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Infrared plastic solar cell

A Project Submitted to the Scientific Committee in the Chemistry Department in Partial Fulfilment of the Requirement for the Degree of Bachelor Science in Chemistry.

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بسم الله الرحمن الرحيم

﴿ يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنْكُمْ وَالَّذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ وَاللَّهُ بِمَا تَعْمَلُونَ خَبِيرٌ ﴾

صدق الله العظيم

سورة المجادلة: من الآية (11)

Dedication

"In the name of Allah, the most Gracious and the most Merciful"

To:

My mother & father

My supervisor

With my Love and Respect

My country

AYUB

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Acknowledgement

First of all, I thank ALLAH for this opportunity and his blessing over me. I wish to express my deep gratitude and sincere thanks to my supervisor Dr. Ropak Ahmad Sheakh Mohamad, who encouraged me and provided facilities for this research project. Last but not least, I would like to offer my sincere thanks to my family, friends and classmates who helped me to carry out this project successfully and for their valuable advices and support which have been given to me during this research.

Abstract

Solar panels are active solar devices that convert sunlight into electricity. They come in a variety of rectangular shapes and are usually installed in combination to produce electricity. The primary component of a solar panel is the solar cells, or photovoltaic cell having low efficiency and high cost. plastic solar cell technology, is based on conjugated polymers and molecules. Polymer solar cells have attracted considerable attention in the past few years owing to their potential of providing environmentally safe, flexible, lightweight, inexpensive, efficient solar cells.

Application of nanotechnology in these plastic solar cells will helps us to make solar energy more economical. Production of plastic solar cells using quantum dots could double the efficiency levels currently possible and reduce costs The transparent solar cells is an advance towards giving windows in homes and other buildings the ability to generate electricity while allowing to view from inside. Currently solar energy's biggest problem is the highest cost compared to other sources. But introduction of plastic solar cells with the nanotechnology in solar energy will increase the efficiency and reduce the cost which will give solution to global crisis. If the solar farms can become a reality, it could possibly solve the planet problem of depending too much on the fossil fuels, without a chance of even polluting the environment.

Now days we are able to consume only Twenty percent of energy at most by CdTe solar panels but with the help of infrared plastic solar cell we can make it 30 percent more efficient, even the best plastic solar cells efficiency is only 6 percent.

Key words: Plastic solar cell, nanorods, electrical energy, visible-infrared ray, solar energy, quantum dots.

1. Introduction

This is the time of nanotechnology. But today there is nothing more important than energy, since the lack of energy means a significant obstacle to the present civilization, i.e., not enough food, warm shelter and connection to the Inter- net, including the consumption of nanotechnology products. The development of modern trends of energy demands promising new technologies and even new physical and chemical processes for the establishment and operation of efficient systems to generate, accumulate, transform and transport of energy into its various forms (Ranabhat et al., 2016).

Combustion of fossil fuel dominates today's power generation and, alarmingly, 38% of total world electricity supply still relies on burning coal in 2019. Renewable energy sources such as solar, wind, rain, tides, and geothermal heat have enormous potential to replace conventional fossil fuels in the future. Sunlight has long been identified as the most promising sustainable source of clean energy and thus solar cells have been actively researched over the past decades (Li et al., 2021).

The need to overcome challenges of sustainable energy supply leads to more search on alternative sources, and renewable energy production (Peter and Mbohwa, 2019). People of the world have to pay attention to renewable energy resources due to the limitation and impact of non-renewable energy resources. Due to global warming, greenhouse gas emissions, fluctuating oil prices, and rising electricity demand in developing countries have to consider new solutions. So renewable energy is affected by the current energy structure and direction of energy development as an essential part. Solar energy is a type of renewable energy resource which has been extensive – scale development and full applications due to energy transmission limitations. Usually, solar energy has many advantages than fossil-based coal and oil due to reduce carbon emissions, clean the air, and can generate again within our lifetimes (Arachchige and Weliwaththage, 2020).

If current trends continue, future society will require increased electrical energy. It seems highly probable that greenhouse gas emissions will lead to significant global warming over the next 50 years. Climate change is real and it is happening right now, it is the most urgent threat facing our entire species and we need to work collectively together and stop it. Fortunately, advances in science and technology have provided us with several alternative means of producing energy on a sustainable level, such as wind, geothermal, biomass, and solar (Turner, 1999).

1.1. Solar Cell

A photovoltaic cell, often known as a solar cell, is a device that utilizes the photovoltaic effect to convert solar energy directly into electrical energy. It is a physical and chemical phenomenon called the photovoltaic Effect. These cells' electrical characteristics, such as resistance, voltage, and current, change when they are exposed to sunlight. By assembling the various solar cells into electrical building blocks for photovoltaic structures, solar panels are created. A maximum open-circuit voltage of 0.5 to 0.6 volts (about) can be produced by a single junction common silicon plastic solar cell (Srivastava, 2021).

Solar cells, without any doubt, have been recognized as one of the important energy conversion devices that can directly deliver electricity from sun light. As far as the sun light shines to our planet, the electricity production via solar cells is expected endlessly without any payment for using the sun light. However, we understand very well that the electricity from solar cells is more expensive than conventional electricity from fossil fuel and/or nuclear power stations. The reason is related to the high manufacturing cost for conventional solar cells, which are mostly based on inorganic materials and need high temperature processes and expensive vacuum systems (Kim et al., 2014).

With the increasing demand of electrical energy everyone looking towards sun as a source electrical energy along with its source of heat and light. Each and every photovoltaic device consists of two distinct layers of material, one with an abundance of electrons that work as a negative pole, and one with an abundance of electron holes that work as a positive pole. When photons from the sun or other light source are absorbed, their energy is transferred to the extra electrons in the negative pole, causing them flow to the positive pole and creating new holes that start flowing to the negative pole, thus producing an electrical current which can then be used to power other devices. Conventional semiconductor solar cells are made of polycrystalline silicon or, in highest efficiency ones, crystalline gallium arsenide. Because of their high production costs, these devices have only seen limited use thus far. Even the making of the simplest semiconductor cell is a difficult process that has to take place under exactly controlled conditions, such as high vacuum and temperatures between 400 to 1,400 degrees Celsius (Tanzeela and Fabna, 2020).

It is seen that only thirty percent of entire sun energy can be used in sensible manner by this type of solar cells and since it does not favor on the cloudy day which is a major drawback and leading to the consideration of development of a novel kind of “solar cell” by the use of nanotechnology. The process is same as earlier but in there is a difference in the absorption of wave length of light from the sun (Chandra, 2020).

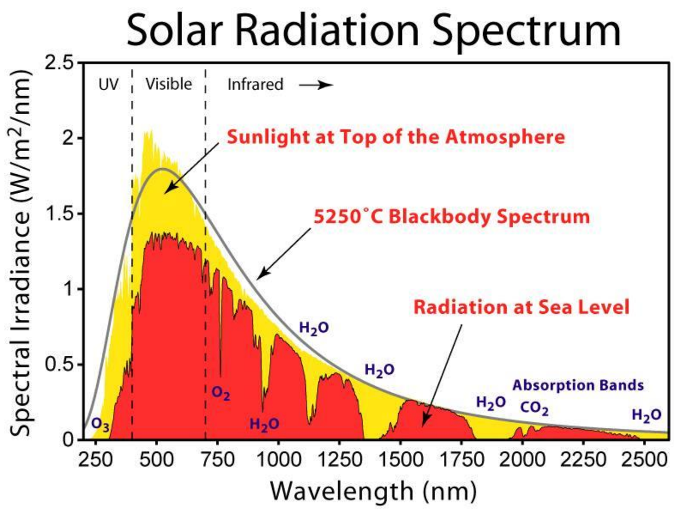

Fig 1. Spectrum of solar Radiation (Earth).

Solar cells need to absorb a range of energy, which corresponds to the solar spectrum to be efficient. The solar spectrum has a range of 100nm to 1mm, but most of the irradiance occurs between 250nm- 2500nm (figure 1) with the maximum in the visible region of light (400-700nm) for air mass (AM) 0, which means that the solar cells should strive to absorb as much in visible region of solar spectrum as possible (Ranabhat et al., 2016).

1.1.1. Brief history of solar cell

The history of the solar cell is really quite interesting (Perlin, 1999). In 1839, Edmond Becquerel found that two different brass plates immersed in a liquid produced a continuous current when illuminated with sunlight. We now believe that he had made a copper – cuprous oxide thin – film solar cell. Later in the 1870s, Willoughby Smith, W. G. Adams, and R. E. Day discovered a PV effect in selenium. A few years later, an American named C. E. Fritts placed a sheet of amorphous selenium on a metal backing and covered the selenium with a transparent gold leaf film. He reported that this selenium array produced a current “that is continuous, constant, and of considerable force — with exposure to sunlight”. At the time, there was no quantum theory and there was considerable skepticism about his claim of converting sunlight into electricity. So, he sent a sample to Werner Siemens in Germany, who was one of the most respected experts in electricity at the time. Siemens’ s observation verified Fritts’ s claims. However, the conversion efficiencies of both the thin – film cuprous oxide and the amorphous selenium solar cells were less than 1% (Fraas and Partain, 2010).

Around 75 years passed while quantum mechanics was discovered, the importance of single – crystal semiconductors was recognized, and p/n junction behavior was explained (Chapin et al., 1991). At Bell Labs had discovered, invented, and demonstrated the silicon single – crystal solar cell with 6% efficiency. Over the few following years, researchers brought the silicon solar cell efficiency up to 15%. The timing was fortunate because Sputnik was launched in 1957 and solar cells were the perfect lightweight low – maintenance remote electric power source. Today, silicon solar cells are being used to power the space station (Fraas and Partain, 2010).

1.1.2. Construction of silicon solar cell

Today’s silicon solar cells that are used to tap energy are basically only a few square centimeters (10cms x 10cms) in area. These solar cells generally contain a thin glass or transparent plastic coating to have protection from the environment. These solar cells can be made from a single crystal or from multiple crystals. Apparently, they are classified as Mono-crystalline, Poly-crystalline, and Thin-film solar cells respectively (Shyam et al., 2020).

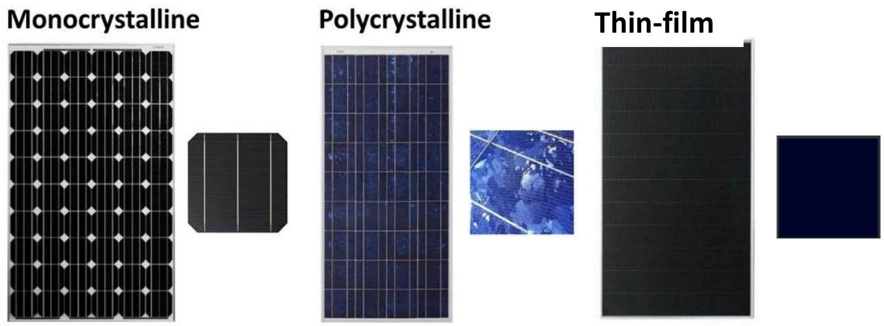

Fig 2. Solar Cell Categorization.

Each tiny solar cell is surprisingly capable of producing about 2 Watts electrical power, which is approximately equal to 15%-20% of light that is incident on it. These solar cells are generally connected in series to boost voltage or in parallel to increase current. This combination of solar cells results in the ultimate formation of a solar panel (Shyam et al., 2020).

A solar panel or a Photovoltaic (PV) module as it is technically named, usually is fabricated with 36 interconnected solar cells, laminated by glass or plastic and confined within an aluminum frame. For more power output more than one such module may be interconnected. At the back of each solar panel, there are standardized sockets that effectively combine the individual output from each module into one final driving output. Connection of several modules constitutes a solar array. The figure given below clearly depicts the difference between a solar cell, panel and an array (Moaz, 2021).

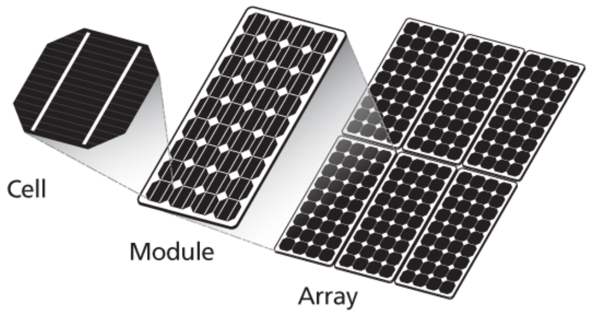

Fig 3. A Solar Cell, Solar Panel & Solar Array.

Further a photovoltaic system is also categorized into 2 forms, such as Stand-Alone system and Grid-Connected system. A standalone system, as the name implies is directly wired with the required application or load. It is backed-up by a battery set, which provides current whenever the panel fails to do so. Typically, stand-alone systems are employed in remote locations, where linking to a centralized station is very expensive (Shyam et al., 2020).

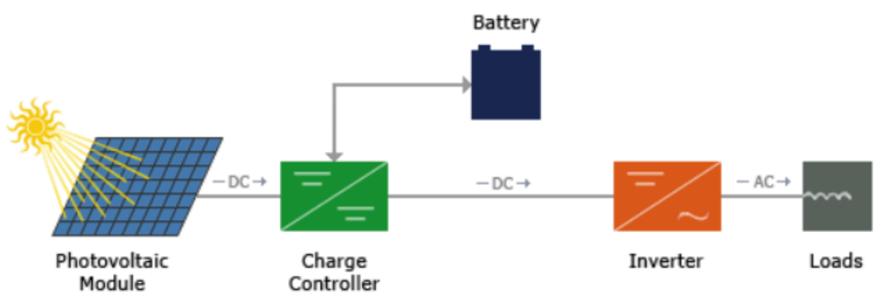

Fig 4. A Stand-Alone PV Module.

On the other hand, a grid-connected system is an interconnection of several solar arrays s and hence provides public utility power. The grid-connected pv systems are either unidirectional, which supply power during mid-day peak or bidirectional, wherein the excess, unused power is fed back to the grid. Thus, a grid-connected system effectively eliminates the need for any storage batteries (Chitransh and Singh, 2021).

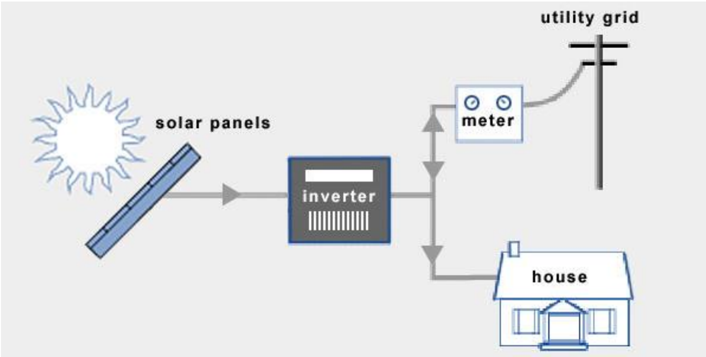

Fig 5. Grid-Connected PV System.

2. Infrared plastic solar cell

The discovery of conductive plastic (1977) (a double bond polymer features combine to make electrons move through them), prof.Alan Haig was awarded the Nobel Prize for this since; there has been interest in the use of these materials in the manufacture of solar cells (Dosaya and Bhati, 2016). Plastic solar cell is invented by the scientists and it is capable of converting the power of the sun into electrical energy on the cloudy days also. The "plastic solar cells" are not new but the material that is present today is not able to collect and convert the visible light of the sun when the half part of the power of the sun fall in the spectrum which is visible and the other part fall in the "infrared spectrum." The plastic compound that is used as a new material has the ability of harnessing the portion that fall in the infrared region (Kumar et al., 2020).

It is the fact that the heat is emitted by all the warm bodies and the heat is also emitted by the humans and the animals also even when there is dark. The plastic material takes the help of nanotechnology and includes the first generation “solar cells” that has the ability of harnessing the invisible infrared rays of the sun. It is expected that this new invention of “plastic solar cell” will work more efficiently in the future as compared to the “solar cell” of today. The specially designed nano particles that are known as “quantum dots” are combined by the researchers with a polymer so as to create a plastic that has the ability to detect the energy in the infrared region also (Chandra, 2020).

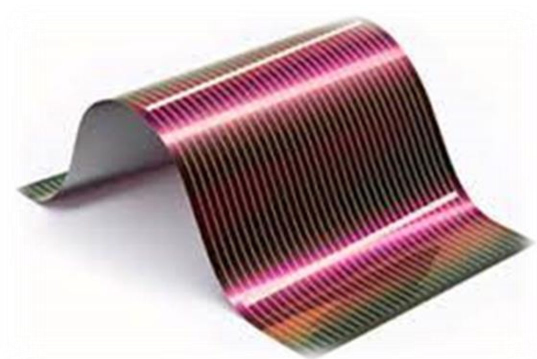

Fig 6. Infrared plastic solar cell.

With further advances the new plastic solar cell could allow up to 30% of sun’s radiant energy to be harnessed completely when compared to only 6% in today plastic best plastic solar cells (Dosaya and Bhati, 2016). The solar farms are able to harness a huge amount of sun energy that can be used to fulfill all our requirements of the energy. It has the potential to replace the other sources that produce electrical energy by which coal is produced which is a greenhouse gas. The solar energy that reaches to the earth is hundred times more than our consumption. If one percent of the earth is covered by the solar farms, then it is possible to substitute all the energy practices with the power source which is clean and can be renewed. The efficiency of current standard commercial photo voltaic cell, which is considered to be the best “solar cell”, is attained by the first basic “solar cell” and these are semi-conductor protectors that has the of converting thirty percent of the sun energy to the electrical energy (Chandra, 2020).

This innovation made us to believe that plastic solar cells could one day become more efficient than the conventional solar cell. Polymers offer the advantage of solution processing at room temperature, which is cheaper and allows for using fully flexible substrates, such as plastics. Thus, replacing the silicon with polymer nanowires would make the solar cell much lighter, and eventually cheaper. The technology takes advantage of recent advances in nanotechnology, specifically the production of nanocrystals and nanorods. These are chemically pure clusters of 100 to 100,000 atoms with dimensions on the order of a nanometer, or a billionth of a meter. Plastic solar cells are hybrid of tiny nanorods dispersed in an organic plastic. Polymer layer is sandwiched between two electrode 1 and electrode 2 (Tanzeela and Fabna, 2020).

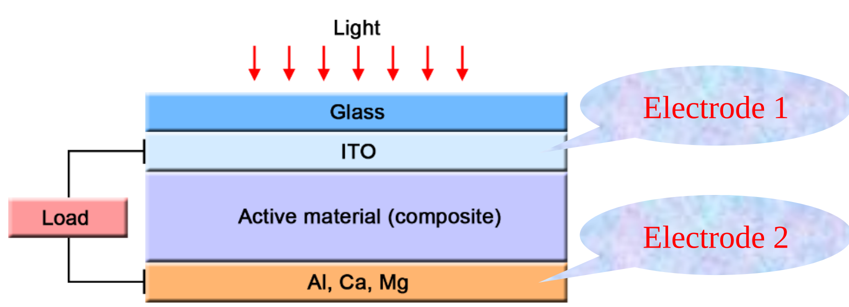

Fig 7. Plastic solar cell: organic material sandwiched between two electrodes.

The most commonly used method in production of plastic solar cell are vacuum evaporation and solution processing technique. The technique used for deposit conjugate semiconductor polymers are printing/coating. Spin coating, doctor balding, as well as screen printing methods are applied for plastic solar cell. Such printing/coating technique leads to large production with low energy consumption (Tanzeela and Fabna, 2020). Solar energy reaching the earth is 10000 times than what we consume (Dosaya and Bhati, 2016).

2.1. Designing of plastic solar cell

The plastic solar cell designed is actually a hybrid, comprised of tiny nanorods dispersed in an organic polymer or plastic (Tanzeela and Fabna, 2020).

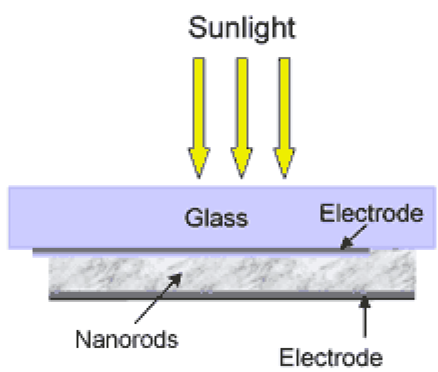

Figure 8. Schematic diagram of plastic solar cell.

The electrode layers and nanorod/polymer layers can be applied in separate coats, making production fairly easy. Significantly, using rod-shaped nano-crystals instead of spheres provided a directed path for electron transport to improve solar cell performance. These types of hybrid solar cells are reported to attain a monochromatic power conversion efficiency of 6.9 percent, one of the highest ever reported for a plastic photovoltaic device. The nanorods act like wires. When they absorb light of a specific wavelength, they create an electron plus (electron hole - a vacancy in the crystal that moves around just like an electron). The electron travels the length of the rod until it is collected by the aluminum electrode. The hole transferred to the plastic, which is known as a hole-carrier, and transfer to the electrode, creating a current. Plastic solar cell structure is the most successful structure developed, in which a blend of donor and acceptor with a bi continuous phase separation can be formed (Tanzeela and Fabna, 2020).

When the sunlight passing through the transparent electrode is absorbed by the semiconducting donor and acceptor materials in the photoactive layer, excitons (bounded electron–hole pairs) are formed, and then the excitons scattered to the interfaces of the donor/acceptor where the excitons dissociate into electrons on the lowest unoccupied molecular orbital level of the acceptor and holes on the highest occupied molecular orbital level of the donor. The dissociated electrons and holes are driven by built-in electric field and then moved to negative and positive electrode, respectively, and then collected by the electrodes to realize the photon-to-electron conversion. The absorption band of P3HT/PCBM covers the range from 380 to 670 nm, which means that the photons with energy between 2.0 eV and 3.3 eV can be absorbed by the active layer, and the excitons will be formed. To make better utilization of the sunlight, active layer materials with broad absorption band is required, and for this purpose, more and more low band gap (LBG) materials have been developed and great successes have been made in the past decade(Dosaya and Bhati, 2016).

2.2. Working of plastic solar cell

Infrared polymeric cell is an amalgamation of nanotechnology and solar technology. Their power-conversion efficiencies can be greatly improved by incorporating specially designed polymeric molecules or developing multi-junction structures that can cover a broader range of solar spectrum (Xia et al., 2010). The technology takes advantage of recent advances in nanotechnology specifically the production of nanocrystals and nanorods. The basic concept behind production of electricity from solar energy is based on photoelectric effect. In photoelectric effect, when electromagnetic waves strike the surface, electrons are ejected if photons have sufficient amount of energy. Electrons produced are being made travelled, using semiconducting polymers where P-N junction is formed. The voltage produced organic solar cell (OSC) is governed by the highest occupied molecular orbitals (HOMO) of the donor Material and the lowest unoccupied molecular orbital (LUMO) of the acceptor material as shown in the figure 9. Hence to increase the efficiency, the polymer absorption window should be increased, which is done by making use of nano rods and quantum dots. Nanorods or quantum dots decreases the energy band gap between the donor and the acceptor polymer by forming intermediate energy level in the active layer, ensuring easy formation of electron-hole pair (Ameri et al., 2013).

The nanorod also acts like wires. When they absorb radiation of a specific wavelength, they generate an electron-hole pair in the polymeric matrix that moves around just like an electron and the electron transverse the length of the rod until it is collected by electrode as shown in the figure 10. Quantum dots (QDs) and nanorods possess potential to improve performance and efficiency of PSCs because of its quantum effect and unique optical properties (Patel et al., 2017).

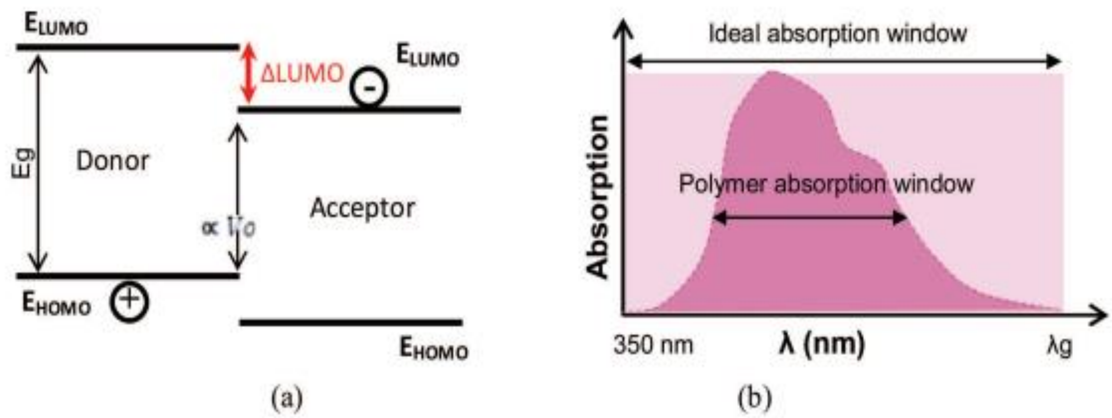

Figure 9. (a) Schematic energy band diagram of a bulk hetero junction single junction organic solar cell, (b) Illustration of the full/ideal absorption window compared to the narrow absorption window of polymers.

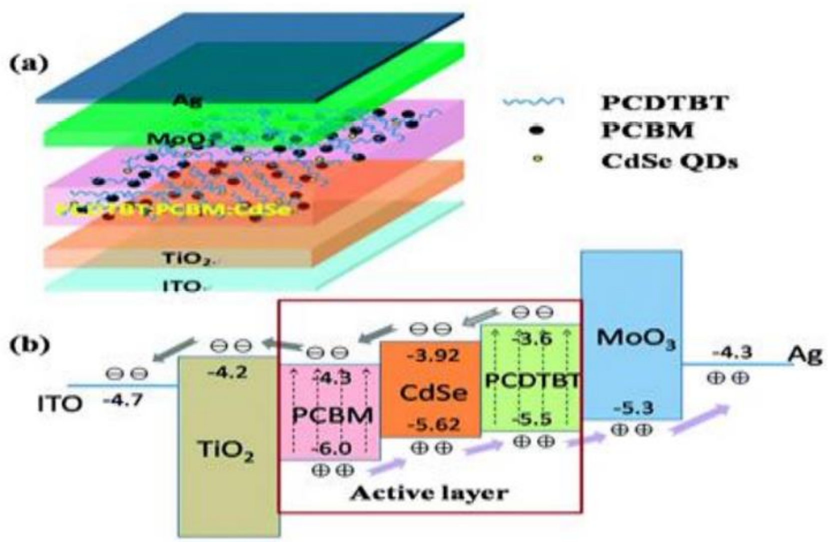

Figure 10. (a) The device structure of the infrared polymer solar cells (b), Scheme of energy levels of the materials involved in the infrared polymer solar cells.

3. Screen printing technology

Screen printing is a large area of the dye sheet fast, inexpensive deposition technique commonly used in industry. From this standpoint, it is the ideal technology for mass production of polymer-based solar cells. In addition, screen printing allows to easily define the composition of the substrate deposition area receives. It is important, for example, a photoelectric conversion device manufacturing integrated into other electronic devices containing a substrate is provided. Further, in the production of large-area energy collection system, it is necessary to manufacture a number of individual solar cells connected together. Screen printing, individual devices can easily be on the same substrate, in order to optimize the limited power of the entire system (Dosaya and Bhati, 2016).

In industrial processes, films created with screen printing usually have a thickness greater than 0.5 mm. The use of screen-printing to fabricate a polymer layer with a thickness less than 100 nm, serving as the whole transport layer in an organic light-emitting diode has been recently demonstrated. Although, in this case, the printed films were not smooth and the screen footprint is visible to the naked eye. Here, we use screen printing to install an ultra-thin and smooth active layer in a bulk heterojunction photovoltaic device, consisting of a conjugated polymer/fullerene blend, with a thickness of 40 nm and root-mean-square (rms) surface roughness of 2.6 nm. This device yields a power conversion efficiency of 4.3% when illuminated by monochromatic light with a wavelength of 488 nm (Tanzeela and Fabna, 2020).

The stand-out feature of the utilizing polymer plastics is that it allows the involvement of the above said technologies to fabricate solar cells at room temperature itself. This comforts the manufacturer as no special environment is required to be set-up for plastic solar cells manufacture (Shyam et al., 2020).

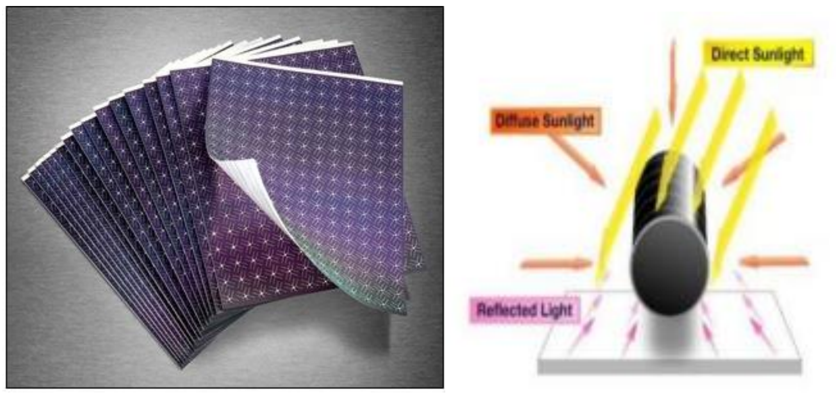

Fig 11. Nano rod in a plastic solar cell.

The next figure elucidates on the screen-printing technique that is involved in the fabricating plastic solar cells for higher energy conversion (Shyam et al., 2020).

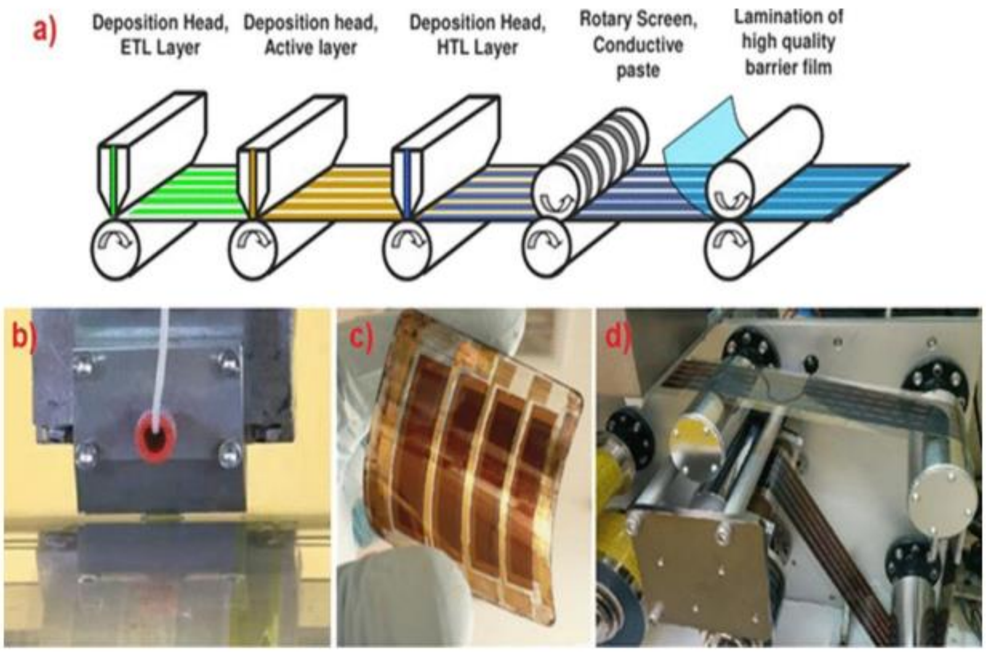

Fig 12. Screen printing of plastic solar cells.

4. Application

1. In remote areas, we require lots of electricity so we can use plastic cells as a poster of power solar panel by connecting number of cells (Srivastava, 2021).
2. The phones or any other device that do not have wire can be powered by any chip if it is coated in the material (Kumar et al., 2020).

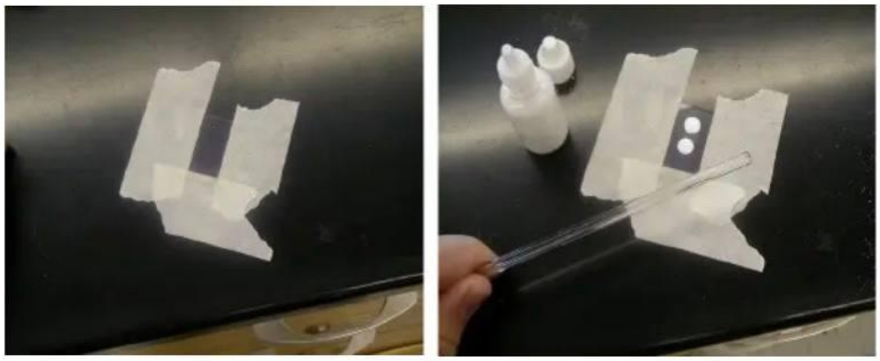

Fig 13. Plastic solar cell as chip.

3. These cells can also be used in portable devices by spraying it on those devices as a paint (Chandra, 2020).
4. The solar farm that has plastic material can be set in the deserts for the generation of clear energy and this has the potential to fulfill the power requirements of entire planet (Chandra, 2020).
5. Disposal solar panels can be made in thin sheets with about 6-10 sheets stacked together and made into a poster can help them to some extent in this regard. This poster could be mounted behind a window or attached to a cabinet (Dosaya and Bhati, 2016).

Fig 14. Plastic solar cell as poster.

6. Solar plastic cells can also be used in charging electrical hydrogen cars by placing plastic cells with proper connections on the top of those cars (Chandra, 2020).

Fig 15. Hydrogen Powered Car with Plastic Solar Cells on top.

7. Plastic cells can also be used in Light House for ocean navigation (Srivastava, 2021).

Fig 16. Ocean Navigation with Plastic Solar Cells.

5. Limitations

1. The biggest problem with this is cost effectiveness. But that could change with new material. But chemists have found a way to make cheap plastic solar cells flexible enough to paint onto any surface and potentially able to provide electricity for wearable electronics or other low power devices (Dosaya and Bhati, 2016).
2. Relatively shorter life span when continuously exposed to sunlight (Dosaya and Bhati, 2016).
3. The main requirements of plastic solar cells are continued and constant monitoring and also requires high maintenance which is difficult to handle (Srivastava, 2021).

6. Advantage

Plastic cells are very efficient and very useful in the upcoming future because these cells have a lot of advantages and some of those important advantages are:

1. When we talk about application purposes, plastic cells are more practical and efficient (Srivastava, 2021).
2. Plastic cells are not very compact when used in making solar panels and they form light structure which is easily manageable conventional cells are used for large applications which have a huge budget package. Whereas plastic cells can have vast applications due to its feasibility as they can sew into fabric (Srivastava, 2021).

3. Conventional solar cells are only used for large applications with big budgets. But the plastic solar cells are feasible as they can be even sewn into fabric-thus having vast applications (Kumar et al., 2020).
4. They are cheap compared to conventional solar cells and are light in weight (Patel et al., 2017).
5. Flexibility and independence of non-renewable resources is a major selling point of these cells. They absorb in a wide spectrum range from the ultra-visible range up to 1000nm (Patel et al., 2017).
6. Instead of the expensive vacuum which is used in the conventional solar cells, polymer solar cells can be printed or coated which are produced from solution (Patel et al., 2017).
7. With newly designed nano particles called quantum dots the plastic solar cell could give efficiency up to 30% when compared to only 6% of today's plastic solar cells (Patel et al., 2017).

7. Disadvantage

1. Polymeric solar cells degrade and hence they fail to last even a year against the silicon-based cells which have a life span of 25 years (Patel et al., 2017).
2. When compared to traditional technologies, infrared polymeric solar cells have far lower efficiencies (Patel et al., 2017).
3. Due to their constant degradation they require better maintenance as well as constant level of monitoring (Patel et al., 2017).
4. Photocurrent responses above 750 nm are very low and hence it is necessary to develop electron accepting polymers that can easily collect solar light (Patel et al., 2017).

8. Conclusion

The usage of energy is growing with increasing population and this cannot be satisfied by the existing energy resources. Due to some disadvantages of Conventional solar cells, there is being limited. But plastic solar cell helps in converting sun's infrared radiation and can produce electricity even on cloudy days have led to overcome few disadvantages of conventional solar cells. No bigger plants are required for manufacturing. If the manufacturing of Nano technology-based equipment increases then it is easier for us to manufacture it. In near future it may be possible that some methods will be developed to increase its life span. It is modified into any shape and size above Nano level. There is no restriction of installation due to its light weight and also it is easier to transport it from one place to another place and due to printing technology, it is cheaper than the conventional solar cell.

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حکومەتی هەرێمی کوردستان-عێراق

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زانکۆی سەلاحەدین-هەولێر

کولێژی زانست

بەشی کیمیا

خانەی خۆری پلاستیکی ژێر سوور

پرۆژەیەک پێشکەش بەلیژنەی زانستی کراوە لە بەشی کیمیا لە بەشی جێبەجێکراو پێویستە بۆ پلەی زانستی بەکالۆریۆس لە کیمیا

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