e-ISSN: 2455-667X

Annals of Natural Sciences
(Peer-Reviewed/Referred International Journal)
Vol. 4(3), Sept. 2018:23-36
Journal's URL: http://www.crsdindia.com/ans.html
Email: crsdindia@gmail.com

Annals of Natural Sciences

ORIGINAL ARTICLE

A Review on Different Types of Solar Cells and Their Characteristics

Vijay Aithekar
Department of Science, Faculty of Education of Methodology,
Jayoti Vidyapeeth Women's University, Jaipur, Rajasthan, India
Email:Vijayaithekar@gmail.com

ABSTRACT

A solar cell is any device that directly converts sunlight into electricity. To generate electric power, the sunlight on the plates produces both a current and voltage. This process requires firstly, a substance in which the absorption of light which raises an electron to a high energy stage and secondly, the movement of this electron from the solar cell into an external circuit. The electron then dissipates its energy in the circuit and back return to the cell. A range of materials and process can potentially satisfy the supplies for photovoltaic energy exchange, but in reality all photovoltaic energy conversion uses semiconductor materials in the form of a p-n junction. So to development of sustainable energy, such as solar energy, in this paper we will study the different types of solar cell and their characteristics.

Key words: *solar energy, renewable energy, buried contact technology, solar cell application*

Received: 14th June 2018, Revised: 30th July 2018, Accepted: 8th August 2018

How to cite this article:
Aithekar V. (2018): A Review on Different Types of Solar Cells and Their Characteristics. Annals of Natural Sciences, Vol. 4[3]: Sept., 2018: 23-36.

INTRODUCTION

The solar cells are devices which convert solar energy into electricity directly, or by first converting the solar energy into heat or chemical energy.Many of cells are used to form make solar modules which are used to capture energy from sunlight, are called solar panels.of cells used to make solar modules which are used to capture energy from sunlight, are known as solar panels.

1. The solar cells are high reliability; it means it is used in space where repair is too expensive or not possible .eg.satillites, remote site water pumping.
2. The solar cells are used at low cost or we can say that they utilize their manufacturing cost. The cell uses the energy from sunlight which is free of cost, while the fossil fuel energy is much expensive because fuel is expensive.
3. The pv systems are clean and silent because they burn no fuel and have no moving parts; e.g. tourist sites, caravans and campers.
4. The pv systems are made of ant size, so the owner of solar cell can enlarge the size of solar as he need energy.; e.g. calculators, watches, light meters and cameras

CLASSIFICATION OF SOLAR CELL

1. Amorphous Silicon Solar Cell (A-Si):

Amorphous silicon solar cell is the non-crystalline solar cell which is used widely to form pocket calculators and also used for powers at some private homes. After its discoverers; the process of degradation is called the Staebler-Wronski Effect. To achieve better result it requires the use of thinner layers to increase the electric field strength across the material. Amorphous silicon solar cells are formed by vapor deposition method. The main advantage of amorphous solar cell is their lower manufacturing cost , which makes these cells very cost competitive.

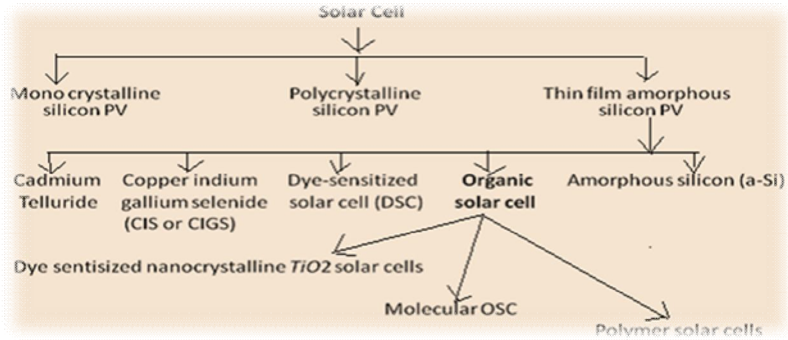

Fig. 1: Types of solar cell

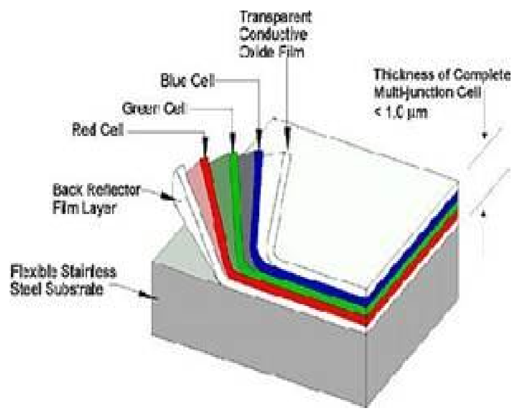

Fig. 2: Amorphous silicon solar cell

2. BIOHYBRID SOLAR CELL:

A bio hybrid solar cell is a solar cell which is made using the combination of organic matter (system 1) and inorganic mater (system2). Bio hybrid solar cells have been made by a team of researchers at Vanderbilt University. The team used the system 1(a photoactive protein complex located in the thylakoid membrane) to recreate the normal method of photosynthesis to gain a high efficiency in solar energy conversion. These bio hybrid solar cells known as a new type of renewable energy [3][4].

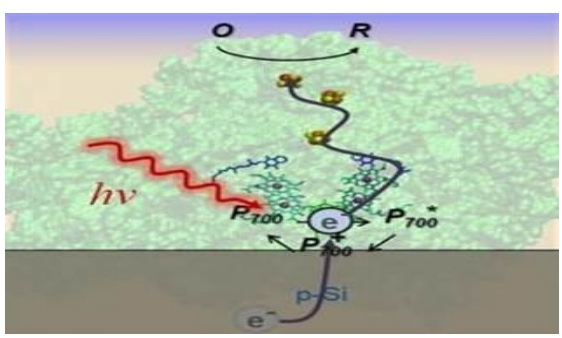

Fig. 3: Biohybrid solar cell. [41]

3. BURIED CONTACT SOLAR CELL:

The buried contact solar cell based on coated metal contact inside a laser formed hollow, is a high efficiency commercial solar cell. The buried contact technology overcomes many of the disadvantages associated with screen printed contacts and thus buried contact solar cell have performance up to 25%,which is better than commercial screen printed solar cell. A schematic diagram of a buried contact solar cell is shown in the (fig.4) below [5]. The main advantage of buried contact solar cell is that it can be used as concentrator system.

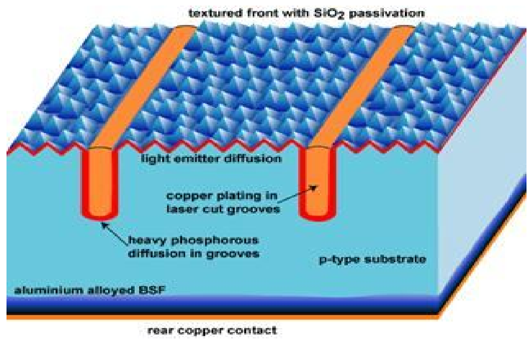

Fig. 4: buried contact solar cell

4. CADMIUM TELLURIDE SOLAR CELL (CdTe):

Cadmium telluride solar cell describes a photovoltaic technology that is based on the use of CDTE, a thin semiconductor layer which is made to absorb and convert sunlight into electricity. Cadmium telluride (CdTe) photovoltaic describes a photovoltaic (PV) technology that is based on the use of cadmium telluride, a thin semiconductor layer designed to absorb and convert sunlight into electricity. Cadmium telluride solar cell is only the solar cell which based on thin technology with lower costs and shortest energy payback time of all solar technologies.[9][10][11][17] CdTe solar cell is used in some of the world's largest photovoltaic power stations, such as the Topaz Solar Farm.

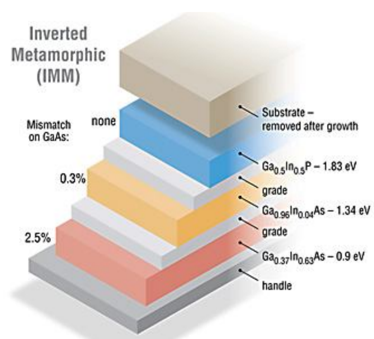

Fig. 5: Cadmium telluride solar cell

5. CONCENTRATED PV CELL (CVP AND HCVP):

A Concentrating Photovoltaic (CPV) system convert sunlight energy into electrical energy by the same way that which a conventional photovoltaic technology does.For achieve maximum cell efficiency, we uses a advanced optical system to concentrations a large area of sunlight. On the basis of concentration there is two types of PV system first is low-concentration (LCPV) and second is high concentration (HCPV).

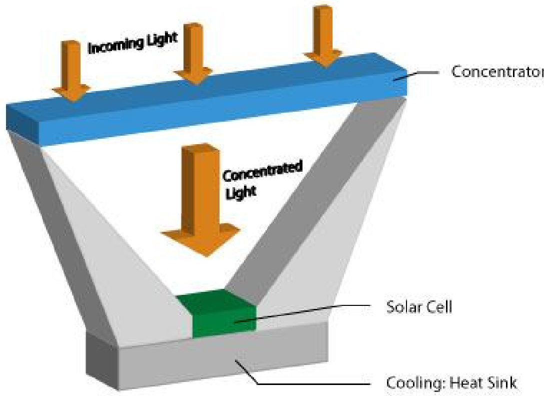

Fig. 6: Concentrated pv solar cell

6. DYE-SENSITIZED SOLAR CELL (DSSC):

Dye Sensitized solar cells (DSSC) is a third generation photovoltaic cell that converts any visible light into electrical energy, also sometimes referred to as dye sensitized cells (DSC).Due the way in which it followers nature's absorption of light energy, this new generation of advanced solar cell can be compared with artificial photosynthesis. Dye Sensitized solar cells (DSSC) were invented in 1991. A dye-sensitized solar cell (DSSC, DSC or DYSC [21]) is a low-cost solar cell belonging to the group of thin film solar cells. [22].

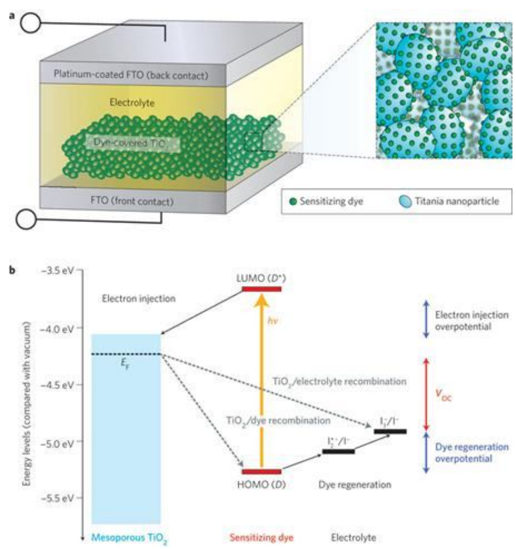

Fig. 7: Dye-Sensitized Solar Cell (DSSC)

7. GALLIUM ARSENIDE GERMANIUM SOLAR CELL (GA As):

Gallium arsenide is composed of 2 base elements; gallium and arsenic. When these two separate elements bind together, they form the aforementioned compound, which displays many interesting characteristics. Gallium arsenide is a semiconductor with greater saturated electron velocity and electron mobility than that of silicon. A semiconductor is a material that has electrical conductivity between an insulator and a conductor; it may vary its ability to conduct electricity when it is cool versus when it is hot. This makes it very useful in many applications. Another novel quality to gallium arsenide is that it has a direct band gap. This is a quality that denotes a compound that can emit light efficiently. Gallium arsenide (GA As) is a compound of the elements gallium and arsenic. It is an III-V direct band gap semiconductor with a zinc blended crystal structure.

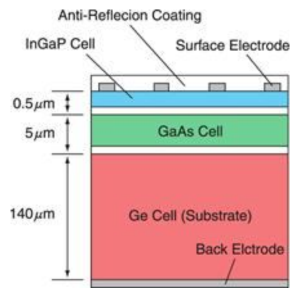

Fig. 8: Gallium Arsenide Germanium Solar Cell (GA As)

8. HYBRID SOLAR CELL:

Hybrid solar cells combine advantages of both organic and inorganic semiconductors. Hybrid photovoltaic have organic materials that consist of conjugated polymers that absorb light as the donor and transport holes.[25] Inorganic materials in hybrid cells are used as the acceptor and electron transporter in the structure. The hybrid photovoltaic devices have a potential for not only low-cost by roll-to-roll processing but also for scalable solar power conversion.

The other material simplifies exciting dissociation at the junction. Charge is transferred and then separated after an existing created in the donor is delocalized on a donor-acceptor complex.[28] The energy required to separate the exciting is provided by the energy offset between the LUMOs or conduction bands of the donor and acceptor. After dissociation, the carriers are transported to the respective electrodes through a percolation network. The average distance an exciting can diffuse through a material before annihilation by recombination is the exciting diffusion length. This is short in polymers, on the order of 5–10 nanometers. [29] The time scale for radioactive and non-radioactive decay is from 1 picoseconds to 1 nanosecond. [30]

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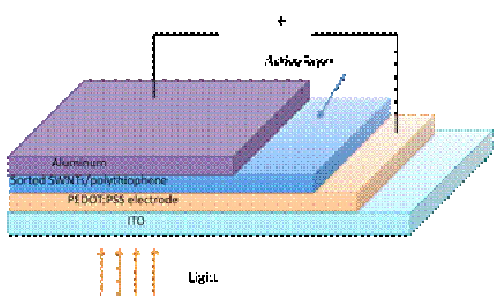

Fig. 9: Hybrid solar cell

9. LUMINESCENT SOLAR CONCENTRATOR CELL (LSC):

A luminescent solar concentrator (LSC) is a device that uses a thin sheet of material to trap solar radiation over a large area, before directing the energy (through luminescent emission) to cells mounted on the thin edges of the material layer. The thin sheet of material typically consists of a polymer (such as polymethylmethacrylate (PMMA)), doped with luminescent classes such as organic dyes, quantum dotsor rare earth complexes. [31].

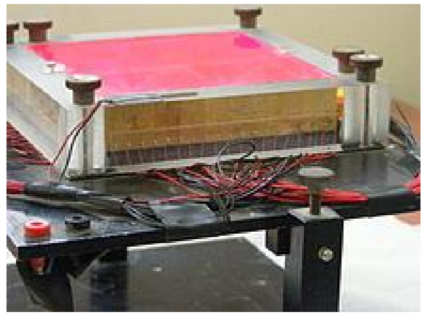

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Fig. 10: Luminescent Solar Concentrator Cell (LSC)

10. MICRO MORPH CELLS (TANDEM-CELL USING A-Si/ c-Si):

Micro morph cells are thin film solar cells based on a multi-junction–architecture consisting of two solar cells that are loaded on top of each other. While the thin amorphous silicon top cell absorbs the blue light, the thicker microcrystalline silicon bottom cell absorbs the red and near-infrared light, allowing this so-called tandem cell to cover a wider range of the solar spectrum. "Micro morph" tandem solar cells consisting of a microcrystalline silicon bottom cell and an amorphous silicon top cell are considered as one of the most promising new thin-film silicon solar-cell concepts. Their promise lies in the hope of simultaneously achieving high conversion efficiencies at relatively low manufacturing costs.

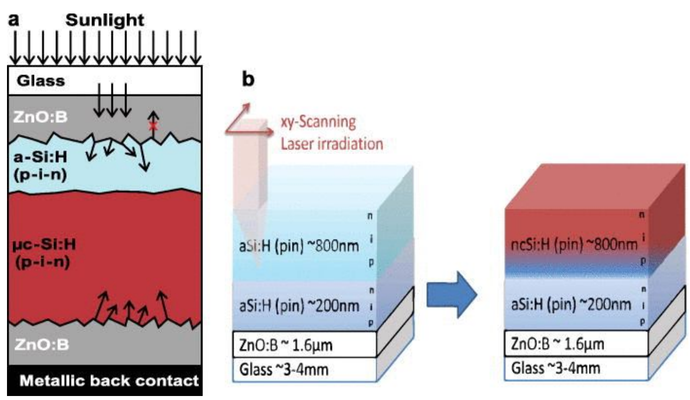

Fig. 11: Microform solar cell

11. MON CRYSTALLINE SOLAR CELL (MONO-Si):

Mon crystalline silicon (or "single-crystal silicon", "single-crystal Si", "mono c-Si", or just mono-Si) is the base material for silicon chips used in virtually all electronic equipment today. Mono-Si also serves as photovoltaic, light-absorbing material in the manufacture of solar cells. It consists of silicon in which the crystal lattice of the entire solid is continuous, unbroken to its edges, and free of any grain boundaries. Mono-Si can be prepared intrinsic, consisting only of exceedingly pure silicon, or doped, containing very small quantities of other elements added to change its semiconducting properties.

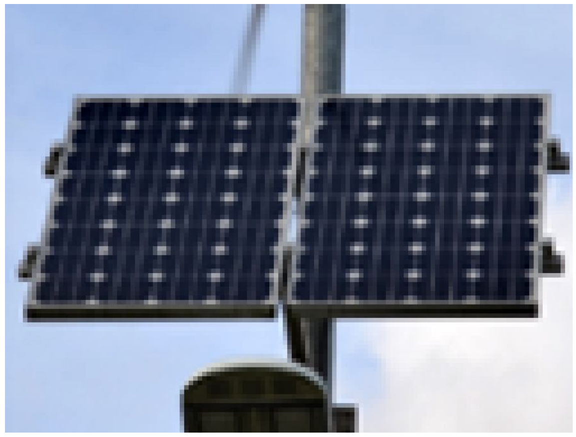

Fig. 12: Mono-crystalline solar cell

12. MULTIFUNCTION SOLAR CELL (MJ):

Multi-junction (MJ) solar cells are solar cells with multiple p–n junctions made of different semiconductor materials. Each material's p-n junction will produce electric current in response to different wavelengths of light.

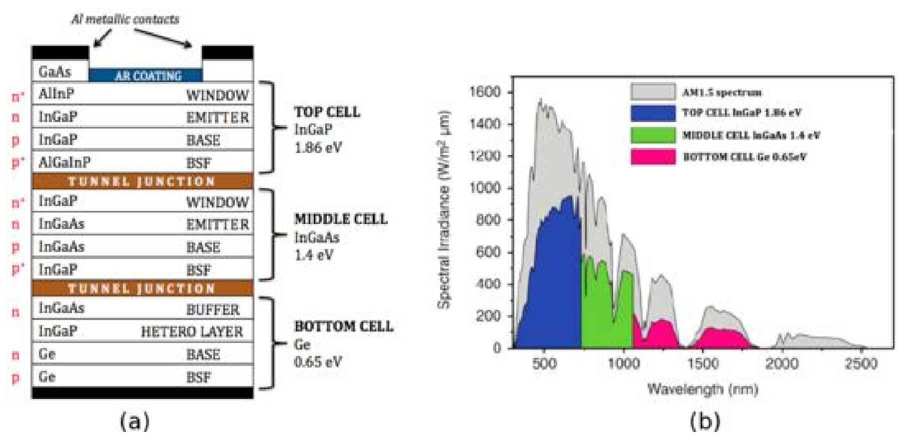

Fig. 13: multijunction solarcell

13. NANO CRYSTAL SOLAR CELL:

Nano crystal solar cells are solar cells based on a substrate with a coating of Nano crystals. The Nano crystals are typically based on silicon, CdTe or CIGS and the substrates are generally silicon or various organic conductors. Quantum dot solar cells are a variant of this approach, but take advantage of quantum mechanical effects to extract further performance. Dye-sensitized solar cells are another related approach, but in this case the nano-structuring is part of the substrate. Previous fabrication methods relied on expensive molecular beam epitaxial processes, but colloidal synthesis allows for cheaper manufacture. This involves placing an amount of the quantum dot solution onto a flat substrate, which is then rotated very quickly. The solution spreads out uniformly, and the substrate is spun until the required thickness is achieved.

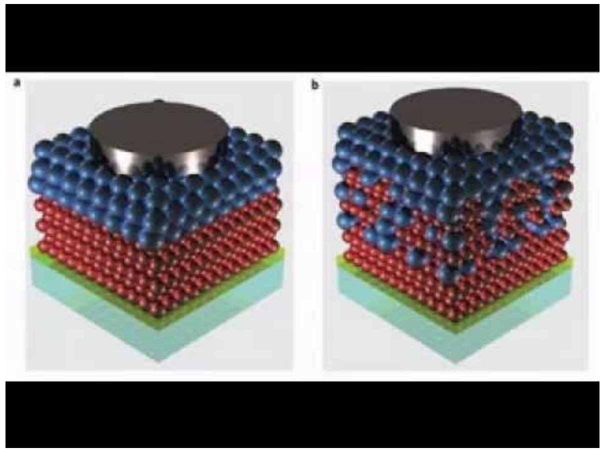

Fig. 14: Nano crystal solar cell

14. PEROVSKITE SOLAR CELL:

On the basis of the ABX3 crystal structure of the absorber materials, the name 'perovskite solar cell' is derived, which is referred to as perovskite structure. The perovskite absorber is methyl ammonium lead trihalide (CH3NH3PbX3, where X is a halogen ion such as I−, Br−, Cl−), with an optical bandgap between 2.3 eV and 1.6 eV depending on halide content is most commonly studied.Formamidinum lead trihalide(H2NCHNH2PbX3) has also shown capacity, with band gaps between 2.2 eV and 1.5 eV. The minimum band gap is closer to the optimal for a single-junction cell than methyl ammonium lead trihalide, thus it should be capable of higher efficiencies. [35]

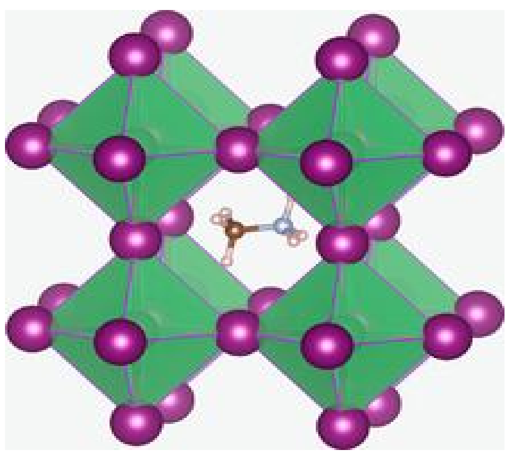

Fig. 15: Pervoskite solar cell

15. PHOTO ELECTROCHEMICAL CELL (PEC):

Photo electrochemical (PEC) cells offer a promising technology of hydrogen production driven directly by solar energy, thus materials limitations have significantly hindered their efficiency. The main advantage of our research is to improve the efficiencies of PEC cells by identifying and engineering corrosion resistant semiconductors that exhibit the optimal conduction and valence band edge alignment for PEC applications. This type of solar cells utilize light energy to perform a chemical reaction, in this case the splitting of water into hydrogen and oxygen gases.

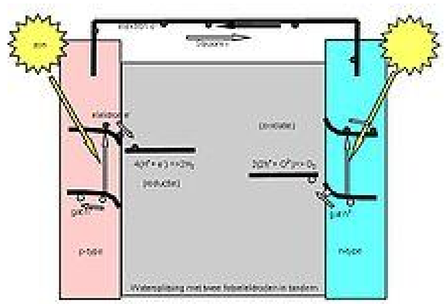

Fig. 16: Photoelectrochemical cell

16. POLYMER SOLAR CELL:

In this type of solar cell, the material used to absorb the solar light in organic solar cells, is an organic material such as a conjugated polymer. The basic principle of both polymer solar cell and other forms of solar cells however is the same, namely the transformation of the energy of the energy in the form of electromagnetic radiation into electrical energy. i.e. a physical phenomenon called the photovoltaic effect. The use of semiconductors is used to energy conversion. Perovskite solar cell is mainly different from other solar cell on the basis of simplicity process.

17. POLYCRYSTALLINE SOLAR CELL (MULTI-SI):

Polycrystalline silicon, also called polysilicon or poly-Si, used as a row material by the solar photovoltaic and electronics industry, is a high purity silicon solar cell.

This type of solar cell is made of metallurgical grade silicon by a chemical purification process, called Siemens process. This process involves distillation of volatile silicon compounds, and their decomposition into silicon at high temperatures. When produced for the electronics industry, polysilicon contains impurity levels of less than one part per billion (ppb), while polycrystalline solar grade silicon (SoG-Si) is generally less pure. .[39].

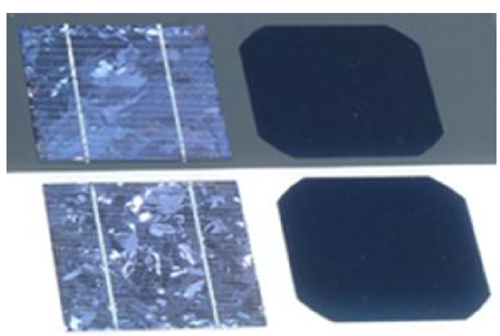

Fig. 17: Polycrestalline solar cell

18. QUANTUM DOT SOLAR CELL:

A quantum dot solar cell is a solar cell which is made by the uses quantum dots as the absorbing photovoltaic material. It attempts to replace bulk materials such as silicon, copper indium gallium selenide (CIGS) or CdTe. In this type of solar cell the quantum dots have band gaps that are tunable across a wide range of energy levels by the dot's size.

Fig. 18: Quantum dot solar cell

19. THIN FILM SOLAR CELL (TFSC):

A thin-film solar cell (TFSC), also called a thin-film photovoltaic cell (TFPV), is a second generation solar cell which is made by depositing one or more thin layers, or thin film of photovoltaic material on a substrate, such as glass, plastic or metal. Thin-film solar cells are commercially used in several technologies, including cadmium telluride (CdTe), copper indium gallium dieseline (CIGS), and amorphous and other thin-film silicon (a-Si, TF-Si).

Fig. 19: Thin film solar cell

CHARACTERISTICS

1. AMORPHOUS SILICON:

The density of amorphous silicon solar can be calculated as 4.09×10^22 atom/cm^3 at 300 k temperature. This process was done by thin strips of amorphous silicon. The main advantage of amorphous silicon solar cell is their lower manufacturing cost, which creates these cells very cost competitive.

2. BIOHYBRID SOLAR CELL:

The Principle advantage of bio hybrid solar cell is the way it converts solar energy to electricity with almost 100% efficiency. This means that almost no power is lost through the conversion of chemical to electrical power. The cost in manufacturing of bio hybrid solar cell is also less because extracting the protein from spinach and other plants is cheaper compared to the cost of metals needed to produce other solar cell.

3. BURIED CONTACT SOLAR CELL:
In the buried contact solar cell, a key high efficiency feature is that the material is hidden in a laser formed groove inside the silicon solar cell. This process allows for a large metal height to width aspect ratio.

4. CADMIUM TELLURIDE SOLAR CELL:
Cadmium telluride photovolatics is used in world's largest solar power station. The conversion efficiency of this solar cell is 21%.CdTe pv has the smallest carbon footprint, lowest water use and shortest energy payback time, on a lifecycle basis. On a lifecycle basis.[12,13,14,15].

5. CONCENTRATOR-PHOTOVOLTAIC (CPV):
It is a photovoltaic technology that produce electicity from sunlight. It uses lenses and curved mirrors to focus sunlight onto small ,but highly efficient multi junction solar cell.CPV system often uses solar followers and sometimes a cooling system to further increase their efficiency.[19]. Currently, CPV is not used in the PV roof top segment and far less common than conventional PV systems. [20].

6. DYE SENSITIZED SOLAR CELL:
The DSSC has a number of attractive features; that,it is simple to make using conventional roll printing techniques ,is semi flexible and semi transparent which offers a variety of uses not applicable to glass based system. [23] These types of solar cell also belonging to thin film solar cell of third generation.

7. Gallium arsenideis:
This used to made of several devices such as microwave frequency integrated circuits,infrared light emitting diodes,laserdiodes,monolithic microwave integrated circuits, solar cells and optical windows[24]. Due to greater photon flux of photons above 1.87 eV,the cell have low current. This result of low current in the Gallium Arsenide junction and pannier the overall efficiency since the InGaP junction operates below MPP current and the GaAs junction operates above MPP current. The bands gap of junction in the range of 1.92 to 1.87. The band gape of GaAs junction is lower 1.42.

8. HYBRID SOLAR CELL:
To manufacture the photovoltaic layer, an organic material is mixed with a high electron fetch material in Hybrid solar cell [26]. In a hetrojunction type photoactive layer, two materials are assembled together, which can have large power conversion efficiency than a single material [27].One of the material acts as proton absorber and other acts as exciting donor.

9. CONCENTRATED CELL:
The ratio of incoming and emitted irradiance is known as concentration factor. If let the input irradiance is 2 kW/m^2 and the output irradiance is 8 kW/m^2 that provide us concentration factor, which is 4. The ratio of incoming radiant flux (in watts) and the outgoing wattage are known as efficiency. Or the fraction of the incoming energy that the device can delivers as usable output energy (not the same as light or electricity). The half of received wattage is re-emitted, implying efficiency of 50%, in the previous example.

10. CRYSTALLINE SILICON SOLAR CELL (C-Si):
The crystalline silicon solar cell is basically the monocrystalline form of silicon, and it is used for producing micro chips, In electronics. This silicon contains much lower impurity

levels then those required for solar cell. The conversion efficiency crystalline solar cell is much high.

11. MULTIFUNCTION SOLAR CELL:
The multi junction solar cell has the multiple band gap so the different wavelength of sunlight can be absorbed and so this solar cell is used in many ways. The main drawbacks of this solar cell that it have complex structure so it is very costly. [33].

12. NANO CRYSTAL SOLAR CELL:
We can increase the efficiency of solar cell using nanocrystalls.By this process we increase the efficiency up to 60% .The nanocrystal solar cell is also cheaper.[34].

13. PEROVSKITE SOLAR CELL:
Metal halide perovskites possess unique features that make them exciting for solar cell applications. The manufacturing cost of this type solar cell is less because of low cost raw material and low cost fabrication method. These features combined result in the possibility to make a low cost, high efficiency, thin light weight and flexible solar modules.[36][37][38].

14. PHOTO ELECTROCHEMICAL CELL (PEC):
The photo electrochemical cell is defined as a cell by simply immersing a semiconductor into a liquid electrolyte. PEC is not sensitive to the defects in semiconductors. This solar cell is possible to realize the direct energy transfer from photons to chemical energy.

15. POLYMER SOLAR CELL:
In photovolatics, the conjugated polymers are best alternatives for use in low cost electronics. In recent reports, polymer based solar cell have reached power conversion of 5 %. Polymer solar cells are attractive because they can be manufactured on plastic substrates by a variety of printing techniques.

16. POLYCRYSTALLINE SOLAR CELL (MULTI-SI):
Polycrystalline (sometimes also called multicrystalline) solar panels are the most common because they are often the least expensive. The use of polycrystalline silicon in the manufacturing of solar cell requires les material and so provides higher profits and increased manufacturing throughput. These type of PV doesn't need to be deposited an a silicon wafer to form a solar cell, but it can be deposited on other cheaper material; thus it reduce the cost.

18. QUANTUM DOT SOLAR CELL:
Quantum dot solar cells are designed by the use of quantum dot as the absorbing photovoltaic materials. Quantum dots have been referred to as "artificial atoms". Quantum dots have band gapes that are tunable across a wide range of energy levels by changing the dots size. The dots can be grown over a range of sizes, allowing them to express a variety of band gaps, without changing the underlining materials or construction techniques [40]. In typical wet chemistry preparation the tuning is accomplished by varying the synthesis duration or temperature.

19. THIN FILM SOLAR CELL:
Thin film solar cell are used in various technologies including cadmium telluride, copper indium gallium dieseline and amorphous thin film silicon. The fundamental advantage of thin film comes in the form of the amount of material we need. These types of solar cells can be used in many flexible applications such as so-called solar shingles, roofing materials that double as electricity generators.

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