A Review of Solar Cells and their Applications

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ABSTRACT

A solar cell or a photovoltaic cell is an electronic-device which is used to convert the sun's energy into electrical energy. Sunlight falling on these solar or photovoltaic cells produces current and voltage which generate electric power. This process requires a semiconductor material for the absorption of sunlight which raises an electron from its higher energy state and movement of this higher energy electron from the semiconductor material of the solar cell into an external circuit. The electron then casts away its energy into the external circuit and again returns back to the solar cell material. A variety of semiconductor materials are used for solar energy conversion, also most of the solar energy conversion process employ semiconducting materials in form of a p-n junction. With the increase in utilization of renewable energy, such as solar energy, in this article we will study about the types of solar cells and their applications.

Keywords: Solar cell, Photovoltaic cell, Semiconducting materials, Renewable energy

1 Introduction

In today's world global warming becomes the long-term rise of planet's temperature caused by activities as powering houses with electricity, generation of electricity and heat by the combustion of fossil fuels etc. which causes a huge amount of greenhouse gas emission etc. which cause global warming, so in order to reduce some extent of this global warming and pollution continuous practices of renewable resources are increasing. Our earth meets an enormous supply of solar energy. This non-conventional energy can be used as a resource for generating electricity. This can be done by using several types of solar cells (also called photovoltaic cells or PV cells for converging solar energy according to the requirement. A solar cell or a photovoltaic cell is a device which is used to convert the sunlight's energy directly into an electrical energy with the process of photovoltaic effect, which involves a physical and a chemical occurrence. Solar cells are the blocks of photovoltaic modules, known as solar panels. The operation of a solar cell requires 3 basic features which are:

1. The immersion of sunlight for generation of either electron-hole pair or exactions.
2. The dissociation of charge carriers of opposite type.
3. The segregate extraction of those carriers into an external circuit.

2 Types of Solar Cells and their Applications

Solar cells are generally named according to the material of semiconductor they are made of. These materials have determined characteristics for the absorption of sunlight. The light absorbing materials of solar cells are based on the requirement and application. Solar cells are confined into first, second and third generation cells.

- "First generation cells" are also called conventional or traditional cells which are made up of crystalline silicon.
- "Second generation cells" are thin film solar cells which involve amorphous silicon, CdTe and CIGS cells.

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- "Third generation cells" are a number of thin-film technology using organic materials, inorganic nanoparticles or hybrids.

In today's time solar energy is looked about for developing countries as the fastest expansion in the solar energy market [1]. The different types of solar cells are mentioned below:

2.1 Monocrystalline Solar Cell (Mono-Si)

Monocrystalline silicon or "single crystal silicon" or "single-crystal Si" or "mono-Si" is the base matter for silicon chips of cylindrical shape. The cylindrical silicon band or strip increases from a single crystal of silicon having high purity as the semiconductor. Its efficiency lies between 15% and 20%. As the cell is composed of a single crystal, it offers the electron extra space for movement for a better flow of electricity [2]. In order to maximize the use of the cells, the circular board or microchip are wire cut to an octagonal-shaped microchip. These cells are very affordable and have been needed for the improvement of electronic devices. A Mono-crystalline solar cell is shown in figure 1.

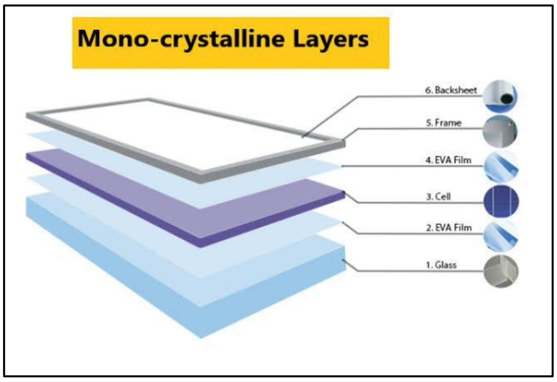

Figure 1: *Mono-crystalline solar cell*

2.2 Polycrystalline Solar Cell (Multi-Si)

Polycrystalline silicon is also known as "polysilicon", "multi-crystalline silicon" is a high purity silicon used as the base matter in solar cells which are produced by cooling and solidifying molten silicon. It is manufactured from the metallurgical quality of silicon by a chemical purification process known as "Siemens Process". Polysilicon comprises small crystals which are larger than 1 mm and are also called crystallites which gives the matter its classic metal flake effect. These semiconductors are highly growing in the photovoltaic market and utilize nearly all the globally manufactured polysilicon. Almost 5 tons of polysilicon are needed for producing 1 megawatt (MW) of solar energy. A Polycrystalline solar cell is shown in figure 2.

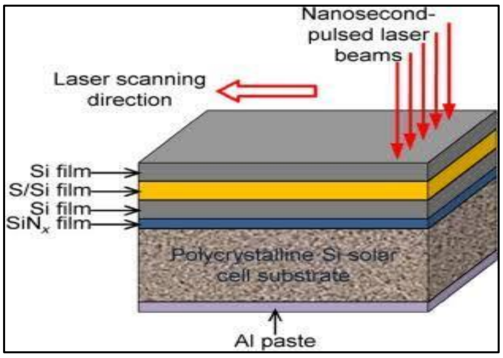

Figure 2: *Polycrystalline solar cell*

2.3 Amorphous Solar Cell (A-Si)

Amorphous silicon is a non-crystalline type of silicon material, which is produced using semiconductor techniques. They are the most efficient cell in the market today as they provide higher efficiency than other two i.e., monocrystalline and polycrystalline [3]. The width of the photovoltaic cell is only 1 macron, or around 1/300th the proportion of monocrystalline solar cells. These are more flexible and can handle higher temperatures better. They are traditionally used for smaller scale applications. An Amorphous solar cell is shown in figure 3.

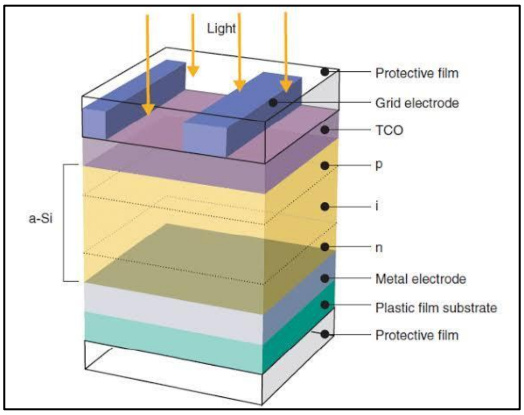

Figure 3: *Amorphous solar cell*

2.4 Cadmium Telluride Solar Cell (CdTe)

The name Cadmium telluride solar cells express solar technology based on the utilization of CdTe. It has the lowest impurity and waste, water provision, and energy compensation time of all types of solar panels. Moreover, Cadmium as a waste and by-product in the mining industry is a very abundant resource and thus has low cost. It has crucial advantages for using as a matter for solar cells because of its capacity to maintain better electronic characteristics under thin film form [4]. A Cadmium-telluride solar cell is shown in figure 4.

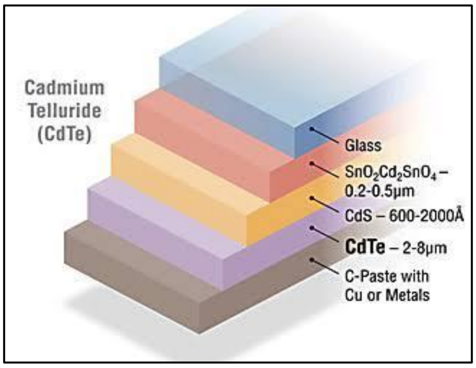

Figure 4: *Cadmium-telluride solar cell*

2.5 Thin-film Solar Cell (TFSC)

A thin-film solar cell (TFSC) is also known as thin-film photovoltaic cell (TFPV) and it is the second-generation of PV cell which are manufactured from accumulation of one or more thin layer or thin film of semiconducting substance over a membrane such as glass, polymer, metal, plastic etc. The thickness of the film differs from a few nanometers (nm) to tens of micrometers (μm) which is much thinner than the thin-film's adversary technology. These have thin-film frames and are lighter, thus, they are used for powering traffic lights as well as street lights. The rooftop of buses/EVs are equipped with these solar panels for

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powering small appliances. Its installation cost is also very low [5]. A Thin-film solar cell is shown in figure 5.

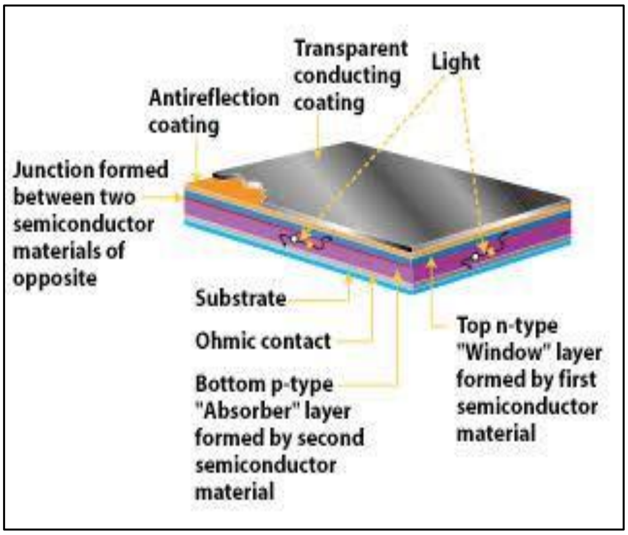

Figure 5: *Thin-film solar cell*

2.6 Perovskite Solar Cell (PSC)

This name of the solar cell is "perovskite solar cell" which is obtained from the ABX3 crystal model of the absorber matter, also known as "perovskite structure". These are organic solar cells and are thin-film equipment and are built with layers of matter which are either printed or coated with liquid inks or vacuum-accumulation. Due to organic panels their stability is very low and sensitive to moisture. In spite of significant development in considering the stability and deterioration of perovskite solar cells they are not presently feasible in the market because of their bounded operational lifespan [6]. The capacity of perovskite solar cells is incredible and if the matter's ability can be acquired then it can completely transfigure the competence of solar energy. A Perovskite solar cell is shown in figure 6.

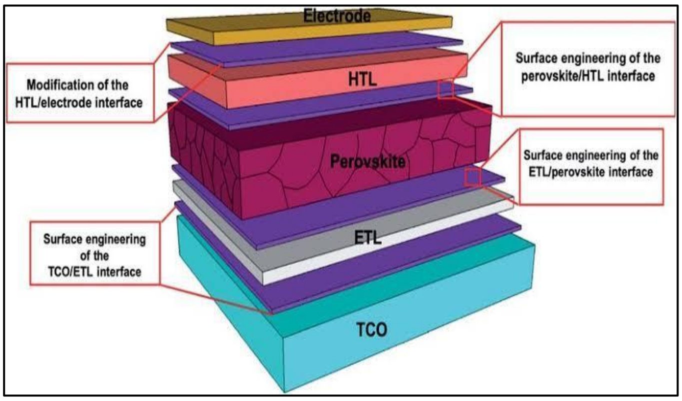

Figure 6: *Perovskite solar cell*

2.7 Dye-Sensitized Solar Cell (DSSC)

Dye-Sensitized solar cells are also known as the third generation PV cell that is used to convert any visual light into electricity i.e., allows to convert artificial as well as natural light into electricity. It is generally based upon a semiconductor set up between a photo-sensitized anode and an electrolyte creating a photochemical system. The working principle of the DSSC includes light immersion, electron introduction, transmission of carrier and collection of current. These panels can work in less intense light like at dawn, dusk or in cloudy weather also. The DSSCs are a combination of solar cells and redox batteries to provide nighty power [7]. A Dye-sensitized solar cell is shown in figure 7.

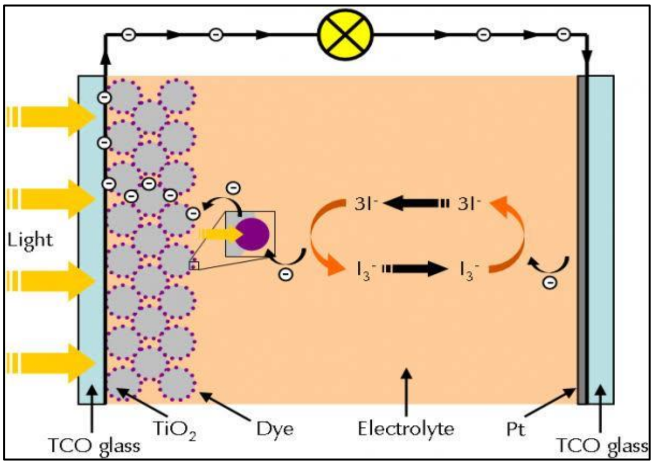

Figure 7: *Dye-sensitized solar cell*

2.8 Copper Indium Gallium Selenide Solar Cell (CI(G)S)

A Copper Indium Gallium Selenide (CIGS) Solar Cell is a thin-film solar cell manufactured by the accumulation of a thin layer of copper, indium, gallium and selenide on substrate membrane such as glass, plastic, polymer, metal etc. in addition of electrodes on the forward and backward for the collection of current [6]. It has a very high absorbing coefficient so a very thin film is needed than other thick semiconductor materials. It has high efficiency and low manufacturing cost [8]. CIGS has the benefit of being able to accumulate substrate matters, give rise to high flexibility, and light weight of solar panels. Enhancements in the efficiency have made the CIGS an organized technology out of other solar cell materials. A Copper Indium Gallium Selenide solar cell is shown in figure 8.

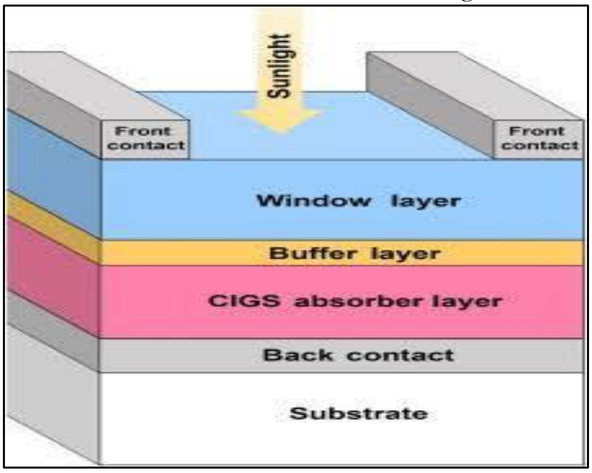

Figure 8: *Copper Indium Gallium Selenide solar cell*

2.9 Hybrid Solar Cell (HSC)

Hybrid Solar Cell is a mixture of an organic and an inorganic semiconductor material. Its organic material comprises a combination of polymers that absorbs the sunlight as the donor and transit holes, while the inorganic materials act as the acceptor and electron transmitter in the architecture. These materials create a layered mound that is stuffed between two electrodes. An opaque metallic electrode creates the back exposure and a conducting semi-transparent material, such as indium tin oxide allows light to enter the front side of the equipment [9]. These solar cells have high efficiency and sustainability and can generate

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power efficiently in all types of weather. The key disadvantage is that it does not have a grid isolation device to power electricity in case of blackout. A Hybrid solar cell is shown in figure 9.

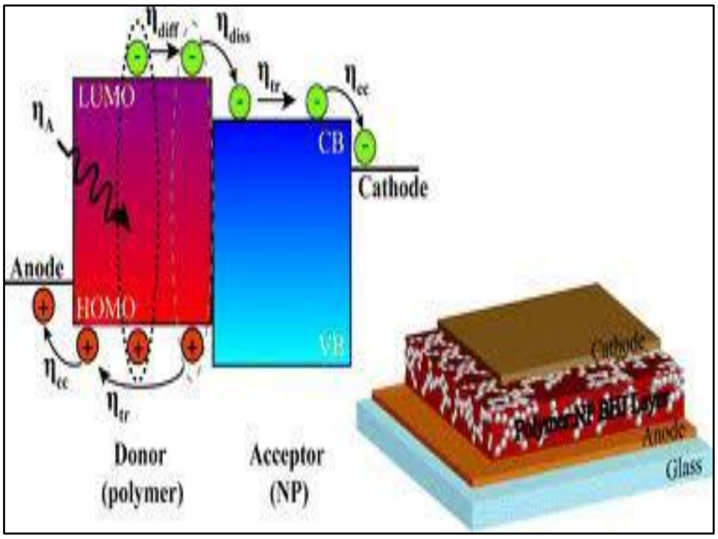

Figure 9: *Hybrid solar cell*

2.10 Quantum Dot Solar Cell (QDSC)

A quantum dot solar cell is a type of PV cell which uses quantum dots as the captivating photovoltaic material. Quantum dots can be termed as "artificial atoms". It tries to restore massive semiconducting materials such as silicon, indium, selenide, copper, gallium or cadmium telluride. It has 'multiple exciton generation' (MEG) effect that extracts more energy out of each photon [10]. In addition, in these solar cells the bandgap is established by the choice of material, so a collection of materials is used to enhance the efficiency of the solar spectrum. This capability of improving the bandgap makes quantum dot advantageous for solar cells. A Quantum-dot solar cell is shown in figure 10.

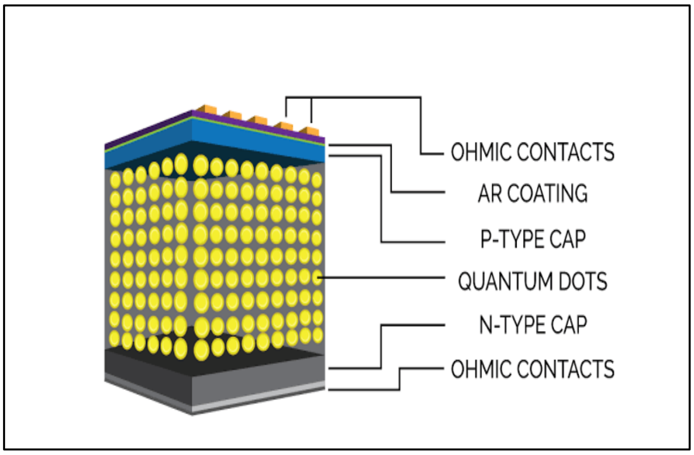

Figure 10: *Quantum-dot solar cell*

2.11 Biohybrid Solar Cell (BSC)

A biohybrid solar cell is a type of photovoltaic cell which is made by utilizing a mixture of organic as well as inorganic material. The system made use of photosystem I to restore the natural photosynthesis phenomenon to attain a higher efficiency of solar energy conversion. Several layers of photosystem I absorb photovoltaic energy and then convert it into chemical energy and generate a current which passes through the cell. With the passage of time the photosystem is made obvious and seems as a thin green film. The film is so thin that it increases and enhances the conversion of energy. The biohybrid solar cells are very advantageous to use because they have an efficiency of 100%. A Biohybrid solar cell is shown in figure 11.

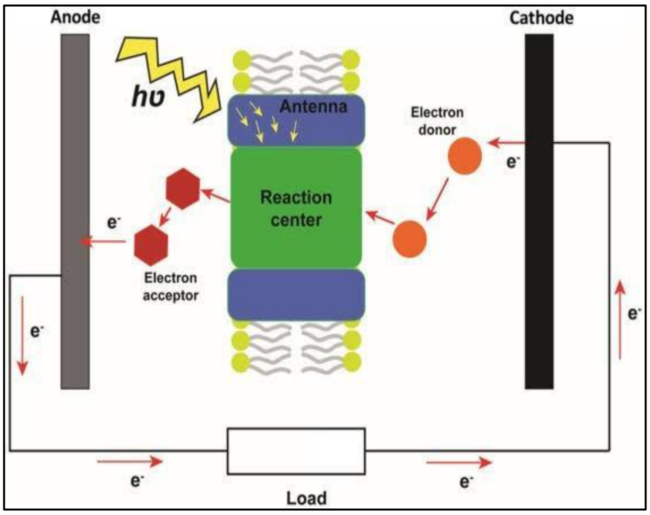

Figure 11: *Biohybrid solar cell*

2.12 Multi-junction Solar Cell (MJSC)

Multi-junction solar cells are photovoltaic cells which make use of several p-n junctions made up of different types of semiconducting materials. Each p-n junction of different material will produce electric current with respect to variable wavelengths of light. The utilization of multiple semiconductor materials permits the consumption of a wide range of wavelengths, increasing solar cell's sunlight into electrical energy conversion efficiency. These multi junction solar cells have higher efficiencies (of about 80%) than that of single junction solar cells (of about 35%) but they are currently extremely expensive. A Multi-junction solar cell is shown in figure 12.

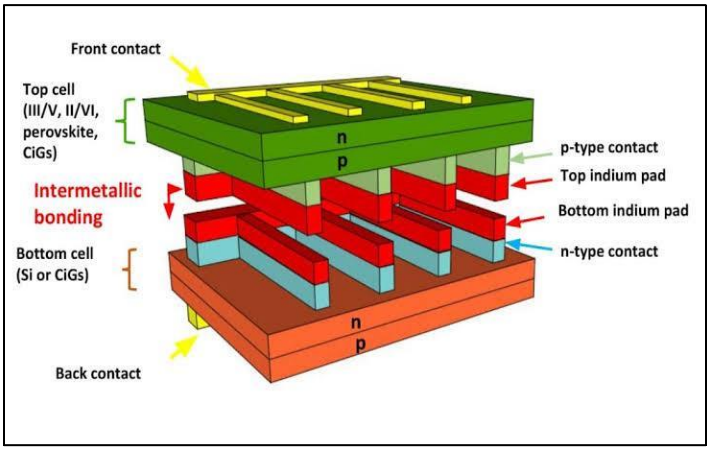

Figure 12: *Multi-junction solar cell*

2.13 Nanocrystal Solar Cell (NSC)

Nanocrystal solar cells are photovoltaic cells which are based upon coating of nanocrystals over the substrate material. The nanocrystal solar cells are generally based upon CIGS, CdTe or silicon and the membrane are usually silicon or other organic semiconductors. A thin-film of nanocrystal can be acquired by the process called "spin-coating". A single nanocrystal structure in which arrangement of single molecule between the electrodes, distant by ~1 exciton diffusion length, is offered to enhance the efficiency of equipment. Although research is still in its infant stage, in the future nanocrystal solar cells may offer

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advantages such as clean power generation, better efficiency, flexibility and lower costs. A Nanocrystal solar cell is shown in figure 13.

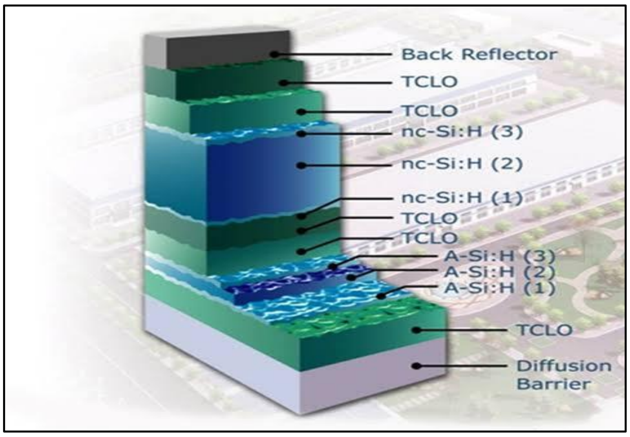

Figure 13: *Nanocrystal solar cell*

2.14 Third-generation Photovoltaic Cell (TGPVC)

Third-generation photovoltaic cells are characterized by organic solar cells, quantum dot solar cells, dye-sensitized solar cells, and perovskite solar cells. They have drawn enormous attention as they are cost effective, flexible, lightweight and have a large area which allows a large-scale application in wearable equipment. It comprises a collection of alternatives to cells made up of semiconducting p-n junction (first generation) and thin-film cell (second generation), while third-generation systems consist of multi-layer cells made up of gallium arsenide or amorphous silicon. Third generation solar cells have capability to generate high efficiency photons into electricity conversion equipment at a lower production rate. In addition, the main ingredient that is refined silicon, has become very expensive which makes it challenging to lower the cost of the solar cells. A Third- generation photovoltaic cell is shown in figure 14.

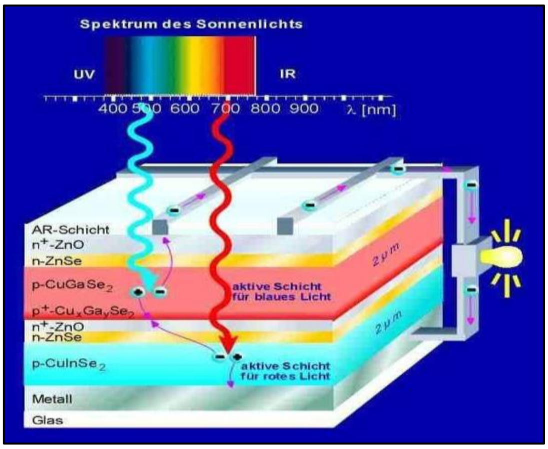

Figure 14: *Third- generation photovoltaic cell*

2.15 Plasmonic Solar Cell (PSC)

A plasmonic solar cell is a photovoltaic cell which converts sunlight into electricity by utilizing plasmons, while the photovoltaic effect takes place in another material. For the application of solar cells, plasmon resonances in small metal molecules are employed to absorb solar energy and transmit it to a very thin semiconductor layer which gives rise to free charge carriers which can contribute to the generation of electricity. The breadth varies from that of conventional silicon photovoltaic to about less than 2 μm thick. Plasmonic solar cells enhance immersion by scattering sunlight by utilizing metal nanoparticles excited at the surface plasmon resonance placed in the front of the thin film solar cells. A Plasmonic solar cell is shown in figure 15.

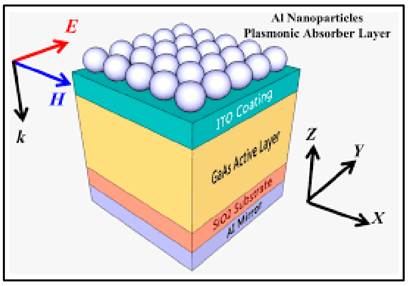

Figure 15: *Plasmonic solar cell*

3 Applications

Some of the applications of solar cells are as follows:

- **Power-plants:** In power plants the solar energy i.e., sun's heat is used to boil the water to generate steam which rotates the turbine to convert solar light into electrical energy by using solar panels, thermoelectric technologies, and photovoltaic technologies.
- **Homes:** In homes solar energy is used for electricity generation, also solar energy is used for running solar heaters for hot water supply. Besides, solar energy is absorbed and stored in batteries by chemical process for their utilization throughout the day when sunlight is not available which also reduces the expenditure of electricity bills of homes.
- **Commercial use:** The PV modules or solar cells are utilized to provide electricity supply to different buildings, hospitals, malls, or other parts on a large scale in a reliable manner.
- **Ventilation system:** Solar energy is utilized for running ceiling fans, pedestal fans, centrifugal fans, bath fans, window fans and floor fans in houses which are used to control moisture, smell, and take out heat of rooms, kitchen, bathrooms etc. These fans add a huge amount to the utility bus, so solar energy is used for running these fans to reduce the expenditure of electricity bills.
- **Power pump:** Solar energy can be utilized to run 6-power pumps, but they run on DC-current, so the water circulates throughout the homes.
- **Swimming pools:** It provides great pleasure and also helps to increase flexibility and strength, but during winter the swimming pool water becomes very cold, and it is difficult to keep water hot in the pools with minimal power consumption. For which solar blanket can be used in the pool to keep water hot or solar hot water heating panels with solar hot water heating systems can be installed.
- **Solar lighting:** These lighting store the natural energy of the sun during daytime and then convert this energy into electrical energy to light up during night or when sun is not available which can reduce load from power plants.
- **Solar cars:** It includes electrical vehicles which can be recharged from solar energy. Solar cells are employed in these vehicles that capture sunlight and then convert it into electrical energy which is further stored in batteries by chemical process and are used with the vehicle so that it can be driven at night time also.
- **Remote applications:** Remote hospitals, schools, clinics, community halls and other buildings may use solar cells and batteries anywhere to generate and consume electric power.

4 Result and Conclusion

We know that as the time passes the available fossil fuels and other non-renewable resources are going to be exhausted and they also take thousands of years to form again, also in today's world life without electricity

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is seems to be impossible. So, we need an alternate way of generating electricity i.e., renewable energy. Solar energy is one of the most essential natural sources of energy which are available incredibly and will not exhaust with the period of time. In present time solar energy is used on **a** very large scale for producing electricity i.e., almost 5000 trillion kWh per year of energy occurs over India's land area with most parts going through 4 to 7 kWh per sq. m per day. Also, the efficiency of solar energy is also very good.
In addition to being an alternate source of electricity generation, solar energy is a very clean and emission free resource of energy. The solar energy can be stored in batteries and can be used for night as well as cloudy seasons. It requires low maintenance cost, is sustainable and is reliable (can be used on small as well as large scale, depending upon the requirement). It also reduces the load from the power plants and reduces the expenditure of electricity bills.
At present, there are enormous variations of solar systems that have been improved which are utilized to capture solar energy corresponding to consumption. Besides, several types of semiconductor materials are used for making solar panels which are chosen according to efficiency needed i.e., thin plate, layers of thin plates, thick plates, single layer, multi layers etc.
The solar energy market exposition has been developing because of government's targets for sustainable energy generation and controlling carbon footprint, and the International Energy Agency (IGA) has said that "solar energy could be the world's biggest source of electricity by 2050".

5 Declarations

5.1 Competing Interests

The authors declare no conflict of interest.

5.2 Study Limitations

There are no limitations that significantly affect the research outcome.

5.3 Warning for Hazard

This work does not involve any chemicals, procedures, or equipment with unusual hazards.

5.4 Ethical Approval

Ethical approval is not required for this study.

5.5 Informed Consent

No human or animal subjects were involved in this research; hence no informed consent was obtained.

5.6 Publisher's Note

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