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Survey Article

Theoretical Survey of Advanced Developments in Different Generations of Photo–Voltaic Solar Cells for Sustainable Feature

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Abstract— There is an advanced development in the generations of Solar cells, and this article analyses and reviews about it. A greater interest has been developed in renewable energy resources despite Global awareness of Environmental problems. Out of the alternatives of energy resources, the solar energy is the best and as the sunlight is profuse in nature led to the demand for solar energy. An electronic device which contains Solar cells or photo voltaic cells directly generates electricity from sunlight. The solar photovoltaic's are low cost, clean, reliable and affordable in the long run. The solar cell technology has gained a greater attention since two decades. The Growth of population and development in technology has created demand for renewable energy resources all over the world. The generations of Solar cells, their efficiency, life span, cost, best semi conducting solar cell among them, pros and cons, and the applications were discussed and analyzed in this article. The stages of development from generations to generations were discussed along with the upcoming trends in solar energy technology.

Keywords— Solar cells, Semiconductor materials, Photovoltaic generations, Efficiencies, Pros and Cons.

1. Introduction

A solar cell is an apparatus that transforms solar energy into electrical energy by means of photo voltaic effect. A renewable energy source that has a lot of promise to address today's energy issues is the solar photovoltaic cell. Long –term costs are low and solar photovoltaic's are dependable, clean and scalable energy source. Solar radiation that is incident is transformed into electrical energy using solar photovoltaic technology. The first generation of silicon cells made of silicon compounds [1].Research indicates that in order to improve solar cells efficiency and increase their capacity to absorb incident solar light, more developments are necessary. Solar energy produced by the sun and is combination of heat and light. From the sun, this energy travels to the ground, where solar collectors catch it and convert it into whatever kind of energy that is needed. [2].Charles Fritts created the solar cell for the first time in 1883 by covering selenium with gold, although the devices efficiency was just 1%. The band gap of the materials utilized for this purpose needs to be very near to 1.5eV.The fallowing materials is communally used: Silicon (Si), Gallium arsenide (GaAs), Copper indium selenium (CuInSe2) and Cadmium telluride (CdTe). An individual photovoltaic device is known as a solar cell. The solar module is made up of many solar cells coupled in a parallel or series configuration with blocking or by pass diodes. If you have multiple modules or panels connected together as an array [1-3]. Diagrams of solar cells, Solar Panels and solar arrays are displaced in Figure.

Figure.1. a schematic representation of a solar cell, solar panel, solar array

2. Construction of Solar cell

Figure.2. Shows the construction of solar cell. It is composed of P-Type and N-Type semiconductor material. P-type has minor doping, and N-Type has high doping. To collect current, conducting electrodes are utilized at the top and bottom.

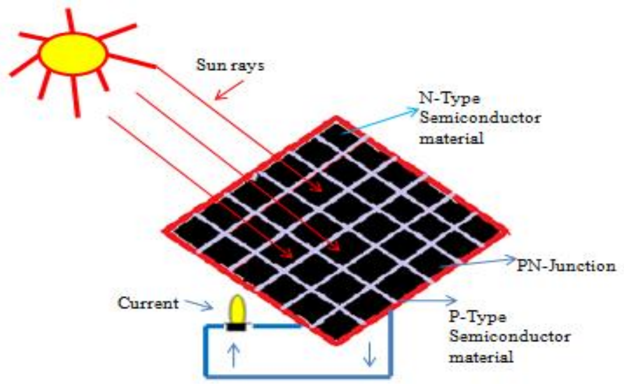

Figure.2. Construction of Solar c ell

While the top layer is partially covered since sunlight shouldn't be completely blocked, the bottom layer is completely covered by the conductive layer. The application of antireflective coating is necessary since semiconductors are usually reflective. The entire setup is shielded by a thin glass cover to prevent mechanical shock [4].

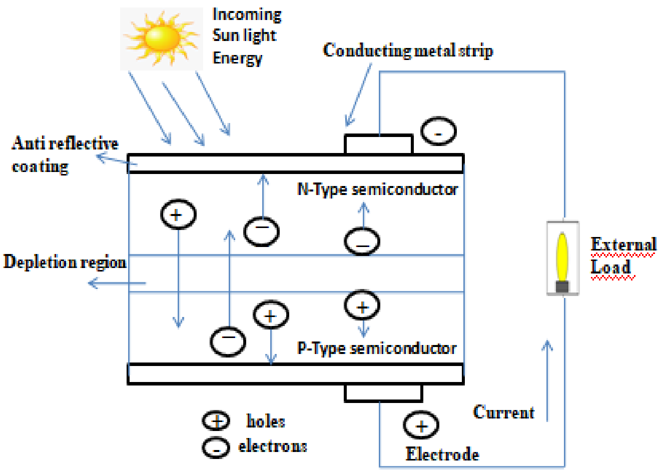

Figure.3. Solar cell working

3. Solar cell working

The photovoltaic effect is the foundation of the operation of solar cells . Its effect where current or voltage is generated when exposed to light. In this sense, solar cells transform solar radiation into electrical energy. A depletion layer develops where the P–type and N-type semiconductor materials converge [5]. The photons, a tiny energy bundle with an energy greater than the energy gap, are released when solar radiation strikes a solar panel, providing energy to the holes and electrons in the depletion area. They function as a battery as the electrons travel toward the N-type and the holes travel toward the P-type. Thus, the mobility of electrons and holes produces electric current [6]. As seen in fig. 3, if this cycle is completed without recombination, current will flow to the highly linked load.

4. Characteristics

Typically, a solar cell uses the photovoltaic effect to the function as a PN-junction .The solar cell generates DC voltage when it is exposed to sunlight. The short circuit current (Isc) , open circuit voltage (Voc), fill factor (FF), and solar energy conversion efficiency (η) of a solar cell are its fundamental metrics .Figures.4.and.5 depict the solar cells circuit diagram and V-I characteristics.

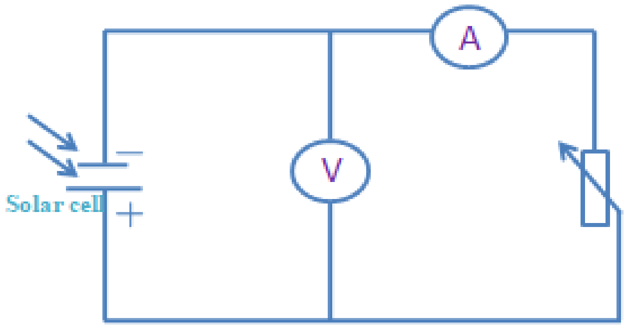

Figure.4. Circuit diagram for V-I Characteristics of solar cell

Open circuit voltage (Voc): The highest voltage that a solar cell can produce while its terminals are open, or the voltage produced when there is no current flowing through it (no load I=0 and R=∞). It is denoted by Voc.Shot circuit current(Isc): Short circuit current is denoted by the symbol Isc, is the current that can pass through a cell when its two terminals (R=0 and V=0) are shorted. Fill Factor: The ratio of the solar cells maximum power (P_{max}) to the product of Voc and Isc is known as the fill factor. F.F = Im xVm/Isc xVoc. The resistive losses of a solar cell determine its fill factor. [7-8].Fii factor determines the power conversion efficiency of organic solar cell. An ideal solar cell has a fill factor of 100%, meaning that there is no loss; this value is not achievable. A high gap cell made of these materials will have high fill factor. Efficiency (**η**): The percentage of incident power that a solar cell can convert to electricity is known as its efficiency. It can be computed using the formula **η**= P_{out}/P_{in}, which is the ratio of maximum power output (P_{out}) to maximum power (P_{in}).

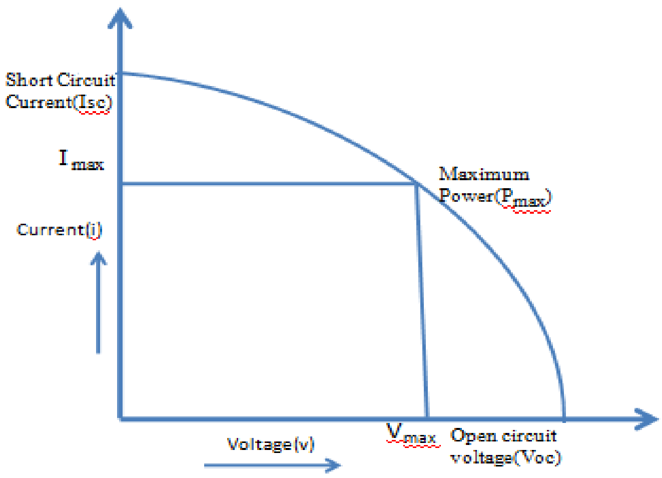

Figure.5 I-V Curve of solar cell

The ability of these photo generated minority charge carriers to reach the PN junction and then recombine with majority charge carriers in the vicinity in the majority of the material determines the efficiency of these solar cells.

5. Applications of Solar cells

Solar cells, also known as photovoltaic (PV) cells, find a broad range of applications across different sectors due to their capability to convert sunlight into electricity. Some common applications of solar cells are Street Lightings, Space based power systems, water pumping, Solar-powered Vehicles, Commercial and Industrial Buildings, solar panel houses, Solar water heaters, Solar Powered roads[8-9]as shown in figure.6.

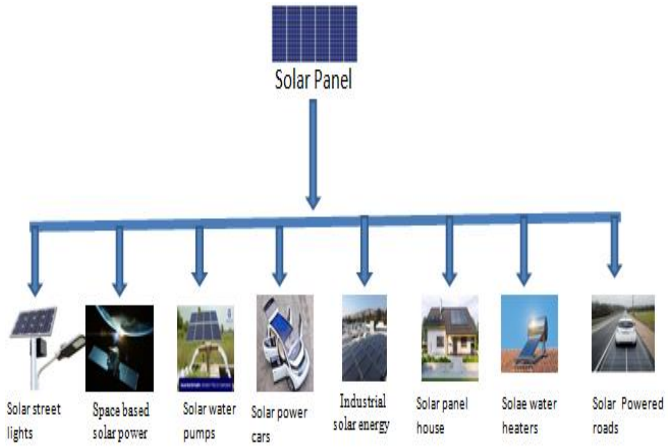

Figure.6. Applications of solar cells in different fields

6. Different Generations of Solar cells

First and second, third, and forth generation of solar cells can be distinguished from each other by different materials that go into their construction. The crystalline silicon used in the first generation of solar cell, also known as conventional, traditional, or wafer based cells, is the material that makes up the majority of Photovoltaic technology used commercially it includes silicon and poly silicon. Both Monocrystalline and polycrystalline solar cells require silicon as a component [11]. The fallowing generations thin film solar technology is used in the production of solar cells. Materials such as amorphous Silicon (a-Si), Cadmium Sulfide(Cd), Cadmium Telluride (CdTe),Copper Indium Gallium Dieseline (CIGS),etc are used in second generation solar cells[12].The third generation of solar cells includes a number of thin film technologies, communally called emerging photovoltaic's, majority of which still in the research and development stage and have not yet been utilized commercially.Advanced principles are used in third generation solar cell technology to efficiently create solar energy by utilizing solar photons and gathering the maximum amount of incident solar energy on the cells.This group include solar cells with Dye Sensitization, organic photovoltaic cells, multi junction solar cells Quantum Dot solar cells, and Perovskites solar cells among others [13].Hybrid solar cells are a type of forth generation solar cells. In hybrid solar system, the solar inverter and solar panel are connected. These technologies are being researched because they have the potential to produce inexpensive, highly efficient solar cells [14]. The various generations of solar photo voltaic cell technology depicted in figure.7 below.

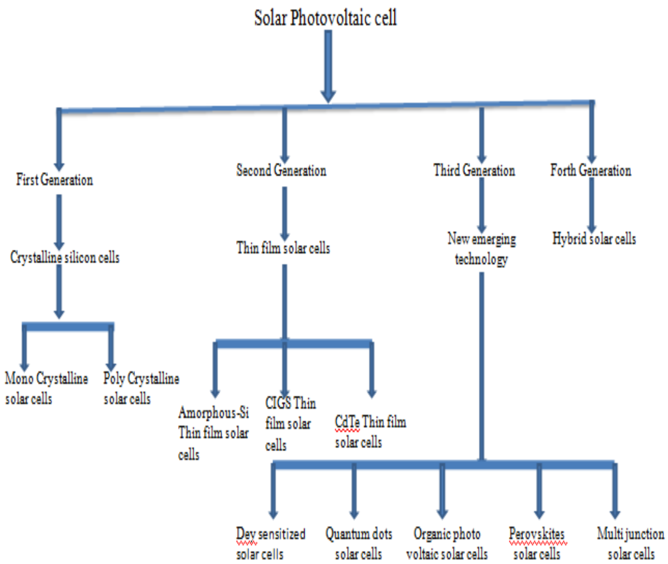

Figure.7.Current trends of development for different types of solar cell technologies.

1. First Generation

Silicon with a crystalline structure was utilized to first generation of solar photovoltaic cells, and due to its simple processing and high power efficiency, silicon is still one of the material used extensively in solar photovoltaic technology. These solar cells are the most commercially efficient and are used globally [15]. Improvements in sustainability and efficiency are the primary goals of the ever –expanding silicon material research. Two further categories are used to further categorize silicon based solar cells.1.Solar photovoltaic cells made of silicon(Si) that are monocrystalline or multicrystalline .Since solar cell panels have black, silver, and white frames, they usually appear black in color.

1.1. Monocrystalline Solar cells

Compared to other types of solar cells, monocrystalline solar cells are more efficient at converting radiation from the sun into electrical energy. A monocrystalline solar cell is made of single silicon crystals. In silicon (Si) materials, the energy band gap is 1.1 eV. A monocrystalline cell has more space for the electrons to travel around and generate greater an electrical current because it is made of single crystalline silicon. monocrystalline solar cells are therefore more efficient than polycrystalline ones. monocrystalline solar panels account for over 80% of the solar market. Because they are very effective and have lengthy life span.7.1 (a) and 7.1(b) below depict the monocrystalline solar cell and solar panel.


Figure.7.1 (a) Mono crystalline cell **Figure.7.1 (b)** Mono crystalline solar panel

Even in the 15-25% efficiency range, monocrystalline cells still have the highest efficiency, performance, stability, and power output. It will function more effectively with low amounts of sun light. The 25-years life span of monocrystalline solar panels is longer [15-16]. Even with extreme heat and warm temperatures, these monocrystalline cells can function better. Since they are constructed of the best silicon, there is greater space for electron mobility. The cost of these solar cells is higher than that of polycrystalline solar cells, and there is more silicon wastage during the manufacturing process. Furthermore, compared to the other type of solar cells, monocrystalline solar cells are more expensive.

1.2 Polycrystalline solar cells

Silicon is also used to make polycrystalline solar cells. To form them, several silicon pieces are heated and then poured into square modules. After cooling, these crystals are finely sliced and joined to create polycrystalline solar cells.These materials having energy band gap of 1.7eV.Compared to monocrystalline solar cells typically have lower efficiency. Since there would be less area in the polycrystalline cells, the electrons cannot travel freely. Polycrystalline silicon materials were manufactured and availed at low-cost. The solar cell with polycrystalline structure is dissipated in figures 7.2(a) and 7.2(b).


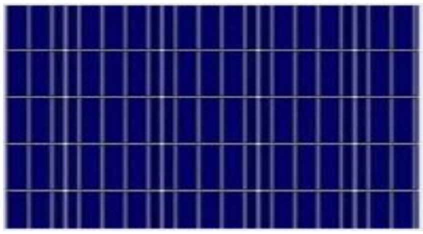

Figure .7.2(a). Poly crystalline solar cell **Figure.7.2 (b).**Poly crystalline solar panel

Polycrystalline solar cells use less silicon in their production process. Compared to monocrystalline solar cells, these solar cells are more affordable. Large solar forms, roof-mounted arrays, traffic signals, residences, and other structures employ polycrystalline solar panels since they are more affordable and environmentally kindly to make [17].The efficiency of polycrystalline solar panels is believed to be between 13 to 16%, and they also often have a lower heat tolerance and they require more space. The silicon quality is lower and the appearance of polycrystalline solar cells is less uniform. Due to low level of silicon purity polycrystalline solar cells are less efficient with life span of 14 years when compared to monocrystalline solar cells.

2. Second Generation

Thin film technology was used to create solar photovoltaic cells of the second generation. Multiple thin film layers of photovoltaic materials are present in thin film solar cells, which constitute the new generation of the solar cells. Because silicon wafer technique typically uses pure crystalline silicon. The technique of obtaining pure silicon is expensive and complicated. if silicon thin films(1µm) can be deposited, solar cell cost can be decreased. Compared to wafer based-technology, thin film technology uses a very little amount of silicon. Compared to conventional silicon cells, thin solar cells are more flexible, lighter, and have an interesting appearance. These are less efficient than crystalline silicon cells, therefore larger space is required. It is advised to use the thin film solar cell panels for small-scale and commercial applications.A conductive sheet, a protective layer, and photovoltaic material makeup each thin film solar cell. These are composed of many thin layers of photovoltaic materials. Thin-film solar cells differ from polycrystalline and monocrystalline solar cells [18-19].The type of thin film photovoltaic cell determines its efficiency, which varies. There are many different shapes and materials used to production thin film solar cells. Thin film solar cells come in a verity of PV materials, are light weight, flexible, and low profile in design. In comparison to monocrystalline and polycrystalline solar cells are less expensive but offer lower performance and a shorter life span. Thin film solar cells typically have efficiency rates between 6 to 13%. They are less efficient and have a lower power capacity. These categories can be applied to thin film solar cells based on the kind of photovoltaic material that is employed 1.Amorphous silicon cells (A-Si) 2.Cadmium Telluride (CdTe) cells 3.Copper Indium Gallium Diselenide (CIGS).

2.1. Amorphous Silicon (a-Si) Solar cells

New thin film solar cells for another name for amorphous silicon solar cells. Compared to monocrystalline and poly crystalline silicon solar cells, amorphous solar cells are made using a different process, use less power and silicon material, and have more appealing appearance. The structure typically exhibits the P-i-N or N-i-P kind of duality, in which the amorphous silicon P- layer and N-layer are mostly utilized to establish the internal electric field (i-layer). The non crystalline allotropic from of semiconductor silicon known as amorphous silicon solar cells or a-Si, has a high capacity for light absorption and can be used in solar cells with very thin layers that are typically 100 times thinner than crystalline silicon. The semiconductor is a direct band gap type. These materials have an energy band gap of 1.7Ev. Consequently, extremely thin film solar cells made on amorphous silicon can be manufactured. The market favors amorphous silicon because of its better performance and lower cost and the light absorption sheets thickness is about 1 micron. Amorphous silicon, germanium, monocrystalline silicon nitrates are the several types of amorphous silicon materials used in thin film technology. Chemical vapor deposition is used to apply a thin coating of silicon to the metal, plastic, or glass basis of these non-toxic cells. Amorphous solar cells absorb a large percentage of the light spectrum and perform well in low light. In order to reduce the possibility of cracks, they might also be twisted. The quick efficiency lo0ss of amorphous panels is one of their drawbacks. It widely used in micro devices, household applications buildings, crocks, electronic watches, outdoor lighting, and pocket calculators[18-19].The amorphous solar panel and cell are displayed in the fallowing figures. 7.3(a) and 7.3 (b).


Figure.7.3 (a). Amorphous Solar cell **Figure.7.3 (b).**Amorphous Solar Panels

Amorphous solar cells are created in a verity of shapes, including square, round, and hexagonal, and they are made at a relatively low cost. These cells are incredibly adoptable and versatile. They function well in lowlight and have lower heat sensitivity. Compared to mono and polycrystalline solar cells, the efficiency of amorphous solar cells decreases over time and their life span is shorter. Lower efficiency and challenging doping material selection are two drawbacks of amorphous solar cells. Standard homes should not use amorphous solar cells[18-20]. In most cases, the efficiency is between 6 to 8%

2.2 Cadmium Telluride (CdTe) Solar cells:

Cadmium telluride (CdTe) thin film solar cells are the second thin film material and are most prevalent photovoltaic technology in the world market, behind crystalline silicon. Their energy band gap of 1.45eV and longer stability make CdTe solar cells the most effective thin film material. These solar cells convert energy more quickly are light weight, flexible, and have lower carbon footprint than typical silicon thin film cells. They also cost less. Because telluride is so hard to come by, manufacturing it is challenging. These cells do a good job of collecting sunlight and transforming it into energy. The average life span of cadmium telluride (CdTe) solar cells is 20 years. The principle problem of these solar cells is that they contain a large amount of cadmium, which is a toxic element [20-21].During the manufacturing process, extra care must be taken to ensure that the cells do not pose a risk to people or the environment. On rooftops, when utilized to produce electricity. Currently 5% of the global market, first solar cells CdTe solar cells have an efficiency of 14 to 16%, considerably lower than the normal efficiencies of silicon solar cells. The cadmium Telluride(CdTe) Panel was shown in fig.7.4

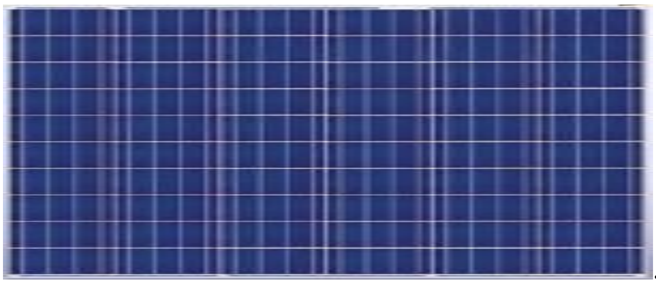.

Figure.7.4. Cadmium Telluride (CdTe) solar Panel

Tellurium is a difficult element to locate but a vital component in production where as cadmium is a plentiful material. Cadmium is highly dangerous element with a restricted supply of raw sources.

2.3. Copper Indium Gallium Diselenide (CIGS) Solar cells:

CIGS solar cells are thin film photovoltaic devices that capture solar radiation transform it into electricity by using semiconductor layers of Copper Indium Gallium Diselenide (CIGS).The hetrojunction arrangement of CIGS cells is more intricate. A small coating of copper indium gallium diselenide solid solution is deposited on a glass or plastic backing during the manufacturing process, and electrodes are positioned on a glass or plastic backing during the manufacturing process, and electrodes are positioned on the front and back of the object to collect current. One of the most popular and extensively used thin film solar cells on the market today, this kind of cell has great stability and exceptional solar absorption properties. PN junctions in CIGS solar cells are called hetrojunctions because they can be made of a variety of semiconductor materials. Batteries with a large band gap window layer can be made by hetrojunctions, which lowers surface recombination. Due to the film technology, its direct band gap material will be able to absorb more sunlight. There is a 1.7eVenergy band gap. The band diagram of the P-N hetrojuncton shows the discontinuities and device architectures of the valiancy band and conduction band. This type of junction illustrates the potential for energy barriers to emerge in the contest of charge carrier transit. Recombination is less likely when minority carriers in the p-type absorber layer convert to majority carriers on the nearby interface zone, decoupling the physical and electrical junctions through the creation of buried junctions. Research has demonstrated that CIGS thin film technology can achieve up to 20% efficiency. Compared other semiconductor materials, the CIGS materials have a higher absorption coefficient because their photo sensitive layer is thinner. The biggest disadvantage of CIGS, in comparison to other silicon or CdTe solar panels was their high manufacturing cost. Increasing efficiency will take a long period [20-22]. **Figure.7.5**.Solar panel with Copper indium gallium diselenide(CIGS)

Figure.7.5. Solar panel with Copper indium gallium diselenide (CIGS)

Twelve years is the average lifespan for CIGS.CIGS solar cells are slim, Light weight and flexible and does not contain the toxic element Cadmium. Compared to crystalline silicon solar panels are less efficient and use far less efficient and use far less material during manufacturing. Another issue that needs to be address in CIGS solar cell research is material availability. Other than the rare metals gallium and indium, most of the parts of this kind of solar cell are widely available in the earth’s crust. Furthermore the costs of these two rare metals are high.

3. Third Generation

Third generation of photovoltaic technology is solution-processed and semiconducting based. On more modern chemical compounds, these generation counts are predicated. Third generation or developing technologies were introduced as a result of the high costs and high efficiencies of traditional Si-based solar cells. These technologies have low weights, low costs, good efficiency, and flexible manufacturing techniques. As a result, third generation solar cell technology is developing quickly. These can be divided into five categories: 1.Organic photovoltaic (OPV)solar cells 2.Perovskites solar(Psc) cells 3. Quantum Dot(QD) solar cells, Dye-sensitized(DSsc) solar cells and 5. Multi junction solar cells [23].Third generation n solar cells also include organic photovoltaic's (OPV), up conversion and down conversion, hot-carrier and multiple exaction cells. in this category, the solar cells where developed and have efficiency up to 40%

3.1. Dye- Sensitized Solar cells (DSSc):

A dye- Sensitized solar cell is a type of thin film solar cell. When the solar cells dye comes into touch with sun light, it produces electricity. The user can utilize it to turn both artificial and natural light into energy. These solar cells are some of the least expensive ones in the market. Many researchers have been drawn to these solar cells because of their easy fabrication, cost-effectiveness, and environmental friendliness, making them a great substitute for silicon solar cells. Generally, DSSCs are made up of four parts Photo anode, which is made up of semiconductor with large band gap, the counter electrode, the sensitizer, which is serves as a light harvester, and the electrolyte. The most used traditionally components are TiO_2 photo anode. Solar cell efficiency of about 10 % to 15% and silicon-based solar cells can achieve efficiency of 20%. The DSSCs were showed in the fig. 7.6

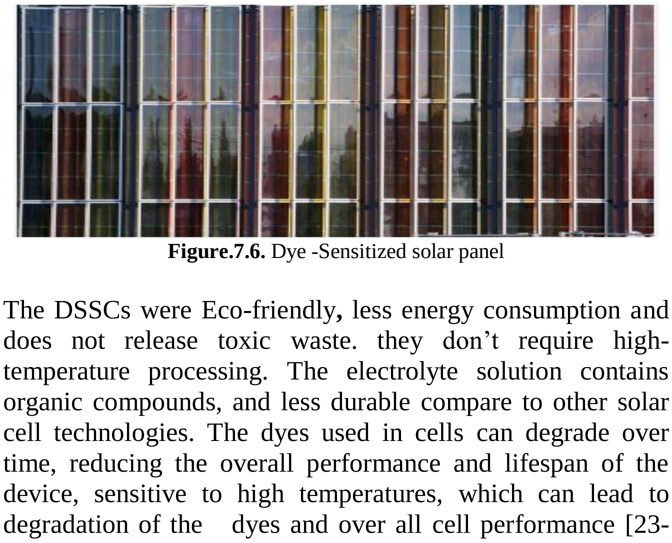

Figure.7.6. Dye -Sensitized solar panel

The DSSCs were Eco-friendly**,** less energy consumption and does not release toxic waste. they don't require high-temperature processing. The electrolyte solution contains organic compounds, and less durable compare to other solar cell technologies. The dyes used in cells can degrade over time, reducing the overall performance and lifespan of the device, sensitive to high temperatures, which can lead to degradation of the dyes and over all cell performance [23-25].

3.2. Quantum Dot Solar cells (QDSc):

The appealing photovoltaic material utilized in the Quantum Dot solar cell is Quantum dots. These materials are described as actual particle sizes smaller than the Bohr radius of the excitations and are usually composed of elements II-VI or III-V of the periodic table. The potential of quantum dots to substitute other materials such as Silicon (Si), Copper Indium Gallium Diselenide (CIGS) or Cadmium Telluride (CdTe) for bulk materials and is enormous. A high extinction coefficient and a short band gap with a shape and size that can be easily changed are characteristics of quantum dots solar cells, or nanoscale semiconductor crystals. They are less than 10 nm. Because the dots' sizes vary, quantum dots exhibit an adjustable band gap over a wide variety of energy levels. Through a process known as multiple exaction creation, quantum dots are able to collect extra photon energy that is often wasted to heat generation. In order to produce electron hole pairs (e-/h+), an incident light radiation pass through a quantum dot solar cell's transparent electrode and onto a layer of dots that absorbs light electric current is produced when the charged particles eventually separate and go to their respective electrodes[26]. With this method, 10% - 15% efficiency can be achieved in Quantum Dot solar cells. In Figure 7.7, the Quantum Dot solar cell where shown.

Figure.7.7.Quantum dot solar panel

QDSc is utilized in entire buildings, including windows it is inexpensive to produce and uses little energy. It is also exhibits fluorescence, resistance to balance, and the ability to generate fluorescent light with varying wave lengths. Quantum computers leverage cubits, which can exist in multiple states simultaneously, Solving Complex Problems, Parallelism and Entanglement, Revolutionizing Industries, Enhanced Machine Learning These properties make Quantum Dot perfect tools for visualization of brain structures and mechanism underlying its functions. Due to unique quantum dot properties even single molecules under study can be observed and QDSc has high toxicity in nature, Degradation, hard to control the size of the particles, Exponential computational power [26-27].

3.3. Perovskite Solar Cells (PSCs):

The third-generation PV technology known as Perovskite solar cells (PSCs), which developed from DSSCs, has been found to have significant potential as a renewable energy source in the feature. Perovskite solar cells come in two varieties wafer based silicon cells and thin film based cells. Wafer based solar cells are not as efficient in hot and low light conditions, and their expensive cost is one of their main draw backs. Perovskite thin film solar cells, which span the visible to near infrared spectrum(800nm), have a high absorption coefficient. A direct optical band gap of around 1.5eV is provided by Perovskite solar cells. Photo conversion efficiency ranged from 3.8% to 22% in Perovskite solar cells. Perovskite solar cells are consequently widely believed to have the potential to replace traditional silicon solar cells in the near feature due to their rapid increase in photo conversion efficiency. Perovskite solar cells can be made using a verity of methods, including spray coating, spin coating, screen coating, and thermal evaporation [28].Figure7.8 shows the Perovskite solar cell.

Figure.7.8.Perovskite solar panel

Perovskite material is cheaper than silicon. Low manufacturing cost and simplified structure, light weight, flexibility. Its features a high dielectric constant, quick charge separation, a long carrier separation lift time, and a long electron and hole transport distance. In comparison to silicon solar cells, Perovskite have lower film quality and thickness and are made of dangerous and unstable elements. Perovskite material will break down quickly due to exposure of heat, moisture, snow etc, and use of toxic lead in Perovskite is a matter of environmental concern [28-30].

3.4. Organic Photovoltaic (OPV) Solar cells:

In solar cell technology, Organic Photo Voltaic Cells (OPV) represents the most recent development. The method used in photovoltaic is the same for silicon and organic solar cell. The inexpensive nature of the chemicals of their distinct device structure offer a far larger coverage area and are more durable than conventional solar cells. Organic solar cells, because of their distinct devise structure, offer a far larger coverage area and more durable than conventional solar cells. The last category of solar panel made on thin film is the organic photovoltaic panel. It generates energy by means of conductive organic polymers or tiny organic molecules [31]. An organic solar cell uses organic polymers to achieve photovoltaic conversion, which turns solar light into electricity. To conduct an electrical current, many layers of thin organic vapor or solutions are positioned in between two electrodes in these photovoltaic cells. This is very light-weight, flexible thin film solar cell. The technology is less expensive from a manufacturing to market cost because of the abundance of organic resources used [32].Efficiency is an issue with organic photo voltaic solar cell. The photo conversion efficiency falls between 9 to 12% of its range. Furthermore, compared to other thin film technologies now on the market, organic photovoltaic cells are shorter life span. And organic photovoltaic cells still experience cell degradation. The Organic Photovoltaic (OPV) Solar Panel is showed in figure.7.9.

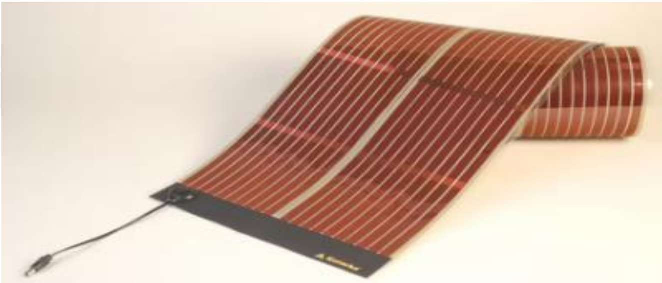

Figure.7.9.Organic Photovoltaic Solar Panel

The organic photovoltaic solar cell is new research and development; many industrial professionals see it as the feature of the solar energy industry. Comparing to inorganic photovoltaic cells, like silicon solar cells organic photovoltaic solar cells have lower efficiency, lower stability, lower strength, and shorter life span [31-33]

3.5. Multi Junction Solar cells:

An emerging technology that has promise for improving solar panel efficiency is multi junction solar cells. They are at in the testing and research stages, so they are not currently on the market for the installation of solar cell. Multiple P-N Junctions made of various semiconductor materials make up multi junction solar cells. Different light wavelengths cause each materials p-n junction to generate electrical current. Multiple layers of various semiconductor materials combine to form multi junction solar cells. Solar cells with two, triple, four, five, and six connections have been among the many types of junctions used thus far. The layers that follow are able to capture more light per unit area and produce more energy because the radiation that passes through the layer is absorbed by them. Because of this, single junction cells are less efficient than multi junction cells [34]. Because different layers have different bad gaps, light that passes through the first layer is absorbed by the ones that flow. Multi junction solar cells that combine the semiconductor of columns III and V in the periodic table are called III-V multi junction cells. It is composed of three distinct semiconductor layers: Germanium (Ge) Gallium Indium Phosphate (GaInP), and Indium Gallium Arsenide (InGaAs). Multi function cells are exceedingly expensive and are exclusively employed in specialized applications like space exploration, drones, and certain military uses; despite their 45% efficiency [34–35].The Multi junction solar panel was showed in fig 7.10.

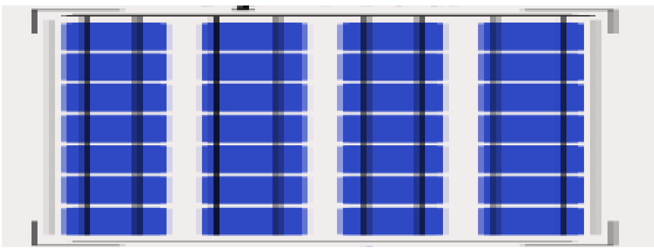

Figure.7.10.Multijunction Solar Panel

The greatest option for producing green electricity is to use multi-junction solar cells, which enable us to absorb a far larger portion of the sun spectrum. The process of producing Multi junction solar cells is more intricate and costly, and the carriers must diffuse out to the metal contacts, limiting the number of junctions that may be stacked very high. As of right now these cells are available for purchase. To produce the most electricity possible, they require intensely concentrated sunlight.

4. Fourth Generation:

The benefits of fourth-generation solar cells are various. A number of researchers are attempting to improve efficiency through the use of various fabrication techniques. The hybrid solar cell is the fourth generation.

4.1 Hybrid Solar Cells:

Conjugated polymers (organic) used in hybrid solar cells that transfer light through the holes and absorb it via the donor. The acceptor and electron transporters are employed in hybrid cells made of inorganic materials. Inorganic and organic semiconductor materials are combined to create hybrid solar cells. Traditionally, inorganic materials mostly silicon, have been used to make solar cells. These materials have high conversion efficiency but are expensive to produce. However, organic materials used to make solar cells have a lower cost of manufacture, and chemical synthesis and molecular design can determine how functional they are. As a result, hybrid solar cells combine the benefits of these two technologies to produce an affordable and incredibly effective solar cell. Hetro-junction with intrinsic thin layers (HIT), which combines crystalline and amorphous silicon materials, is an illustration of these technology.HIT modules having a 21% conversion rate. For the same module size, the commercial rate conversion efficiency of HIT modules is higher than that of conventional C-Si modules [36]. The array of solar panels and the solar inverter are connected in a hybrid solar system. The solar battery and utility grids are connected to the inverter. Solar energy is absorbed by the solar panel and transformed into DC electricity. The linked solar inverter receives the electricity and uses it to convert DC to AC. Home appliances run on the conventional electrical current, or AC, as was previously established. The hybrid solar panel was showed in figure 7.11.

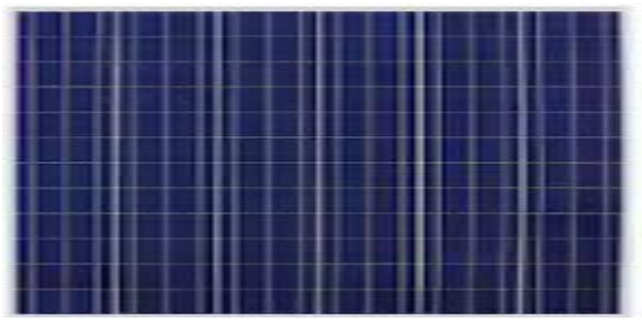

Figure.7.11.Hybrid solar panel

The cost of hybrid solar cells is low. Systems using hybrid solar cells operate more sustainably and efficiently. It helps store excess solar energy and provides constant power. The solar energy reserves can be utilized in the evening. Load shifted or self-use are the terms for this procedure. A power backup system is standard on all hybrid inverters. With hybrid solar cells, you can't connect as many devices because of their restricted number complicated controlling, high installation costs, shorter battery life, and more area needed to install the entire system [36-37].

7. Conclusion

Solar energy has the potential to displace non-renewable energy sources and is regarded as a major renewable energy technology. The solar energy systems key component, the solar photo voltaic cell is in charge of converting sun energy into electrical energy. The solar energy system operates better overall and can be used in more places thanks to the usage of novel materials. If you're looking for the highest efficiency and have a limited space, monocrystalline solar panels might be a good choice. With their greater efficiency rate, monocrystalline solar panels can produce more electricity in a smaller space. In addition their cost is higher than that of polycrystalline solar panels. If you're more budget-conscious and have ample space, polycrystalline solar panels could work. In India, poly crystalline solar panels are the most widely utilized kind. They are good efficiency rate and affordable. Thin-film panels might be suitable if you need flexibility in installation. Although polycrystalline solar panels cost less, their average efficiency rate is only 20%. However, if your solar project is smaller or you need less energy to power to your home, they can be an excellent choice. monocrystalline is used to create the most effective solar panels currently available on the market, which has efficiencies of up to 22%-23%. A number of considerations, including location, shade, and financial constraints, go into selecting solar panels for a house or commercial building**.** Polycrystalline solar panels, for instance, might be a wise choice if there is no shade issue and the area gets plenty of sun light. Conversely monocrystalline solar panels would be preferable option if there is a chance of shade and location receives less sun light. Subsequent studies ought to concentrate on substances capable of making solar photovoltaic's economical and environmentally friendly.

The Future of Solar cell technology

In the coming years the Solar cell technology will be the trustable energy resource as the planet Sun doesn't shade or perish and the Solar energy can be generated all the days in a year. The requirements for solar energy devices can be grown up. The performance and advancement of solar cell technology is seen rising, due to its efficiency, lower cost, light weight, flexibility and easy installation.

Conflict of Interest

This copy has not been communicated or is in process anywhere else. Therefore, there is no conflict of the addicted for us to encounter.

Data Availability

The authors are ready to communicate any data regarding this research in further information.

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