SOLAR CELL CHARACTERTICS USER MANUAL

A PROJECT REPORT SUBMITTED TO

PALAMURU UNIVERSITY, MAHABUB NAGAR

For the Degree of

BACHELOR OF SCIENCE

IN

PHYSICS

UNDER THE FACULTY OF PHYSICAL SCIENCE

By

1. M.Bhanu prakash	: 20033056441024
2. M.Aravind kumar	: 20033056441025
3. M.Naresh	: 20033056441026
4. P.Anitha	: 20033056441027
5. Ramesh	: 20033056441028
6. Sana Begum	: 20033056441029

Department of Physics SCNM GDC Narayanpet.

UNDER THE GUIDANCE OF

E NARAYANA GOUD

Assistant professor

DEPARTMENT OF PHYSICS

SCNM GDC NARAYANPET, NARAYANPET DISTRICT - 509210

June 2023

June 2023

CERTIFICATE

This is certify that the work incorporated in the project report entitled“SOLAR CELL CHARACTERTICS USER MANUAL” Submitted to Palamuru University, Mahbubnagar, is benefited work of **1.** M.Bhanu Prakash, **2.** AravindKumar, 3.Naresh, **4.** P.Anitha **5.** Ramesh, **6.** Sana begum,of B.Sc. (Physics) during the academic year 2022-23 who carried out the project work under my super vision.

E. NARAYANA GOUD
GOUD
Guide
Department of Physics
SCNM GDC Narayanpet

E. NARAYANA

Head
Department of Physics
SCNM GDC Narayanpet

31/5/2023

INTERNAL EXAMINER

EXTERNAL EXAMINER

Date: / / 2023

Head
Department of Physics
Degree College
509 210.

ACKNOWLEDGEMENT

I wish to thank the principal Sri. **G. Ranga Reddy** of our college for permitting us to use all the facilities available in the institution for my project work. We would also like thank the head of the Physics Department **Sri. E NARAYANA GOUD** and all the non- teaching staff of our college for their support in completed the work successfully.

We are grateful to our guide **Sri. Narayana Goud** for his encouragement, guidance and supervision of our project work during the year. I must acknowledge the financial support given to this project by my parent without which it would have been difficult to complete the work in time.

Place: **Signature of Students**

Narayanpet

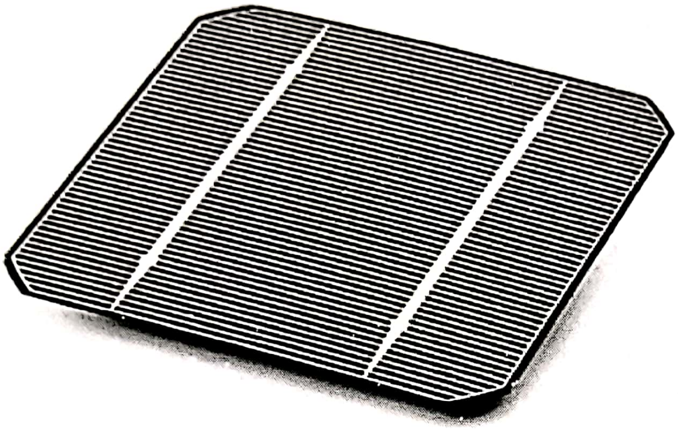
1.M.Bhanu prakash : M.Bhanu
2.M. Aravind kumar :
3.M.Naresh : Naresh
4.P.Anitha : P.Anitha
5.Ramesh :
6.Sana Begum :

INDEX

Introduction

Solar cell

A **solar cell**, or **photovoltaic cell**, is an electronic device that converts the energy of light directly into electricity by the photovoltaic effectwhich is a physical and chemical phenomenon.t is a form of photoelectric cell, defined as a device whose electrical characteristics, such as current, voltage, or resistance, vary when exposed to light. Individual solar cell devices are often the electrical building blocks of photovoltaic modules, known colloquially as solar panels. The common single junction silicon solar cell can produce a maximum open-circuit voltage of approximately 0.5 to 0.6 volts



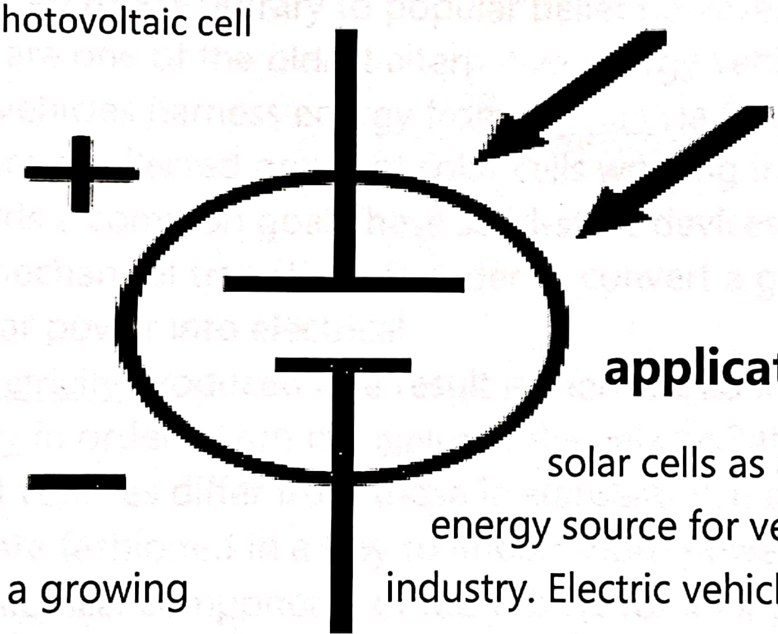
Solar cells are described as photovoltaic, regardless of whether the source is sunlight or artificial light. In addition to producing energy, they can be used as a photodetector (for example infrared detectors),

detecting light or other electromagnetic radiation near the visible range, or measuring light intensity.

The operation of a photovoltaic (PV) cell requires three basic attributes:

- The absorption of light, generating excitons (bound electron-hole pairs), unbound electron-hole pairs (via excitons), or plasmons.
- The separation of charge carriers of opposite types.
- The separate extraction of those carriers to an external circuit.

Symbol of photovoltaic cell



Vehicular applications

Application of solar cells as an alternative energy source for vehicular applications is a growing industry. Electric vehicles that operate off of solar energy and/or sunlight are commonly referred to as solar cars.[*citation needed*] These vehicles use solar panels to convert absorbed light into electrical energy that is then stored in batteries.[*citation needed*] There are multiple input factors that affect the output power of solar cells such as temperature, material properties, weather conditions, solar irradiance and more

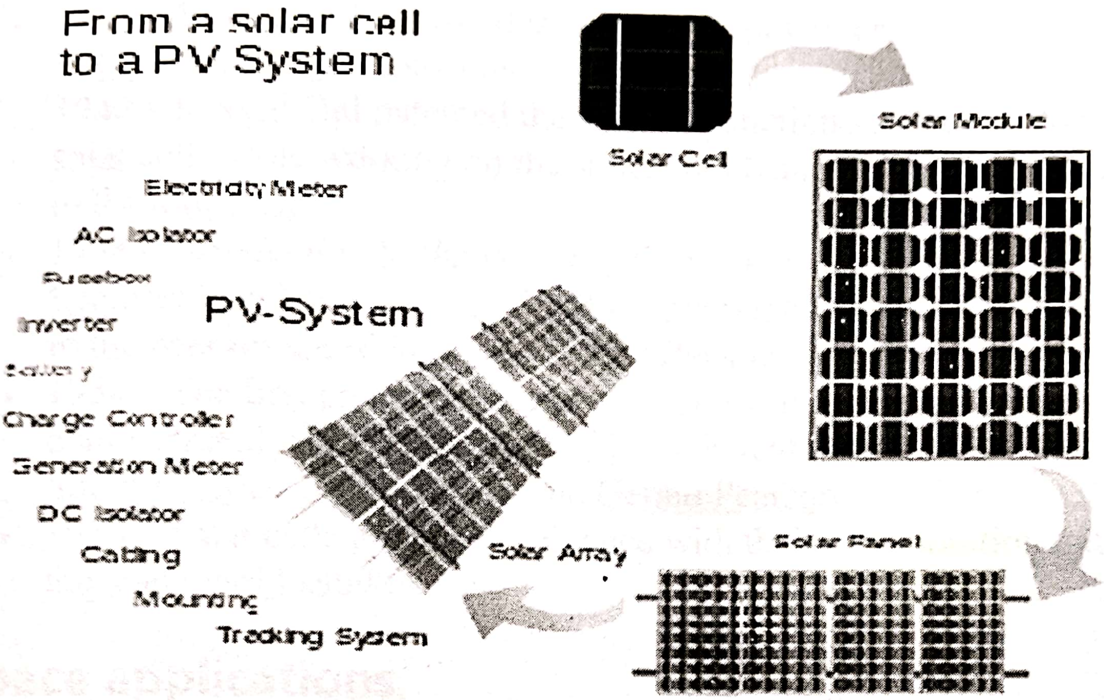
The first instance of photovoltaic cells within vehicular applications was around midway through the second half of the 1900's. In an effort to increase publicity and awareness in solar powered transportation Hans Tholstrup decided to set up the first edition of the World Solar Challenge in 1987. It was a 3000 km race across the Australian outback where competitors from industry research groups and top universities around the globe were invited to compete.General Motors ended up winning the event by a significant margin with their Sunraycer vehicle that achieved speeds of over 40 mph.Contrary to popular belief however solar powered cars are one of the oldest alternative energy vehicles. Current solar vehicles harness energy from the Sun via Solar panels which are a collected group of solar cells working in tandem towards a common goal These solid-state devices use quantum mechanical transitions in order to convert a given amount of solar power into electrical power. The electricity produced as a result is then stored in the vehicle's battery in order to run the motor of the vehicle.Batteries in solar-powered vehicles differ from those in standard ICE cars because they are fashioned in a way to impart more power towards the electrical components of the vehicle for a longer duration.

Cells, modules, panels and systems

Multiple solar cells in an integrated group, all oriented in one plane, constitute a solar photovoltaic panel or module. Photovoltaic modules often have a sheet of glass on the sun-facing side, allowing light to pass while protecting the semiconductor wafers. Solar cells are usually connected in series creating additive voltage. Connecting cells in parallel yields a higher current.

However, problems in paralleled cells such as shadow effects can shut down the weaker (less illuminated) parallel string (a number of series connected cells) causing substantial power loss and possible damage because of the reverse bias applied to the shadowed cells by their illuminated partners.

Although modules can be interconnected to create an array with the desired peak DC voltage and loading current capacity, which can be done with or without using independent MPPTs (maximum power point trackers) or, specific to each module, with or without module level power electronic (MLPE) units such as microinverters or DC-DC optimizers. Shunt diodes can reduce shadowing power loss in arrays with series/parallel connected cells.



From a solar cell to a PV system. Diagram of the possible components of a photovoltaic system

- 1888 – Russian physicist Aleksandr Stoletov built the first cell based on the outer photoelectric effect discovered by Heinrich Hertz in 1887.
- 1904 – Julius Elster, together with Hans Friedrich Geitel, devised the first practical photoelectric cell.

- 1905 – Albert Einstein proposed a new quantum theory of light and explained the photoelectric effect in a landmark paper, for which he received the Nobel Prize in Physics in 1921.
- 1941 – Vadim Lashkaryov discovered *p*-*n*-junctions in Cu_2O and Ag_2S protocells.
- 1946 – Russell Ohl patented the modern junction semiconductor solar cell, while working on the series of advances that would lead to the transistor.
- 1948 - *Introduction to the World of Semiconductors* states Kurt Lehovec may have been the first to explain the photo-voltaic effect in the peer reviewed journal *Physical Review*.
- 1954 – The first practical photovoltaic cell was publicly demonstrated at Bell Laboratories.] The inventors were Calvin Souther Fuller, Daryl Chapin and Gerald Pearson
- 1958 – Solar cells gained prominence with their incorporation onto the Vanguard I satellite

Space applications.

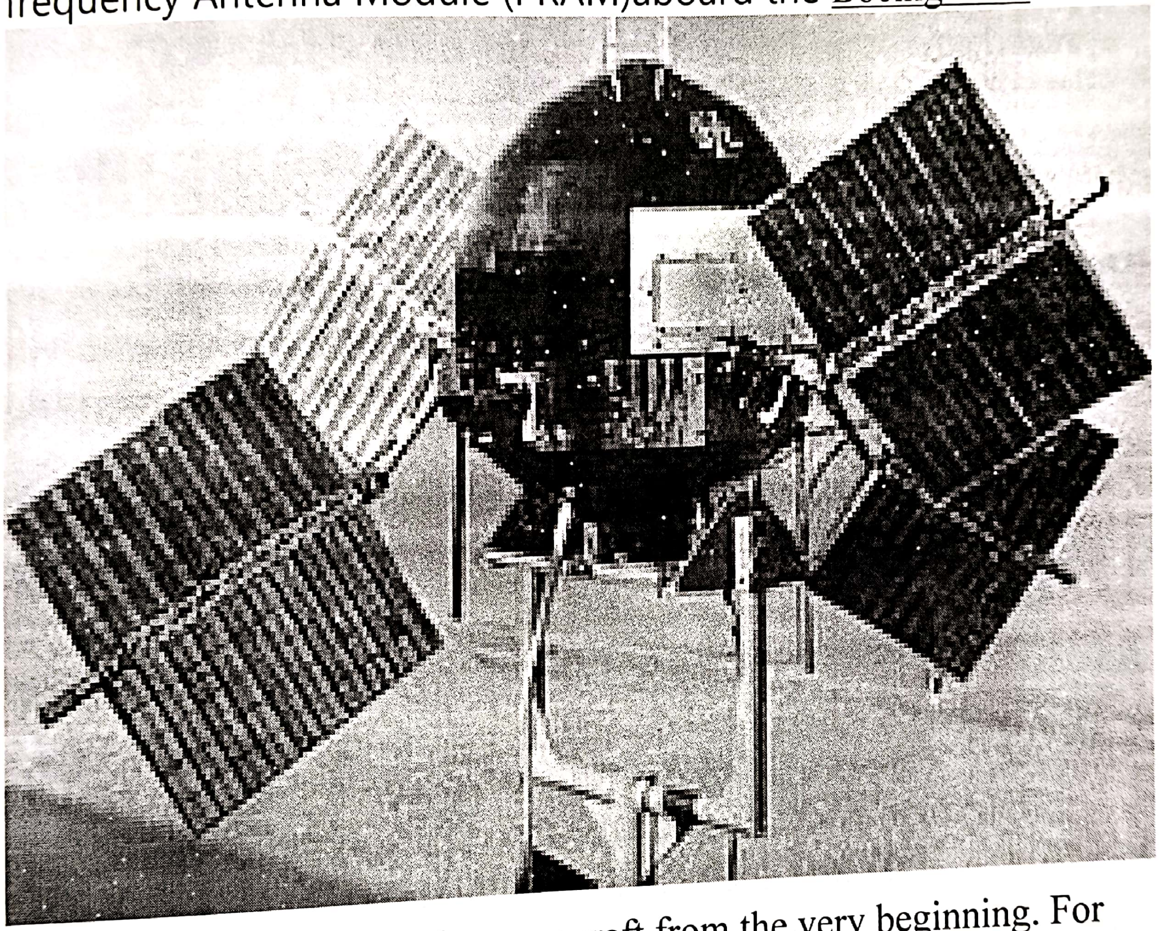
Solar cells were first used in a prominent application when they were proposed and flown on the Vanguard satellite in 1958, as an alternative power source to the primary battery power source. By adding cells to the outside of the body, the mission time could be extended with no major changes to the spacecraft or its power systems. In 1959 the United States launched Explorer 6, featuring large wing-shaped solar arrays, which became a common feature in satellites. These arrays consisted of 9600 Hoffman solar cells.

By the 1960s, solar cells were (and still are) the main power source for most Earth orbiting satellites and a number of probes into the solar system, since they offered the best power-to-weight ratio. However, this success was possible because in the space application, power system costs could be high, because space users had few other power options, and were willing to pay for the best possible cells. The space power market drove the development of higher efficiencies in solar cells up until the National Science Foundation "Research Applied to National Needs" program began to push development of solar cells for terrestrial applications.

In the early 1990s the technology used for space solar cells diverged from the silicon technology used for terrestrial panels, with the spacecraft application shifting to gallium arsenide-based III-V semiconductor materials, which then evolved into the modern III-V multijunction photovoltaic cell used on spacecraft.

In recent years, research has moved towards designing and manufacturing lightweight, flexible, and highly efficient solar cells. Terrestrial solar cell technology generally uses photovoltaic cells that are laminated with a layer of glass for strength and protection. Space applications for solar cells require that the cells and arrays are both highly efficient and extremely lightweight. Some newer technology implemented on satellites are multi-junction photovoltaic cells, which are composed of different PN junctions with varying bandgaps in order to utilize a wider spectrum of the sun's energy. Additionally, large satellites require the use of large solar arrays to produce electricity. These solar arrays need to be broken down to fit in the geometric constraints of the launch vehicle the satellite travels on before being injected into orbit. Historically, solar cells on satellites consisted of several small terrestrial panels folded together. These small panels would be unfolded into a large panel after the satellite is deployed in its orbit. Newer satellites aim to use flexible rollable solar arrays that are very lightweight and can be packed into a very small volume. The smaller size and weight of these flexible arrays drastically decreases the overall cost of launching a satellite due to the direct relationship between payload weight and launch cost of a launch vehicle.

In 2020, the US Naval Research Laboratory conducted its first test of solar power generation in a satellite, the Photovoltaic Radio-frequency Antenna Module (PRAM)aboard the Boeing X-37.



NASA used solar cells on its spacecraft from the very beginning. For Example, Explorer 6, launched in 1959, had four arrays that folded out once in orbit. They provided power for months in space.

Improved manufacturing methods

Improvements were gradual over the 1960s. This was also the reason that costs remained high, because space users were willing to pay for the best possible cells, leaving no reason to invest in lower-cost, less-efficient solutions. The price was determined largely by the semiconductor industry; their move to integrated circuits in the 1960s led to the availability of larger boules at lower relative prices. As their price fell, the price of the resulting cells did as well. These effects lowered 1971 cell costs to some $100 per watt.

In late 1969 Elliot Berman joined Exxon's task force which was looking for projects 30 years in the future and in April 1973 he founded Solar Power Corporation (SPC), a wholly owned subsidiary of Exxon at that time. The group had concluded that electrical power would be much more expensive by 2000, and felt that this increase in price would make alternative energy sources more attractive. He conducted a market study and concluded that a price per watt of about $20/watt would create significant demand. The team eliminated the steps of polishing the wafers and coating them with an anti-reflective layer, relying on the rough-sawn wafer surface. The team also replaced the expensive materials and hand wiring used in space applications with a printed circuit board on the back, acrylic plastic on the front, and silicone glue between the two, "potting" the cells. Solar cells could be made using cast-off material from the electronics market. By 1973 they announced a product, and SPC convinced Tideland Signal to use its panels to power navigational buoys, initially for the U.S. Coast Guard.

Research and industrial production

Research into solar power for terrestrial applications became prominent with the U.S. National Science Foundation's Advanced Solar Energy Research and Development Division within the "Research Applied to National Needs"

program, which ran from 1969 to 1977,and funded research on developing solar power for ground electrical power systems. A 1973 conference, the "Cherry Hill Conference", set forth the technology goals required to achieve this goal and outlined an ambitious project for achieving them, kicking off an applied research program that would be ongoing for several decades.The program was eventually taken over by the Energy Research and Development Administration (ERDA),] which was later merged into the U.S. Department of Energy.
Following the 1973 oil crisis, oil companies used their higher profits to start (or buy) solar firms, and were for decades the largest producers. Exxon, ARCO, Shell, Amoco (later purchased by BP) and Mobil all had major solar divisions during the 1970s and 1980s. Technology companies also participated, including General Electric, Motorola, IBM, Tyco and RCA.

Theory

Solar cell efficiency may be broken down into reflectance efficiency, thermodynamic efficiency, charge carrier separation efficiency and conductive efficiency. The overall efficiency is the product of these individual metrics.

The power conversion efficiency of a solar cell is a parameter which is defined by the fraction of incident power converted into electricity.

A solar cell has a voltage dependent efficiency curve, temperature coefficients, and allowable shadow angles.

Due to the difficulty in measuring these parameters directly, other parameters are substituted: thermodynamic efficiency, quantum efficiency, integrated quantum efficiency, V_{OC} ratio, and fill factor. Reflectance losses are a portion of quantum efficiency under "external quantum efficiency". Recombination losses make up another portion of quantum efficiency, V_{OC} ratio, and fill factor. Resistive losses are predominantly categorized under fill factor, but also make up minor portions of quantum efficiency, V_{OC} ratio. The fill factor is the ratio of the actual maximum obtainable power to the product of the open-circuit voltage and short-circuit current. This is a key parameter in evaluating performance. In 2009, typical commercial solar cells had a fill factor > 0.70. Grade B cells were usually between 0.4 and 0.7 Cells with a high fill factor have a low equivalent series resistance and a high equivalent shunt resistance, so less of the current produced by the cell is dissipated in internal losses.

Single p–n junction crystalline silicon devices are now approaching the theoretical limiting power efficiency of 33.16%, noted as the Shockley–Queisser limit in 1961. In the extreme, with an infinite number of layers, the corresponding limit is 86% using concentrated sunlight.

In 2014, three companies broke the record of 25.6% for a silicon solar cell. Panasonic's was the most efficient. The company moved the front contacts to the rear of the panel, eliminating shaded areas. In addition they applied thin silicon films to the (high quality silicon) wafer's front and back to eliminate defects at or near the wafer surface.

In 2015, a 4-junction GaInP/GaAs//GaInAsP/GaInAs solar cell achieved a new laboratory record efficiency of 46.1% (concentration ratio of sunlight = 312) in a French-German collaboration between the Fraunhofer Institute for Solar Energy Systems (Fraunhofer ISE), CEA-LETI and SOITEC

In September 2015, Fraunhofer ISE announced the achievement of an efficiency above 20% for epitaxial wafer cells. The work on optimizing the atmospheric-pressure chemical vapor deposition (APCVD) in-line production chain was done in collaboration with NexWafe GmbH, a company spun off from Fraunhofer ISE to commercialize production.

For triple-junction thin-film solar cells, the world record is 13.6%, set in June 2015.
In 2016, researchers at Fraunhofer ISE announced a GaInP/GaAs/Si triple-junction solar cell with two terminals reaching 30.2% efficiency without concentration.
In 2017, a team of researchers at National Renewable Energy Laboratory (NREL), EPFL and CSEM (Switzerland) reported record one-sun efficiencies of 32.8% for dual-junction GaInP/GaAs solar cell devices. In addition, the dual-junction device was mechanically stacked with a Si solar cell, to achieve a record one-sun efficiency of 35.9% for triple-junction solar cells.

Materials

Solar cells are typically named after the semiconducting material they are made of. These materials must have certain characteristics in order to absorb sunlight. Some cells are designed to handle sunlight that reaches the Earth's surface, while others are optimized for use in space. Solar cells can be made of a single layer of light-absorbing material (single-junction) or use multiple physical configurations (multi-junctions) to take advantage of various absorption and charge separation mechanisms.

Solar cells can be classified into first, second and third generation cells. The first generation cells—also called conventional, traditional or wafer-based cells—are made of crystalline silicon, the commercially predominant PV technology, that includes materials such as polysilicon and monocrystalline silicon. Second generation cells are thin film solar cells, that include amorphous silicon, CdTe and CIGS cells and are commercially significant in utility-scale photovoltaic power stations, building integrated photovoltaics or in small stand-alone power system. The third generation of solar cells includes a number of thin-film technologies often described as emerging photovoltaics—most of them have not yet been commercially applied and are still in the research or development phase. Many use organic materials, often organometallic compounds as well as inorganic substances. Despite the fact that their efficiencies had been low and the stability of the absorber material was often too short for commercial applications, there is research into these technologies as they promise to achieve the goal of producing low-cost, high-efficiency solar cells.[65] As of 2016, the most popular and efficient solar cells were those made from thin wafers of silicon which are also the oldest solar cell technology.

Monocrystalline silicon

Monocrystalline silicon (mono-Si) solar cells feature a single-crystal composition that enables electrons to move more freely than in a multi-crystal configuration. Consequently, monocrystalline solar panels deliver a higher efficiency than their multicrystalline counterparts.The corners of the cells look clipped, like an octagon, because the wafer material is cut from cylindrical ingots, that are typically grown by the Czochralski process. Solar panels using mono-Si cells display a distinctive pattern of small white diamonds.

Epitaxial silicon development

Epitaxial wafers of crystalline silicon can be grown on a monocrystalline silicon "seed" wafer by chemical vapor deposition (CVD), and then detached as self-supporting wafers of some standard thickness (e.g., 250 μm) that can be manipulated by hand, and directly substituted for wafer cells cut from monocrystalline silicon ingots. Solar cells made with this "kerfless" technique can have efficiencies approaching those of wafer-cut cells, but at appreciably lower cost if the CVD can be done at atmospheric pressure in a high-throughput inline process. The surface of epitaxial wafers may be textured to enhance light absorption.

In June 2015, it was reported that heterojunction solar cells grown epitaxially on n-type monocrystalline silicon wafers had reached an efficiency of 22.5% over a total cell area of 243.4 cm.

Polycrystalline silicon

Polycrystalline silicon, or multicrystalline silicon (multi-Si) cells are made from cast square ingots—large blocks of molten silicon carefully cooled and solidified. They consist of small crystals giving the material its typical metal flake effect. Polysilicon cells are the most common type used in photovoltaics and are less expensive, but also less efficient, than those made from monocrystalline silicon.

Ribbon silicon

Ribbon silicon is a type of polycrystalline silicon—it is formed by drawing flat thin films from molten silicon and results in a polycrystalline structure. These cells are cheaper to make than multi-Si, due to a great reduction in silicon waste, as this approach does not require sawing from ingots. However, they are also less efficient.

Mono-like-multi silicon (MLM)

This form was developed in the 2000s and introduced commercially around 2009. Also called cast-mono, this design uses polycrystalline casting chambers with small "seeds" of mono material. The result is a bulk mono-like material that is polycrystalline around the outsides. When sliced for processing, the inner sections are high-efficiency mono-like cells (but square instead of "clipped"), while the outer edges are sold as conventional poly. This production method results in mono-like cells at poly-like prices.

Cadmium telluride

Cadmium telluride is the only thin film material so far to rival crystalline silicon in cost/watt. However cadmium is highly toxic and tellurium (anion: "telluride") supplies are limited.

The cadmium present in the cells would be toxic if released. However, release is impossible during normal operation of the cells and is unlikely during fires in residential roofs. A square meter of CdTe contains approximately the same amount of Cd as a single C cell nickel-cadmium battery, in a more stable and less soluble form.

Copper indium gallium selenide

Copper indium gallium selenide (CIGS) is a direct band gap material. It has the highest efficiency (~20%) among all commercially significant thin film materials (see CIGS solar cell). Traditional methods of fabrication involve vacuum processes including co-evaporation and sputtering. Recent developments at IBM and Nanosolar attempt to lower the cost by using non-vacuum solution processes.

Silicon thin-film cells are mainly deposited by chemical vapor deposition (typically plasma-enhanced, PE-CVD) from silane gas and hydrogen gas. Depending on the deposition parameters, this can yield amorphous silicon (a-Si or a-Si:H), protocrystalline silicon or nanocrystalline silicon (nc-Si or nc-Si:H), also called microcrystalline silicon.

Amorphous silicon is the most well-developed thin film technology to-date. An amorphous silicon (a-Si) solar cell is made of non-crystalline or microcrystalline silicon. Amorphous silicon has a higher bandgap (1.7 eV) than crystalline silicon (c-Si) (1.1 eV), which means it absorbs the visible part of the solar spectrum more strongly than the higher power density infrared portion of the spectrum. The production of a-Si thin film solar cells uses glass as a substrate and deposits a very thin layer of silicon by plasma-enhanced chemical vapor deposition (PECVD).

Protocrystalline silicon with a low volume fraction of nanocrystalline silicon is optimal for high opencircuit voltage. Nc-Si has about the same bandgap as c-Si and nc-Si and a-Si can advantageously be combined in thin layers, creating a layered cell called a tandem cell. The top cell in a-Si absorbs the visible light and leaves the infrared part of the spectrum for the bottom cell in nc-Si.

The semiconductor material gallium arsenide (GaAs) is also used for single-crystalline thin film solar cells. Although GaAs cells are very expensive, they hold the world's record in efficiency for a single-junction solar cell at 28.8%. GaAs is more commonly used in multijunction photovoltaic cells for concentrated photovoltaics (CPV, HCPV) and for solar panels on spacecraft, as the industry favours efficiency over cost for space-based solar power. Based on the previous literature and some theoretical analysis, there are several reasons why GaAs has such high power conversion efficiency. First, GaAs bandgap is 1.43ev which is almost ideal for solar cells. Second, because Gallium is a by-product of the smelting of other metals, GaAs cells are relatively insensitive to heat and it can keep high efficiency when temperature is quite high. Third, GaAs has the wide range of design options. Using GaAs as active layer in solar cell, engineers can have multiple choices of other layers which can better generate electrons and holes in Gas.

Objective:

The objective of this Lab activity is to study and measure the output voltage and current characteristics of a photovoltaic solar panel and develop an equivalent electrical model for use in computer simulation.

A solar cell is a semiconductor PN junction diode as shown in figure 1. The large surface area indicated in light blue is exposed to incident light energy. Solar cells are usually coated with anti-reflective materials so that they absorb the maximum amount of light energy. Normally no external bias is applied to the cell. When a photon of light is absorbed near the PN junction a hole / electron pair is produced. This occurs when the energy of the photon is higher than the energy band-gap of the semiconductor. The built in electric field of the junction cause the pair to separate and head toward the respective + and - terminals. The energy from the light causes a current to flow in an external load when the cell is illuminated.

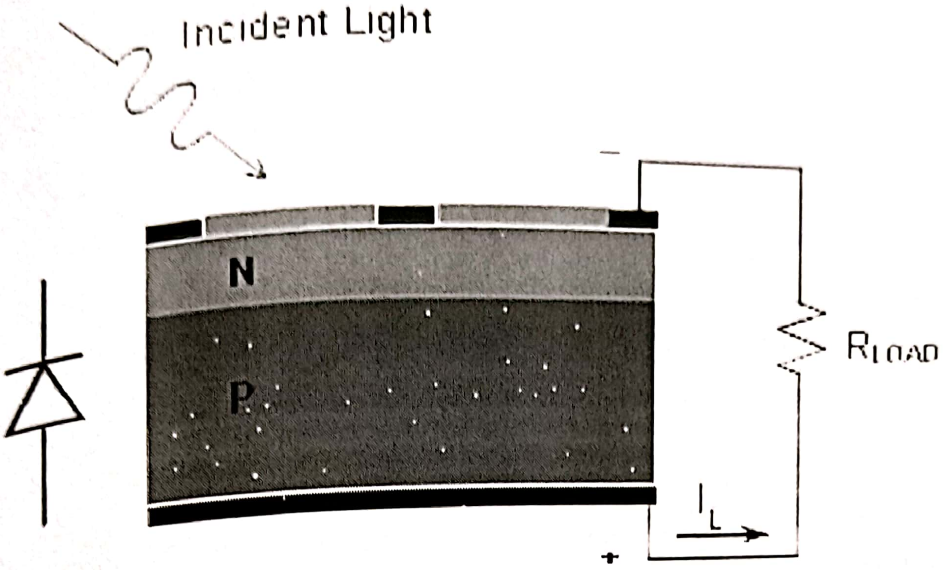


Figure 1 Structure of a basic solar cell.

EXPERIMENT

SOLAR CELL CHARACTERISTICA USER MANUAL

AIM: To plot the Via Characteristic of Solar cell.

MICRO BARD CONSISTS OF

1) solar Cell/ Photovoltaic mounted on the wooden base.
2) Single directional mercurycoated variables intensity source.
3) Voltmeter
4) Ammeter
5) Load resistance.

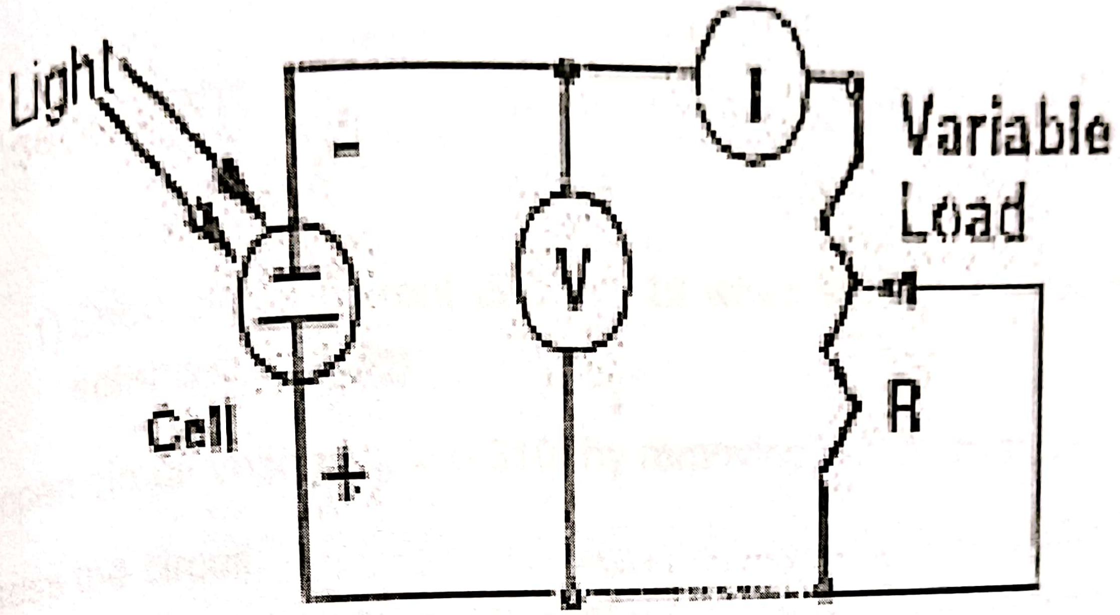
THEORY

Sunlight consists of a littleparticles of solar called photons. As the photo voltaic cell is exposed this Sunlight, may of the photons arereflected pass right through of absorbed by the solar cell.

when enough photons are absorbed by the negative layer of the photovoltaic cell electronsare freed from the negative semiconductor material. Due to the manufacturing process of the positive layer, these freed electrons naturally migrate to the "positive layer. Creating a Voltage differential, similar to a house hold battery.

When the two layers connected flow through the circuit creating electricity each individual solar energy cell produces on 1-2walts. To increase power output cells are combined in a weather tight package called a solar module. These modules from one to several thousand are then wired up in serial and/ or parallel with one another into what's called a solar array to create the desired voltage and ampere output required.

Due to the natural abundance of silicon, the semiconductor material that PV cells are primary mode of and the practically unlimited resource in the sun, solar power cells are very environment friendly. They burn and absolute no moving parts which makes then virtually maintenance free, clean and silent.



Sloar cell circuit diagram

Table

sl.no	Distance between the light source and solar cell(em)	Voltage (mv)	Current (mA)	P=VI
1	0	0.468	1.12	0.524
2	1	0.455	1.09	0.495
3	2	0.444	1.07	0.475
4	3	0.431	1.04	0.448
5	4	0.420	1.01	0.424
6	5	0.408	0.98	0.399
7	6	0.398	0.96	0.382
8	7	0.390	0.94	0.366
9	8	0.383	0.92	0.352

Observations

1) Short circuit current ISC = 1·19 when voltage across the solar cell is (zero)

2) open circuit voltagev_0 = 0.310 (by removing and resistance

across the circuit.

3) maximum point P = VI = (0.310) (1.19).

P = 0.3689

Procedure:

1) Connect the circuit as per the circuit diagram as shown in fig (1).

2) Place the solar cell at a particular distance say1cm from the variable light source.

3) very intensely of the light source, note down the voltage an arrent in the tabular column...

4) Next note the short circuit current ISC. when the voltage across the solar cell is zero and open circuit voltage by removing the load resistance across the solar cell.

(5) calculate power p=VI for each reading.