 0.91 0.96 0.98 0.99 0.995 0.996]
plot(v0230,i0230,'k');
grid on
p0230=times(v0230,i0230)
```

```
%19th june,poly, temp=35
v0300=[20.6 20.2 19.9 19.7 19.4 19.1 18.8 18.6 18.3 17.3 16.4 15.6
13.9 12.5 8.3 6.1 0.3 0]
i0300=[0 0.09 0.19 0.27 0.31 0.37 0.41 0.45 0.50 0.56 0.62 0.65 0.68
0.70 0.71 0.720 0.725 0.730]
plot(v0300,i0300);
grid on
p0300=times(v0300,i0300)
```

```
%day 7,poly, temp=44.
v1130=[21.0 20.5 20.3 20.1 19.9 19.7 19.5 19.3 19.1 18.8 18.6 18.3
18.1 17.6 16.9 15.7 14.4 10.0 3.6 1.9 0.5 0]
i1130=[0 0.07 0.17 0.23 0.32 0.37 0.46 0.52 0.63 0.69 0.76 0.85 0.90
0.94 0.98 1.03 1.1 1.2 1.30 1.32 1.35 1.36]
plot(v1130,i1130,'g');grid on;hold on;
p1130=times(v1130,i1130)
```

```
%day 7,poly, temp=43.
v1200=[20.9 20.6 20.4 20.1 19.9 19.7 19.5 19.3 18.9 18.7 18.5 18.1
17.8 17.2 16.7 15.7 14.3 11.9 8.3 3.5 0.6 0]
i1200=[0 0.07 0.19 0.26 0.35 0.43 0.51 0.57 0.63 0.68 0.72 0.79 0.85
0.92 0.97 1.04 1.09 1.13 1.15 1.160 1.162 1.163]
plot(v1200,i1200,'r');grid on
p1200=times(v1200,i1200)
```

```
%day 7,poly, temp=48.
v1230=[20.1 20.0 19.8 19.6 19.4 19.2 19.0 18.8 18.6 18.3 17.9 17.5
17.0 16.6 15.4 14.7 13.6 11.6 8.0 5.1 0.8 0]
i1230=[0 0.07 0.12 0.21 0.28 0.36 0.40 0.46 0.54 0.61 0.71 0.79 0.87
0.92 1.02 1.06 1.10 1.12 1.13 1.14 1.15 1.16 ]
plot(v1230,i1230,'y');grid on
p1230=times(v1230,i1230)
```

```
%day 7,poly, temp=48.
v0100=[19.5 19.4 19.1 18.9 18.7 18.5 18.3 18.1 17.9 17.7 17.4 17.1
16.8 16.2 15.7 15.2 14.5 13.7 12.7 11.0 9.7 7.0 5.6 2.1 0.8 0]
i0100=[0 0.07 0.18 0.24 0.29 0.37 0.44 0.51 0.56 0.62 0.69 0.77 0.81
0.90 0.96 1.01 1.08 1.11 1.17 1.2 1.21 1.22 1.23 1.240 1.242 1.243]
plot(v0100,i0100,'b');grid on
p0100=times(v0100,i0100)
```

```
%day 7, poly, temp=50
v0130=[19.4 19.1 18.9 18.7 18.4 18.1 17.9 17.7 17.3 17.0 16.7 16.5
15.9 14.7 13.3 12.3 10.9 8.7 7.5 5.6 3.0 0.3 0]
i0130=[0 0.06 0.09 0.11 0.17 0.21 0.25 0.29 0.33 0.39 0.43 0.48 0.53
0.58 0.61 0.64 0.66 0.68 0.69 0.70 0.710 0.715 0.72]
plot(v0130,i0130,'m');grid on
p0130=times(v0130,i0130)
```

```
%21st june,poly, temp=42,slight cloud interruption.
v0200=[20.4 20.2 19.8 19.6 19.4 19.2 19.0 18.7 18.3 17.9 16.9 16.4
15.6 14.8 13.6 12.4 10.9 8.4 4.1 0.8 0];
i0200=[0 0.07 0.19 0.27 0.33 0.40 0.46 0.52 0.59 0.63 0.70 0.76 0.80
0.87 0.94 0.99 1.01 1.03 1.035 1.04 1.042];
plot(v0200,i0200,'c');
grid on
p0200=times(v0200,i0200)
```

```
%21st june,poly, temp=36
v0230=[20.8 20.7 20.4 20.2 20.0 19.8 19.6 19.2 19.0 18.8 18.4 17.9
17.4 16.9 16.0 14.3 11.2 6.20 0.80 0]
i0230=[0 0.07 0.15 0.23 0.29 0.37 0.45 0.51 0.58 0.62 0.69 0.75 0.81
0.85 0.91 0.96 0.98 0.99 0.995 0.996]
plot(v0230,i0230,'k');
grid on
p0230=times(v0230,i0230)
```

```
%day 7, poly, temp=42
v0300=[19.9 19.7 19.5 19.3 19.1 18.9 18.7 18.5 18.3 18.0 17.8 17.3
17.0 16.6 16.2 15.8 14.4 13.5 12.5 11.4 10.4 7.7 4.7 0.5 0]
i0300=[0 0.07 0.12 0.18 0.25 0.31 0.35 0.41 0.45 0.49 0.54 0.59 0.63
0.67 0.71 0.74 0.76 0.78 0.79 0.8 0.81 0.820 0.825 0.830 0.832]
plot(v0300,i0300);grid on
p0300=times(v0300,i0300)
```

```
Voc=[20.0 19.7 20.6 20.9 19.9 20.1];
t=[11.30 12.00 12.30 13.00 14.00 15.00];
plot(t,Voc);grid on;
```

```
Voc4=[20.9 20.9 20.7 20.3 20.5 20.7]
t=[11.00 12.00 12.30 13.00 13.30 14.00]
plot(t,Voc4);grid on;
```

```
t=[11.30 12.00 12.30 13.00 13.30 14.00 14.30 15.00]
Vsc19=[20.9 20.6 20.7 20.1 20.9 20.4 20.8 20.6]
plot(t,Vsc19)
```

```
t=[11.30 12.00 12.30 13.00 14.00 15.00]
Pmax=[14.8 11.5 14.70 14.79 10.43 10.30]
plot(t,Pmax);grid on
```

```
t=[11.00 12.00 12.30 13.00 13.30 14.00]
Pmax4=[16.9 15.1 13.4 11.1 12.4 15.3]
plot(t,Pmax4);grid on
```

```
t=[11.30 12.00 12.30 13.00 14.00 15.00]
Pmax=[14.8 11.5 14.70 14.79 10.43 10.30]
plot(t,Pmax);grid on
```

```
t=[11.30 12.00 12.30 13.00 13.30 14.00 14.30 15.00]
Pmax19=[16.6 17.2 18.9 15.3 16.1 12.9 14.6 10.2]
plot(t,Pmax19)
```

```
t=[11.30 12.00 12.30 13.00 14.00 15.00]
Isc=[1.055 0.9 1.03 1.015 0.744 0.704]
plot(t,Isc);grid on
```

```
t=[11.00 12.00 12.30 13.00 13.30 14.00]
Isc4=[1.19 0.995 0.935 0.82 0.898 0.995]
plot(t,Isc4);grid on;

% 11th, poly, temp=39
v1130=[21.9 21.7 21.4 21.2 21.0 20.8 20.7 20.4 20.1 19.3 18.0 16.1
13.3 10.1 7.9 5.3 2.2 1.1 0.1 0]
i1130=[0 0.07 0.17 0.26 0.31 0.38 0.46 0.54 0.62 0.78 0.90 0.98
1.01 1.02 1.03 1.035 1.04 1.045 1.05 1.052]
plot(v1130,i1130,'g');grid on;hold on
p1130=times(v1130,i1130)

%11th,poly,temp=38
v1200=[22.6 22.4 22.3 22.2 22.1 21.9 21.8 21.7 21.5 21.2 20.8 20.5
20.3 20.1 19.6 19.0 18.2 16.6 14.8 11.8 8.6 4.3 1.9 0.1 0]
i1200=[0 0.08 0.15 0.20 0.26 0.31 0.39 0.45 0.52 0.60 0.68 0.78 0.86
0.96 1.05 1.15 1.26 1.34 1.39 1.41 1.44 1.45 1.46 1.47 1.48]
plot(v1200,i1200,'r');grid on
p1200=times(v1200,i1200)

%11th, poly,temp=40
v1230=[21.5 21.2 21.1 20.7 20.3 20.1 20.0 19.7 19.5 19.2 18.8 17.1
13.7 10.3 3.1 0.9 0]
i1230=[0 0.12 0.18 0.38 0.50 0.57 0.63 0.71 0.78 0.83 0.91 1.11 1.32
1.38 1.410 1.413 1.415]
plot(v1230,i1230,'y');grid on
p1230=times(v1230,i1230)

%11th, poly,temp=38
v0230=[20.3 20.1 19.8 19.6 19.3 19.2 19.0 18.8 18.7 18.4 18.2 17.7
17.0 16.2 15.3 13.9 12.5 9.7 5.5 0.6 0]
i0230=[0 0.06 0.18 0.26 0.36 0.39 0.44 0.48 0.51 0.56 0.61 0.68 0.75
0.79 0.85 0.89 0.90 0.92 0.93 0.935 0.94]
plot(v0230,i0230,'b');grid on
p0230=times(v0230,i0230)

%11th, mono,temp=45
v0300=[20.0 19.7 19.4 18.8 18.6 18.1 17.8 16.9 16.1 14.3 13.4 11.8
9.3 4.4 0.4 0]
i0300=[0 0.06 0.17 0.33 0.40 0.46 0.53 0.63 0.68 0.73 0.77 .80 0.82
0.83 0.84 0.841]
p0300=times(v0300,i0300)
plot(v0300,i0300,'m');grid on

t=[11.30 12.00 12.30 13.00 13.30 14.00 14.30 15.00]
Isc19=[1.35 1.31 1.375 1.17 1.095 1.042 0.996 0.730]
plot(t,Isc19)
```

```
v=[19.4 19.2 19.0 18.9 18.8 18.7 18.5 18.3 18.1 18.0 17.8 17.5 17.4
17.1 16.8 16.5 16.1 15.5 15.0 14.4 13.9 12.9 11.3 9.6 5.7 1.0 0.7 0]
i=[0 0.06 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50 0.55 0.60
0.65 0.70 0.75 0.81 0.85 0.89 0.91 0.93 0.94 0.95 0.96 0.97 0.98
0.981 0.982]
plot(v,i,'g');grid on;hold on;
p=times(v,i)

vp2=[19.63 19.6 19.3 19.0 18.7 18.6 18.4 18.2 18.0 17.7 17.4 17.1
16.8 15.7 15.2 14.8 14.0 13.8 13.2 12.6 11.6 7.7 3.33 0.8 0]
ip2=[0 0.04 0.10 0.20 0.30 0.35 0.40 0.45 0.51 0.57 0.60 0.66 0.74
0.82 0.84 0.85 0.88 0.89 0.92 0.95 0.99 1.00 1.01 1.015 1.02]
plot(vp2,ip2,'r');grid on;
p2=times(vp2,ip2)

vp3=[19.3 19.1 19.0 18.8 18.6 18.5 18.3 18.1 17.9 17.7 17.5 17.4
17.1 16.7 16.3 15.5 15.1 14.8 13.8 13.1 12.3 10.0 8.1 3.2 0.6 0]
ip3=[0 0.07 0.10 0.20 0.25 0.30 0.35 0.40 0.45 0.51 0.56 0.60 0.65
0.70 0.75 0.81 0.85 0.87 0.90 0.92 0.94 0.95 0.964 0.968 0.970
0.972]
plot(vp3,ip3,'y'),grid on;
p3=times(vp3,ip3)
```

## Comparing Energy:

```
%day 7,mono, temp=45.
v1200=[20.3 20.1 19.9 19.7 19.5 19.3 19.1 18.9 18.7 18.5 18.3 18.0
17.7 17.3 16.9 16.3 15.7 14.9 13.5 10.3 6.7 3.7 0.5 0]
i1200=[0 0.07 0.10 0.18 0.23 0.29 0.34 0.39 0.43 0.47 0.52 0.57 0.63
0.68 0.74 0.80 0.84 0.88 0.90 0.91 0.92 0.93 0.94 0.95]
plot(v1200,i1200,'r');grid on
p1200=times(v1200,i1200)
%day 7,mono, temp=56.
v1230=[19.3 19.1 18.9 18.7 18.5 18.3 18.1 17.8 17.6 17.4 17.0 16.7
16.0 15.6 15.1 14.4 13.5 11.9 10.8 8.4 7.5 3.5 0.6 0]
i1230=[0 0.07 0.11 0.18 0.24 0.28 0.34 0.40 0.45 0.50 0.55 0.60 0.67
0.73 0.77 0.82 0.86 0.89 0.91 0.92 0.930 0.932 0.933 0.935]
plot(v1230,i1230,'b');grid on
p1230=times(v1230,i1230)

%day 7,mono, temp=49.
v0100=[19.8 19.7 19.4 19.0 18.6 18.4 18.2 18.0 17.6 17.4 16.9 15.7
14.4 13.3 12.6 10.8 8.8 6.3 4.0 2.4 0.5 0]
i0100=[0 0.07 0.12 0.17 0.24 0.29 0.36 0.42 0.48 0.51 0.54 0.61 0.67
0.74 0.79 0.83 0.88 0.89 0.90 0.91 0.920 0.922]
plot(v0100,i0100,'y');grid on
p0100=times(v0100,i0100)

%day 7,mono, temp=49.
v0130=[18.9 18.6 18.4 18.2 17.5 17.0 16.5 15.9 15.0 14.5 14.0 13.5
12.0 11.1 10.1 9.0 7.1 5.1 4.3 2.0 0.5 0]
i0130=[0 0.06 0.09 0.10 0.16 0.20 0.22 0.25 0.28 0.30 0.33 0.35 0.37
0.38 0.39 0.41 0.43 0.46 0.48 0.510 0.515 0.52]
plot(v0130,i0130,'c');grid on
p0130=times(v0130,i0130)

%day 6,mono,temp=38
v1200=[20.6 20.4 20.3 20.1 20.0 19.9 19.8 19.6 19.4 19.0 18.6 17.9
17.2 16.6 15.9 14.1 10.6 5.7 1.0 0]
i1200=[0 0.07 0.10 0.17 0.23 0.26 0.32 0.36 0.44 0.52 0.59 0.66 0.75
0.81 0.90 0.99 1.02 1.03 1.035 1.04]
p1200=times(v1200,i1200)
plot(v1200,i1200);
grid on
%day 6,mono,temp=46
v1230=[19.9 19.6 19.3 19.1 18.9 18.7 18.5 18.2 18.0 17.7 17.4 17.1
16.7 16.3 15.5 15.0 14.0 12.8 11.1 9.3 7.4 4.8 3.0 0.6 0]
i1230=[0 0.09 0.14 0.20 0.29 0.35 0.43 0.49 0.53 0.60 0.65 0.70 0.75
0.81 0.87 0.93 0.98 1.02 1.06 1.08 1.090 1.092 1.093 1.094 1.095]
p1230=times(v1230,i1230)
plot(v1230,i1230)
```

```
%day 6,mono,temp=41
v0100=[20.2 19.8 19.6 19.4 19.2 18.9 18.7 18.5 18.3 18.0 17.6 17.3
16.7 16.2 15.0 13.8 12.6 11.8 10.9 9.7 7.7 6.4 4.3 2.8 0.7 0]
i0100=[0 0.11 0.17 0.22 0.27 0.36 0.39 0.42 0.48 0.51 0.58 0.63 0.68
0.73 0.79 0.83 0.86 0.87 0.88 0.890 0.892 0.893 0.894 0.895 0.897
0.9]
p0100=times(v0100,i0100)
plot(v0100,i0100)
```

```
%day 6,mono,temp=39
v0130=[20.1 19.9 19.7 19.5 19.3 19.1 18.9 18.7 18.3 18.0 17.6 16.8
16.4 15.8 14.8 13.9 13.0 11.7 8.7 6.2 2.6 0.5 0]
i0130=[0 0.07 0.11 0.18 0.22 0.29 0.33 0.38 0.45 0.52 0.59 0.67 0.70
0.74 0.77 0.80 0.82 0.84 0.860 0.862 0.863 0.864 0.865]
p0130=times(v0130,i0130)
plot(v0130,i0130)
```

```
%day 6,mono,temp=38
v1200=[20.6 20.4 20.3 20.1 20.0 19.9 19.8 19.6 19.4 19.0 18.6 17.9
17.2 16.6 15.9 14.1 10.6 5.7 1.0 0]
i1200=[0 0.07 0.10 0.17 0.23 0.26 0.32 0.36 0.44 0.52 0.59 0.66 0.75
0.81 0.90 0.99 1.02 1.03 1.035 1.04]
p1200=times(v1200,i1200)
plot(v1200,i1200);
grid on
```

```
%day 6,mono,temp=46
v1230=[19.9 19.6 19.3 19.1 18.9 18.7 18.5 18.2 18.0 17.7 17.4 17.1
16.7 16.3 15.5 15.0 14.0 12.8 11.1 9.3 7.4 4.8 3.0 0.6 0]
i1230=[0 0.09 0.14 0.20 0.29 0.35 0.43 0.49 0.53 0.60 0.65 0.70 0.75
0.81 0.87 0.93 0.98 1.02 1.06 1.08 1.090 1.092 1.093 1.094 1.095]
p1230=times(v1230,i1230)
plot(v1230,i1230)
```

```
%day 6,mono,temp=41
v0100=[20.2 19.8 19.6 19.4 19.2 18.9 18.7 18.5 18.3 18.0 17.6 17.3
16.7 16.2 15.0 13.8 12.6 11.8 10.9 9.7 7.7 6.4 4.3 2.8 0.7 0]
i0100=[0 0.11 0.17 0.22 0.27 0.36 0.39 0.42 0.48 0.51 0.58 0.63 0.68
0.73 0.79 0.83 0.86 0.87 0.88 0.890 0.892 0.893 0.894 0.895 0.897
0.9]
p0100=times(v0100,i0100)
plot(v0100,i0100)
```

```
%day 6,mono,temp=39
v0130=[20.1 19.9 19.7 19.5 19.3 19.1 18.9 18.7 18.3 18.0 17.6 16.8
16.4 15.8 14.8 13.9 13.0 11.7 8.7 6.2 2.6 0.5 0]
i0130=[0 0.07 0.11 0.18 0.22 0.29 0.33 0.38 0.45 0.52 0.59 0.67 0.70
0.74 0.77 0.80 0.82 0.84 0.860 0.862 0.863 0.864 0.865]
p0130=times(v0130,i0130)
plot(v0130,i0130)
```



```
%19th june, poly,temp=41
v1200=[20.6 20.3 20.1 19.9 19.7 19.6 19.5 19.4 19.2 19.0 18.9 18.6
18.3 18.0 17.6 17.2 16.5 15.1 13.9 11.8 9.3 6.8 3.8 0.6 0]
i1200=[0 0.07 0.19 0.28 0.37 0.40 0.45 0.51 0.52 0.62 0.66 0.70 0.77
0.84 0.90 0.97 1.04 1.12 1.17 1.25 1.27 1.28 1.29 1.30 1.31]
plot(v1200,i1200,'r');
grid on
p1200=times(v1200,i1200)
```

```
%19th june, poly,temp=43
v1230=[20.7 20.3 20.2 20.0 19.9 19.8 19.7 19.6 19.5 19.4 19.3 19.1
18.9 18.7 18.5 18.1 17.5 16.7 14.2 10.9 5.4 0.6 0]
i1230=[0 0.09 0.15 0.21 0.29 0.37 0.39 0.43 0.46 0.50 0.54 0.59 0.65
0.72 0.80 0.89 1.00 1.13 1.28 1.35 1.371 1.372 1.375]
plot(v1230,i1230,'y');
grid on
p1230=times(v1230,i1230)
```

```
%19th june, poly,temp=40
v0100=[20.1 19.7 19.5 19.4 19.3 19.1 19.0 18.9 18.8 18.6 18.2 18.1
17.8 17.7 17.3 16.9 16.5 15.9 14.6 12.0 8.4 5.3 0.6 0]
i0100=[0 0.07 0.14 0.20 0.25 0.32 0.36 0.42 0.46 0.51 0.62 0.65 0.70
0.74 0.79 0.84 0.90 0.96 1.04 1.11 1.14 1.15 1.16 1.17]
plot(v0100,i0100,'b');
grid on
p0100=times(v0100,i0100)
```

```
%19th june, poly,temp=36
v0130=[20.9 20.7 20.5 20.3 20.0 19.9 19.7 19.4 19.2 19.0 18.8 18.6
18.3 17.9 17.4 16.4 15.4 14.1 12.3 9.4 6.1 0.8 0]
i0130=[0 0.07 0.19 0.26 0.38 0.42 0.50 0.55 0.59 0.65 0.69 0.74 0.78
0.85 0.90 0.98 1.03 1.05 1.06 1.08 1.09 1.092 1.095]
plot(v0130,i0130,'m');
grid on
p0130=times(v0130,i0130)
```

```
%day 7,poly, temp=43.
v1200=[20.9 20.6 20.4 20.1 19.9 19.7 19.5 19.3 18.9 18.7 18.5 18.1
17.8 17.2 16.7 15.7 14.3 11.9 8.3 3.5 0.6 0]
i1200=[0 0.07 0.19 0.26 0.35 0.43 0.51 0.57 0.63 0.68 0.72 0.79 0.85
0.92 0.97 1.04 1.09 1.13 1.15 1.160 1.162 1.163]
plot(v1200,i1200,'r');grid on
p1200=times(v1200,i1200)
```

```
%day 7,poly, temp=48.
v1230=[20.1 20.0 19.8 19.6 19.4 19.2 19.0 18.8 18.6 18.3 17.9 17.5
17.0 16.6 15.4 14.7 13.6 11.6 8.0 5.1 0.8 0]
i1230=[0 0.07 0.12 0.21 0.28 0.36 0.40 0.46 0.54 0.61 0.71 0.79 0.87
0.92 1.02 1.06 1.10 1.12 1.13 1.14 1.15 1.16 ]
plot(v1230,i1230,'y');grid on
p1230=times(v1230,i1230)
```

```
%day 7,poly, temp=48.
v0100=[19.5 19.4 19.1 18.9 18.7 18.5 18.3 18.1 17.9 17.7 17.4 17.1
16.8 16.2 15.7 15.2 14.5 13.7 12.7 11.0 9.7 7.0 5.6 2.1 0.8 0]
i0100=[0 0.07 0.18 0.24 0.29 0.37 0.44 0.51 0.56 0.62 0.69 0.77 0.81
0.90 0.96 1.01 1.08 1.11 1.17 1.2 1.21 1.22 1.23 1.240 1.242 1.243]
plot(v0100,i0100,'b');grid on
p0100=times(v0100,i0100)
```

```
%day 7, poly, temp=50
v0130=[19.4 19.1 18.9 18.7 18.4 18.1 17.9 17.7 17.3 17.0 16.7 16.5
15.9 14.7 13.3 12.3 10.9 8.7 7.5 5.6 3.0 0.3 0]
i0130=[0 0.06 0.09 0.11 0.17 0.21 0.25 0.29 0.33 0.39 0.43 0.48 0.53
0.58 0.61 0.64 0.66 0.68 0.69 0.70 0.710 0.715 0.72]
plot(v0130,i0130,'m');grid on
p0130=times(v0130,i0130)
```