**Introduction of Solar Energy and Photovoltaic device**

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**Abstract**

Photovoltaic cell is an electronic device which Change solar energy into electric energy by the photovoltaic effect. The principal of solar cell depends on Photovoltaic effect which is the physical and chemical phenomenon. Solar cell is the building block of the solar plate or solar panel. The first generation of solar cell is made of silicon and the next generation of thin film and nowadays used organic solar cells. Organic solar cells have attracted a lot of attention in the last years due to their properties for application as flexible, renewable, non conservative energy sources. Since the generation of photo induced charge transfer between organic active layer materials, a great effort has been devoted to explore these organic materials for photonic device. In this research chapter study the basic introduction and properties of photovoltaic cells.

**I Introduction**

The world demand of clean energy includes the course of universal intensification in each sphere of anthropic activity. The supplies of clean energy are connected to global sustainability, gainful prosperity, and progressive of life. To discover sources of clean energy to assure the world’s progressing need is one of human being foremost challenges for the next half century. There is a need of correct national effort assemble our most advanced scientific and technological capacity to solve importance of this constant difficulty and the seriously technical problem. At the present time world required energy at a rate of about 4.1×1020 joules/year, which equivalent to the electric power consumption of 13 trillion watts or 13 terawatts (TW). Even with progressive conservation and energy efficiency trade, fast technology development and gainful growth worldwide, the Earth's population is projected to grow to 9 billion people, accompanied by fast technology development and economic progress worldwide, is projected to generate more than double the require for energy (to 30 TW) by 2050, and more than triple the demand (to 46 TW) by the end of the century [1]. The store of fossil fuels that give energy to society, they will finish short of this requirement over the long time duration and their sustain use and produces harmful side effects such as pollution that harmful human life and greenhouse gases related with climate change. The other renewable fuels are at present far from against with fossil fuels in high cost value and production holding ability. Without achievable options for supplying double or triple today’s energy use, the world’s economic, technological, and progress will be severely limited. Our natural source of clean, energy is the sun. The sun produce 120,000 TW of radiation on the surface of the earth, which is very large further human needs even in the most advancing energy requirement panorama. The sun is our Earth’s natural source of energy that driving the circulation of worldwide wind and ocean currents, the process of water evaporation and condensation. The sun produces rivers and lakes, and biological cycles of the photosynthesis and life which is the first requirement of human life. On covering 0.61% of the land of the Earth with 10% aplicapable solar conversion energy would supply 20 TW of electric power, which is nearly twice the world’s required rate of fossil energy the equivalent 20,000 GW nuclear fission plants.

The energy of sun reaches on the Earth as the form of radiation and scattered from infrared to ultraviolet. The energy of this solar radiation must be captured as excited excitons (electron- hole pairs) in a semiconductor as heat in a thermal storage medium. Excited electrons and holes pairs (excitons) can be captured sudden converted to electrical energy. Natural process of photosynthesis in the presence of sun light and colorful produces food in the form carbohydrates and reduces CO2 in the atmosphere and gain to power for the growth of plants [2]. The green plants themselves obtained biomass for combustion as primary fuels or for conversion in nuclear reactors to secondary fuels like liquid ethanol or gaseous methane and hydrogen. We are now learning to relate the natural photosynthetic process in the laboratory using synthetic molecular collecting, where the excited electrons and holes can drive chemical reactions to generate fuels that connect to our existing energy system. The atmospheric CO2 can be reduced to ethanol or methane or water can be split to produce hydrogen and oxygen. These natural fuels are the source of storage media for solar energy which circulate day-night, winter-summer and cloudy-sunny cycles of solar radiation. Electric and chemical conversion process, solar radiation can be converted in to heat energy. By Solar concentrators focus sunlight collected over a large area to a line or spot where heat is collected in an absorber. The high Temperature 3,000 0C can be produce to drive chemical reactions or heat can be stored at lower temperatures and transferred to a thermal storage medium like water for distributed space heating or steam to drive heat engine. Effective storage of solar energy as heat requires to generating thermal storage media that collect heat efficiently during sunny-day and allow to supply the heat gradually during night or cloudy- day. Heat is one of the most adjustable forms of energy, the common connection in nearly all our energy networks, Solar thermal conversion can replace much of the heat now supplied by fossil fuel.

**II PHOTOVOLTAIC CELL**

**A** PV cell [3] is an opto-electronic device that change the solar energy (Sun Light) into electrical energy directly by the application of photovoltaic effect, which is a physical and chemical Phenomenon, this idea borrows from the green plant. It is a photoelectric device, whose electrical properties, such as voltage, current, or resistance, vary with change in light intensity. A group of Solar cells are assembled together form the solar plate or solar panel. If we increase the number of solar cells than power of solar panel is also increases. These solar plates use in space body as alternative power source, no other source is possible except it. The working of a solar cell depends upon four main properties:

* The maximum light must be absorbed by the active layer materials.
* Generation of charge carriers ([electron](https://en.wikipedia.org/wiki/Electron)-[hole](https://en.wikipedia.org/wiki/Electron_hole) pairs) when light is incident on active layer.
* The charge carriers of opposite types are separated by the properties of internal electric field.
* The separate charge carriers move towards the opposite electrodes.

This effect was experimentally first observed by French physicist in 1839 and he discovered the world's first solar cell in his father's laboratory. The Light effect on Selenium first explains by the first physicist Willoughby Smith. In 1883 Charles Fritts built the first Solid State solar cell by coating the semiconductor selenium with a thin layer of gold to form the junctions and the efficiency of this device about 1%. In 1888 Russian physicist Alexander Stoletoy made the first solar cell based on the outer photoelectric effect discovered by H. Hertz in 1887. Albert Einstein explain the quantum theory of light and photoelectric effect successfully in 1905 for this great discovery he Received Novel price in physics in 1921. Vadim Lashkaryoy proposed P-N junction in Cu2O and silver sulphide photo cell in 1941 {\displaystyle \_{2}}2O2222[4]. Russel Ohl patented the modem junction semiconductor solar cell in 1948. The first solar cell developed by the Daryl Chapin, Calvin Souther Fuller and Gerald Pearson on 25 April 1954 at Bell Laboratories. Solar cells gained importance with their incorporation onto the 1958 Vanguard I satellite.

First time solar in 1958 used as a prominent application on Vanguard satellite, as an alternative power source to the primary battery. To increase the number of solar cells to the outside of the body, the mission time duration could be extended with no any more changes to the spacecraft or its power systems. The United States launched Explorer 6, which have large wing shaped solar panels like as aeroplane it becomes a common feature in satellites. This surface of the satellites consist a large number of solar cells to increase the working time as alternate power source. In 1960s, solar cells were become the main power heart for most Earth orbiting satellites and a number of investigation into the solar system, since they existing 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 some other power options, and were ready to pay for the best possible cells. The space power market for satellite drove the development of higher efficiencies in organic solar cells up until the National Science Foundation program began to push growth of solar cells for satellites applications. In the early 1990s the technology used for space solar cells diverged from the silicon technology used for terrestrial panels, with the spacecraft purpose shifting to gallium arsenide- based III – V semiconductor materials, which then evolved into the modem III- V multifunction solar cell used in spacecraft.

**III TYPES OF PHOTOVOLTAIC CELLS**

**Crystalline Silicon Solar Cells:**

The material crystalline silicon (C-Si) is most important for solar cells which also known as solar grade silicon. The materials silicon is classified into different types according to crystalline and crystal size in the resulting [ingot](https://en.wikipedia.org/wiki/Ingot). The concepts of solar cells are completely based on the P-N junction diode in reverse bias. The traditional solar cells are made of crystalline silicon wafers of size 160 and 240 µm thick [5] in 1950s. Because they are produced from 160-190 [µm](https://en.wikipedia.org/wiki/Micrometers) thick [solar wafers](https://en.wikipedia.org/wiki/Solar_wafer) slices from bulks of silicon, they are sometimes called wafer-based solar cells. Solar cells made from crystalline silicon are single-junction solar cells it is more effective than their best technology, which are the second-generation [thin film solar cells](https://en.wikipedia.org/wiki/Thin_film_solar_cell), the most important being  [CIGS](https://en.wikipedia.org/wiki/Copper_indium_gallium_selenide_solar_cells), and [amorphous silicon](https://en.wikipedia.org/wiki/Amorphous_silicon) . Amorphous silicon is an allotropic substitute of silicon, and amorphous means without shape (non-crystalline form).

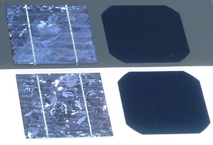


Fig. 1 Structure of Crystalline Silicon Solar Sell

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#### B. Mono-Crystalline Silicon Solar Cell:

Single-crystal silicon (Mono-crystalline silicon) is the base material for silicon chips used in all electronic instruments today. Mono-crystalline (M-Si) layer also serves as, light-absorbing material (active layer material) for the manufacturing of solar cells. It consists of [silicon](https://en.wikipedia.org/wiki/Silicon) in which the lattice structure of the entire solid is continuous, unbroken to its edges, and free of any fragment boundaries. Mono-crystalline (M-Si) can be made by [intrinsic](https://en.wikipedia.org/wiki/Intrinsic_semiconductor), other elements (impurity) added to change its physical and chemical properties. All Most silicon [mono- crystals](https://en.wikipedia.org/wiki/Monocrystal) are manufactured by the Czocgralski method into slabs (sheet) of up to 2 meters in length and weight several hundred kilograms. These slabs are then sliced into thin wafers of few hundred micro meters for the next processing. Mono crystalline silicon is differs from other form, such as the non-crystalline silicon which is used in [thin-film solar cells](https://en.wikipedia.org/wiki/Thin-film_solar_cells) and multicrystalline silicon that consists of small crystals.

**C.** **Thin Film Solar Cells:**

A thin-film solar cell is a next generation of photovoltaic cells that is made by depositing one or more layers of active materials on a substrate of different materials such as glass, plastic or metal. Thin-film solar cells are commercially used in several technologies. Film thickness of the solar cell varies from a few nanometers to tens of micrometers, much thinner than thin-film's corrival technology, the conventional, first-generation crystalline silicon solar cells, that uses slice of up to 200 µm [6-7]. This thin film provided to solar cells flexible substrate, lower in weight and has less friction. It is used in building block of solar plate (solar panel). Other trading applications of thin film solar cells to provided endless electric power to the satellites and alternative source of power to supply the world to short out the electricity problems. Thin-film technology has always been cheaper but less efficient than conventional crystalline silicon solar cells technology. However, it has considerably superior over the years. The solar cells efficiency for CdTe and CIGS is now more than 21 percent, outperforming polycrystalline silicon, the presiding material currently used for solar cells. The working period of thin film solar panel under ideal conditions measured a somewhat faster degradation compared to conventional PV, while a working time of 20 years or more is generally expected. Despite these enhancements, market-share of thin-film never reached more than 20 percent in the last 20 years and has been reducing in recent years to about 9 percent of world wide photovoltaic solar cells in 2013.

**D. Cadmium telluride (CdTe) solar cell:**

Cadmium telluride (CdTe) material has the great properties of the high absorption coefficient and it absorbed about 99% incident light. This  new technology that is based on the use of CdT, a thin layer of active materials (CdTe) made to absorb the sun light and converted into electricity directly. Cadmium telluride solar cells have good properties with low cost in comparing crystalline solar cells. On the stability basis, cadmium solar cell has the smallest carbon footprint, lowest water use and shortest working period of all solar cells technologies. Cadmium telluride energy payback time of less than a year allows for faster carbon reductions without short-term energy deficits. Cadmium solar cells have the drawback of toxicity due to this properties it is harmful for the environment. The toxic properties of cadmium are harmful for environmental concern reduced by the recycling of CdTe modules at the end of their life time. Though there are uncertain [8-9] and the public opinion is doubtful about this CdTe technology. The usage of rare materials may also become a limiting factor to the industrial scalability of CdTe solar cell technology in the mid-term future. The abundance of [tellurium](https://en.wikipedia.org/wiki/Tellurium) of which telluride is the [anionic](https://en.wikipedia.org/wiki/Anion) form is comparable to that of platinum in the earth's crust and contributes significantly to the module's cost.

**E. Multi-junction** **solar cells:**

Multi-junction solar cells are made of multi p-n junctions of different semiconductor materials. Every semiconductor materials p-n junction solar cells will produce electric current with varying of light. The different semiconductors materials absorb maximum range of light and enhance the conversion efficiency. Commercially single-junction solar cells have a maximum observed efficiency 34%. Theoretically, a large number of junctions would have a maximum efficiency of 86.8% under highly sunlight. Currently, the C-Si solar cells have efficiency from 20% to 25%. The conviction of the multi-junction solar cells has reveal performance over 46% under highly sunlight [10-11]. Commercial tandem solar cells have efficiency 30% under one-sun illumination, and improve up to 40% under concentrated sunlight. However, this efficiency is gained at the cost of increased complexity and manufacturing cost. To date, their higher cost and higher [cost to performance ratio](https://en.wikipedia.org/wiki/Price-to-performance_ratio) have limited their use to special roles. In space body applications, these solar cells are emerging in   growing number of installations around the world.

**IV ORGANIC SOLAR CELLS**

An organic Photovoltaic cell (PV cell) is a type of polymer solar cell that uses organic electronics, a branch of electronics that deals with conductive organic materials for light absorption and charge transport to produce electricity from sunlight by the photovoltaic effect. The plastic used in organic solar cells has low production costs in high volumes and has high absorbing coefficient. Combined with the flexibility of organic molecules, organic solar cells have cost-effective for photovoltaic applications. The optical absorption coefficient of organic molecules is high, so a large amount of light can be absorbed with a small amount of materials. The main disadvantages of organic solar cells are low efficiency, low stability and low strength compared to inorganic photovoltaic cells. Organic photovoltaic device made of organic semiconductor of thin films (100nm) such as small-molecule compounds like copperphthalocyanine and carbon fullerene derivatives such as P3HT- PCBM. They can be processed from liquid solution, offering the possibility of a simple roll-to-roll printing process or spin coating process potentially leading to reasonable, major production [12]. In addition, these cells could be beneficial for some applications where mechanical flexibility and disposability are important. The efficiencies of these organic solar cells are, very low, and these are not useful for practical purpose. The energy conversion efficiencies of organic solar cells is very low as compared to inorganic materials solar cells. However, Konark Power polymer reached efficiency of 8.3% and organic tandem solar cells in 2012 reached 11.1%. The active layer of an organic solar cell consists of two materials, one electron donor and one electron acceptor. When a photons are absorbed by active layers and converted into an electron hole pair (excitons), typically in the donor material,[13] the charges tend to remain bound in the form of an electron-hole pair , separating when the excitons diffuses to the donor-acceptor interface, unlike most other solar cell types. The short excitons diffusion lengths of most polymer systems tend to limit the efficiency of such devices. Nanostructure interfaces, sometimes in the form of bulk heterojunction, can improve performance [14]. In 2011, MIT and Michigan State researchers developed solar cells with power conversing efficiency nearly 2% with a transparency to the human eye greater than 65%, achieved by selectively absorbing the ultraviolet and near-infrared parts of the spectrum of sun light with small-molecule compounds [15-16]. Researchers at UCLA more recently developed an similar polymer solar cell, following the same approach that is 70% transparent and has 4% power conversion efficiency [17-18]. These lightweight, flexible cells can be produced in bulk at a low cost and could be used to create power generating windows. In 2013, researchers announced [organic solar cells](https://en.wikipedia.org/wiki/Polymer_solar_cell) nearly 3% efficiency. They used [block copolymers](https://en.wikipedia.org/wiki/Block_copolymers), self-assembling organic materials that arrange themselves into distinct layers. The research focused on P3HT-b-PFTBT that separates into bands some 16 nanometers wide.

**V CLASSIFICATION OF ORGANIC SOLAR CELLS**

1. **Single layer organic solar cell:**

Single layer organic photovoltaic cells are the simplest forms of organic solar cells. These solar cells are made by sandwiching a layer of organic materials between two conductive electrodes one of transparent electrode ITO (Indium tin oxide) with high work function and other of low work function metal such as Al, Mg or Ca. The basic structure of such a cell is shown in Fig. 2.



Fig. 2 Single Layer Organic Solar Cell

In practice, single layer photovoltaic solar cells do not work well due to their low power conversion efficiency. They have low quantum efficiencies less than 1% and low power conversion efficiencies less than 0.1%. A major problem with them is that the electric field resulting from the difference between the two conductive electrodes is not sufficient to break up the photo generated excitons. Often the electrons recombine with the holes rather than reach the electrode. To deal with this problem, the multilayer organic photovoltaic cells were developed.

1. **Double layer organic photovoltaic cells:**

Double layer organic solar cell contains two different layers of organic materials in between the two different conductive electrodes. These two electrodes and layers of materials have different work function and different energy band gap and these layers also have the differences in electron ionization energy and electron affinity due which the electrostatic forces are developed at the interface between the two layers. This electric force is capable to separates the electric charge. The materials are chosen properly to make the differences large enough, so these generated electric fields are strong, which may break up the electron- hole pairs (excitons) much more efficiently than the single layer Crystalline solar cells. The layer which has high electron affinity and ionization potential energy, work as electron acceptor and the other layer as electron donor. This structure is also known as planar donor-acceptor heterojunction.



**Fig. 3 Structure of Double Layer Organic Solar Cell**

In double layer organic solar cell the diffusion length of excitons in active layer materials is order of 5- 20 nm. In order for most electron-hole pairs to diffuse at the interface of layers and break up into electrons and holes, the active layer thickness must be the same order as the diffusion length. However, an active layer of material required to need a thickness at least 100 nm to absorb maximum light. For large thickness, only a small fraction of the excitons can reach the heterojunction interface. To short out this problem, [19] a new type of heterojunction solar cells are developed, which are the disassemble heterojunction solar cells.

**c. Graded heterojunction solar cells:**

Graded heterojunction photovoltaic solar cells have with an active layer of active donor –blend acceptor structure. In this structure electron donor and electron acceptor materials are mixed together as in the bulk heterojunction, but in such a way that the declivity is shallowly. This structure includes the short distance traveled by the electron in the dispersed heterojunction with the gain of the charge gradient of the bi-layer technology.

**d. Bulk heterojunction solar cell:**

Bulk heterojunction is the mixture of conjugate polymer of fullerene derivative of electron donor and electron acceptor. The P3HT material is electron donor and has a narrow energy band gap between LUMO and HUMO and P3HT material has longest absorption wavelength about 650 nm but PCBM material is a good electron acceptor material. The acceptor materials PCBM having high hole mobility it plays an important role of electron acceptor in many organic devices. Organic polymers have large energy band gap compared as inorganic semiconductors materials. They have high absorption coefficient in ultra violate region in comparison to other semiconductor material and high charge carrier mobility [20]. In many organic materials, bulk heterojunction structure has been acquire in the P3HT: PCBM mixture so that the donor/acceptor intersection layer is increase in size. This is shown in the fig.4

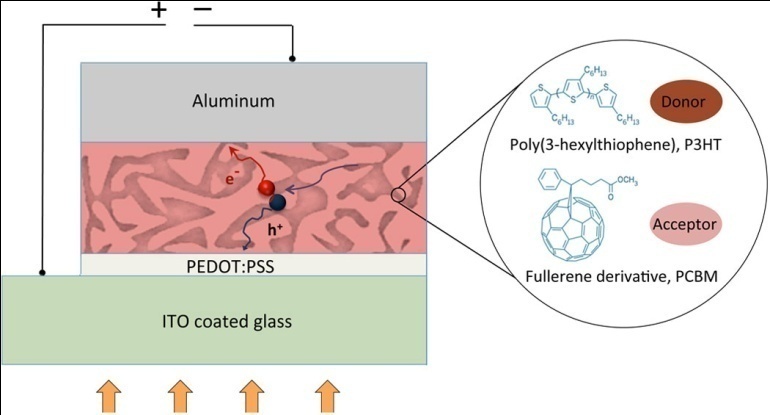


Fig. 4 Structure of Bulk Heterojunction Solar Cell

Bulk heterojunction solar have cells have more advantage over inorganic solar cells is that they are flexible in substrate, low cost fabrication and therefore can be used for a large range of surfaces. They can also be easily produced by [spray deposition](https://en.wikipedia.org/wiki/Spray_forming) method or spin coating, and these are very cheap to manufacture [21]. A disadvantage is that they are not crystalline but instead are produced in a deliberately disordered mixture of electron-acceptor and donor materials. They have a limited efficiency of charge transport. The efficiencies of new types of organic solar cells have increase from 2.5% in 2001, to 5% in 2006 and achieved more than 10% in 2011. This is because to increase process for solution processing of acceptor and donor materials (P3HT) led to more appropriate mixture of the two materials. Further research can forwarded to polymer-fullerene based organic cells that proceed toward the efficiency of current inorganic solar cells. Especially for bulk heterojunction solar cells, considering charge carrier transport is important in enhancing the efficiencies of organic solar cells. Currently, bulk heterojunction solar cells have different charge-carrier mobility. The hole mobility being less in magnitude lower than that of the electron mobility, [22] this results in space charge set-up and fill factor and power conversation efficiency of a solar cell decrease. Due to having low mobility of the charge carriers, efficient bulk heterojunction solar cell has to be formed with thin active layers of materials to avoid recombination of the charge carriers, which is harmful to absorption and adjustability in processing. Simulations have being done in order to have a bulk heterojunction organic solar cell of fill factor above 0.8 and external quantum efficiency more than 90%. There is needed to be balanced charge carrier mobility to overcome a space charge effect, as well as an increase in charge carrier mobility.

**VI Working of organic solar cell**

To form the organic solar cells, the active layer is sandwich between transparent glass electrode (ITO) and metal electrodes like as Ag, Al, Mg and Au. The working material is absorbs the sun light and generate the electron-hole pairs and these electron-hole pairs separated at interfaces and move towards the electrodes. The active layer is made of the organic materials, the electron donor P3HT and PCBM as the electron acceptor. The working principle of organic cells depends on the photo-voltaic effect and the operational mechanism of photovoltaic solar cells can be explained on the basis following diagram.

1. An electron in the highest molecular orbital (HOMO) of an active material to absorbs a photon and excited into the lowest molecular orbital (LUMO), generating an excitons (electron- hole) pairs.

2. The excitons dissociated at the interface of two the materials which are shown in figure.

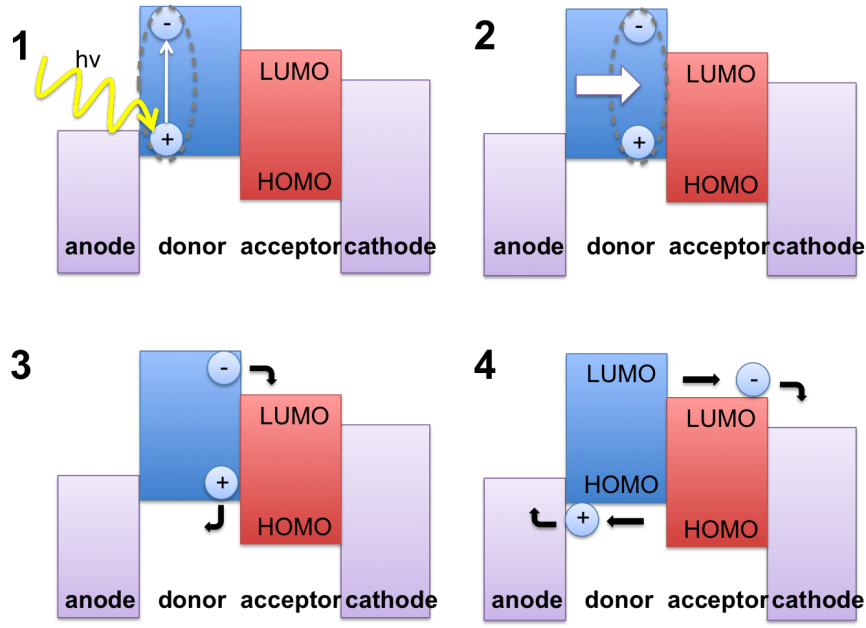


Fig. 5 Operation of Organic Solar Cell

3. The excitons are separated at the interface of the active layer and move towards the opposite charge electrodes.

4. When the opposite charge carrier move towards the opposite electrodes than current will start flow in the circuit.

**VII PROPERTIES OF ORGANIC SOLAR CELLS**

Organic conjugated polymers materials based solar cells are a promising alternate option to the silicon based inorganic solar cell due to following properties [23].

1. Organic devices have high absorption coefficient.
2. Low cost device manufacturing and ease of device fabrication.
3. Ease of processing using conventional polymer processing technologies.
4. Large area device fabrication possible at room temperatures.
5. These devices are light weight and flexible.
6. Organic solar cells are environment friendly, biodegradable and utilize non toxic processing.

**VIII Applications of Solar Cell**

1. They mostly use in the field of satellites.

2. They also use in automatic door.

3. Its may be use in the field of emergency power.

4. Its mostly use in the field of toys, watches and calculator.

5. They mostly use in the field of portable power supplies.

6. They are used to give the power supply and home and other offices.

## IX Current Challenges and Future Scope

The Organic photovoltaic cells has low external quantum efficiency as compared to inorganic silicon solar cells.. The internal quantum efficiency and fill facture of organic solar cells is maximum due to the maximum absorption with active layers on the order of 100 to 200 nanometers, evaporation in opposition to oxidation and reduction, re-crystallization. Due to the temperature variations of the photovoltaic device the solar cell degradation and decreased their efficiency over a long time. The working field of solar cell is increase by the active research in different fields. On the hand the important factor is which effect the motion of the charge carries and dissociation of excitons, the excitons diffusion length, charge separation and charge collection, which are affected by the presence of impurities. In this research chapter study the basic introduction and properties of solar cells and future planning to increase the efficiency and stability remain constant in all weather. The solar cells can be used in long time without any degradation.

**X Conclusion**

In this research work study the basic introduction of photovoltaic solar cells and its types. In an organic solar cell, Bulk heterojunction is formed by blends of electron donor and electron acceptor conjugated molecules that allows light absorption, generation of excitons (electron hole pair) and excitons splitting at donor-acceptor interface and efficiently transportation of positive and negative charges to opposite electrodes. Solar cells become the one of the most important substitute of electricity and it is using in a large scale in the world to generates the electric power by the solar energy.

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