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A Review Paper on Development in Material Used in Solar Pannel as Solar Cell Material

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Abstract

In the present era, While seeing the increasing demand for energy and depletion of resources from which we obtained energy, solar energy suggest as the best alternative energy resource. The light from the sun is not only a non-vanishing resource of energy but also it is an Eco- Friendly resource of energy(free from the environment pollution and noise). It can easily compensate for the energy requirements fulfilled by the other resources, which are depleting and environment challenges, such as Fossil Fuel and petroleum deposits.

Basically, we receive solar energy from the sun in the form of sunlight. This sunlight is converted into electric energy by the use of a solar cell, which uses the principle of Photovoltaic effect. The main two challenges in front of the development and implementation of solar cells are cost and efficiency. Discontinuous supply is also a problem while using solar energy. There are so many researches are going on continuous improvement of the functioning of a solar cell. Solar Cell efficiency, which was below 10% at the development of thin-film solar cells in the 1970s, now the most recent developments in new photovoltaic materials achieving greater than 24% efficiency (PCE). Unfortunately, the cost of electricity from current solar cells is about one order of magnitude higher than commercial prices. However, several of the recent developments hold a promising future for the field. We begin by looking at the development of solar cells in general and the new technologies available.

Keywords — *Solar Pannel. Solar Cell Material*

INTRODUCTION

The everyday sun sends out a huge amount of energy in the form of heat & radiation called solar energy. Solar energy is an unlimited resource of energy at free Cost [1]. The main benefit of solar energy over another conventional energy resource that solar energy can easily be converted into electric energy with the help of photovoltaic solar cells in an Eco-friendly manner[2] [3].

A solar cell is a device that converts the solar energy or light (when falls on it) into electrical energy with the principle of photovoltaic effect (discovered by Alexandre-Edmond Becquerel in 1839, A French Scientist)[4]. A photovoltaic cell is a device that converts sunlight into electricity using semiconductor materials enable electron flow when photons from sunlight absorbed and ejected electrons, leaving a hole that is further filled by the surrounding electrons. This phenomenon is called the photovoltaic effect. The PV cell directs the electrons in one direction, which gives rise to the flow of current. The amount of current is directly proportional to the humble of absorbed photons. So it can be easily said that PV cells are a variable current source. The first solar cell was built by Charles Fritts in 1883 by the use of a thin layer of gold, and a coating of selenium formed a junction. In the starting era, the PCE was very low, about 1% only, but further improvements make it increase. After 1950, the US gives a landmark in the resource of the solar cell. In the conference of 1973, they found solar power corporations and give emphasis on developing solar energy at a reasonable cost; the vanguard satellite employed the first photovoltaic solar panel in space in addition to increasing the mission time. The space companies need a very high quality of solar cell provides high PCE due to which in starting price of solar cell were quite a height. But further improvement and its use in household applications make its price full.

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HISTORY

Solar cells were first used in space applications in the vanguard satellite in 1958. These are used as an alternative power source in place of battery by using the solar cell's mission time could be extended. In 1959 United States used a wing-shaped solar array in its satellite named Explorer 6, which become a common feature. Further, these arrays consisted of 9600 Hoffman solar cells. This time the price of solar cell were quite high because here in space applications only quality matters. The price of solar panels fell when the semiconductor industry moves to Integrated circuits in 19605 led to the availability of layer crystals (boules). So the cost of solar cells falls up to 100$per watt in 1971. In 1969, the US started a research program into the solar panel for terrestrial applications named "Research Applied to Nation Needs" governed by National Science Foundations Advanced Solar Energy Research and Development

Division. This program still continued till 1977 and funded research on developing solar power for ground Electrical Power Systems.

In the 1973 oil crisis, oil companies gave emphasis to start a solar firm and were, for decades, the largest producers. Exxon, ARCO Shell, Amoco, and Mobil all had established their major divisions during the 1970s & 1980s. This all gives an increase in the use of solar energy, decreases in production cost, and an increase in solar cell efficiency.

The cost of solar cells was sufficiently decreased due to process improvements and large production from 96$ per watt in mid -1970s to 68$ per watt in 2016, according to data from Bloomberg New Energy Finance [21] as the semiconductors industry moves to larger crystals order equipment become inexpensive.

DEVELOPMENT OF MATERIAL USED IN SOLAR CELL

The first material used for a solar cell is basically silicon solar cells are named on the basis of semiconducting material used. These materials should have the property absorbing sunlight. Solar cells are basically grouped into first, second, and third-generation cells. The first generation cells are produced by silicon wafers. Second generation cells are thin films solar cells (Amorphous Silicon, Cadmium Telluride, and CIGS cells) and used in photovoltaic power stations, building integrated photovoltaic or in the small stand-alone power system. The third generation of the solar cell includes emerging photovoltaic (a number of thin-film technologies). Third-generation cells, most of them are under research and not commercially used. In spite of solar cell technology very costly and less efficient, there is so many researches are going on in the development of solar cell technology due to its increasing demand and promising nature of unlimited supply.

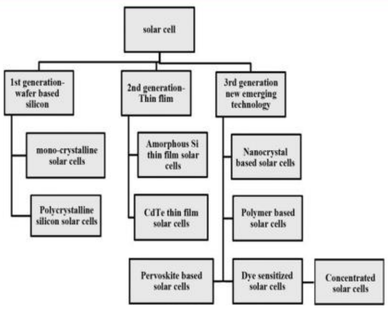

Fig: Classification of solar cells on the basis of generation [54,55].

A. Mono-Crystalline Silicon Solar Cell

These solar cells are first-generation solar cells called a conventional or traditional solar cell. As the name indicates, these solar cell is manufactured from a single crystal of silicon. These silicon crystals are cut from the big sized cylindrical ingots. The method used for manufacturing these cells is called the Czochralski process [5] [7]. The corner of the cells looks clipped like an octagon. These solar panels display a distinctive pattern of small white diamonds. The efficiency of these cells lies between 17%-18% [8].

B. Poly-Crystalline Silicon Solar Cell

Poly-Crystalline PV modules are generally composed of a number of different crystals, coupled to one another in a single cell. The cells are made from cast sugar ingots by cooling and solidification method. This manufacturing is economical. These cells are currently the most popular solar cells that occupy almost 48% of solar cell production worldwide in 2008, yet this efficiency is about 12%-14% [9][10]. Ribbon Silicon is an example of a Polycrystalline silicon solar cell, which is formed by drawing flat thin films from molten silicon. Silicon waste is reduced in this type of cell to a great extent, but these are less efficient.

C. Thin Film Solar Cell – Second Generation Solar Cell

Thin-film solar cells are called a second-generation solar cell and are more economical as compared to the first-generation solar cell. These solar cells have a very thin light-absorbing layer generally of the order of 1micro meter thickness, while first-generation silicon wafer cells have a 250micro meter thick light-absorbing layer [11]. These technologies reduce the amount of active material in a cell. This active material acts as a sandwich between two panes of glass. Examples of this film technology Amorphous Silicon, Cadmium Telluride (CdTe), copper indium gallium Di Selenide (CIGS), etc.

Amorphous Silicon Thin Film Solar Cell

Amorphous Silicon solar cell is an example of the most well-developed technology in a thin-film solar cell. These solar cells are first, which is manufactured industrially. These cells can be manufactured at very low processing temperatures, so various polymer and other flexible substrates can be used, which are cheap as compared to other materials [12]. So these solar cells are comparatively cheaper and widely used. These cells are made of non-crystalline or microcrystalline silicon. Amorphous Silicon has a higher bandgap (1.7ev) than crystalline silicon. Here Amorphous meaning that the comprising silicon material of the cell lacks a definite arrangement of atoms in the lattice, no-crystalline structure, or not highly structured. These are fabricating by waiting for the doped silicon material to the backside of the glass plate by the Plasma Enhanced Chemical Vapour Deposition method (PECVD). The top cell in Amorphous Silicon absorbs the visible light and leaves the infrared part of the spectrum for the bottom cell.

The main drawback of an Amorphous silicon solar cell is its almost unstable efficiency, which varies in the range of 4%-8%. These cells can be easily operated at high temperatures and also suitable in variable climate conditions when son sine for few hours like in water [13].

Cadmium Telluride (CDTC) Thin Film Solar Cell

Cadmium is a toxic material, and Tellurium is available in a limited amount, but in spite of this, Cadmium Telluride is a good option for the development of an economic photovoltaic device. It is the first PV technology that is so far to rival crystalline silicon in cost/watt[8][14][15]. These cells have a bandgap of approximately 1.5ev with high chemical stability. So this is mostly liked the material of thin-film solar cell technology.

These cells have excellent bandgap, which makes the absorption of light easier and also improves efficiency. In the manufacturing of these solar cells, firstly, the CDTE based solar cells are synthesized from polycrystalline material, and glass is chosen as a substrate. After that, multiple layers of CdTe solar cells are coated on the substrate using different methods. This process is called deposition. These cells are made by sandwiching the layer of Tellurium between the layers of Cadmium Sulfide to form a p-n junction diode. As we already discussed that CdTe has a bandgap of approximate1.48ev with high absorption coefficient over $5x10^{15}$/cm [16], so that their efficiency lies in the range of9%-11%[8][17]. However, these cells are also challenging for the environment because cadmium is a toxic element (which can accumulate in human bodies, animals, and plants), and during manufacturing and also after the use of this, disposal of these is a big issue.[18][13] Therefore limited supply of cadmium and hazardous environmental effect associated with its uses is the main issue of using this technology [19]-[22].

Copper Indium Gallium Di-Selenide (CIGS solar cells)

Like Cadmium Telluride and Amorphous Silicon CIGS solar cell is also a thin-film solar cell technology [18][23], the CIGS layer is also thin enough to be flexible, allowing them to be deposited on flexible substrates. CIGS is a quaternary compound semiconductor comprising of four elements, namely- copper, Indium, Gallium, and Selenium. These cells have a higher efficiency of approximately 10%-20%. The manufacturing of CIGS is done by the following techniques: sputtering, evaporation, electrochemical coating techniques, printing, and electron beam deposition [5][24]. It is manufactured by depositing a thin layer of Copper, Indium, Gallium & Selenium on glass or plastic backing, along with electrodes on the front and back to collect current. The substrates for CIGS material can be chosen from the glass plate, polymer substrates, steel, aluminum, etc. It has a high absorption coefficient, so a much thinner film is required than any other semiconducting material. The main feature of CIGS thin-film solar cells is its prolonged life without considerable degradation. Thin-film solar cell market share is stagnated at around 15%, leaving the root of the market. In 2013, the market share of CIGS alone bout was 2%, and all thin-film technologies full below 10%. CIGS cell continues being developed, as they promise to reach silicon like efficiency at low cost.

Third Generation Solar Cell

D. Nanoscale Materials Based Solar Cell

Nano crystal-based solar cells are generally called quantum dots. Quantum dot is just a name of size ranging within a few nanometers, e.g., Porous Silicon or Porous TiO_2 (Titanium dioxide) [25]. Nanocrystals are used as an option for effective and cheap solar cells. It is assumed that the Nanocrystals shape and sized will allow for the customization of bandgap through absorption of light across the whale spectrum. The 3D confinement leads to greater input ionization input and results in multiple change carrier creation from a single photon. The confinement increases the density of states along the band edge in a given dimension.

Substrate
Electron Injection
QD
Hole
Anode (Transparent)

Fig: Schematic diagram of Nanoparticles Materials

With the advancement of technology, nanocrystals of semiconducting material are targeted to replace the semiconducting material in the bulk state, such as Amorphous Silicon, Cadmium Telluride, and CIGS solar cell. These cells are manufactured by mixing the nanomaterials in a bath and coated onto the Si substance. These crystal state very fast and flow away due to centrifugal force. In conventional compound semiconductor solar cells, when a photon will excite an electron, thereby creating one electron-hole pair [27]. However, when a photon strikes quantum dots made of similar semiconducting material, numerous electron-hole pairs (usually 2 or 3 also 7 has been observed in few cases)[26][22] can be formed. Such arrays are cheaper to manufacture than other photovoltaic options because of the ability to process them from a solution. The efficiency of these solar cells is only around 2.5% compared to the theoretical efficiency of 44% [28]. The intrinsic carrier mobility of organic coatings reduces the efficiency of nanoscale solar cells.

E. Polymer Solar Cell

The first polymer/organic solar cell was invented by the research group of Tang et al. in the Kodak Research lab [26]. These cells have the benefit of flexibility due to polymer substance. These cells are composed of a serially connected thin function layer (typically 100nm) coated on a polymer foil or ribbon. It makes a combination of a donor (polymer) and an acceptor (Fullerene). The material used for this purpose is polyphenylenevinylene, carbon fullerenes derivatives, etc.

In 2000 Hegger, Mac Diarmid, and Shirakawa fetched the Nobel prize in chemistry for discovering a new category of a polymer material called conducting polymers. Polymer solar cell also works on the principle of PU effect. They can be processed from a liquid solution, offering the possibility of a simple roll to roll printing process. Yu et al. mixed poly (2-methoxy-5-(2-ethyl hexy loxy)-p-phenylenevinylene). (PPV), C60 and its other derivatives to develop the first polymer solar cell and obtained high power conversion efficiency. After significant researches, they achieved an efficiency of over 3% for PPY-type polymer solar cells. In 2011, MIT and Michigan State researchers developed solar cells with power efficiency nearby 2% with a transparency of 65% [30][31]. Researchers at UCLA more recently developed an analogous polymer solar cell, following the same approach with 70% transparent and has 4% power conversion efficiency[32][33][34]. As energy conversion efficiency achieved to date using conductive polymers are very low compared to inorganic materials. However, Konarka Power Plastic reached an efficiency of 8.3% [29], and organic tendem cells reached 11.1% in 2012. For increasing the function of liquid crystal displays (LCD), A modern recycling concept known as polarizing organic photovoltaics (ZOPVs) was also developed, which was utilizing the same polarizer, a photovoltaic device, and proper solar panel[35][37].

F. Dye-Sensitized Solar Cells (DSSC) or light Absorbing Dye

The first Dye Sensitized solar cell was introduced by Michel Gratzel in the Swiss Federal Institute of Technology [18][5]. These cells are made of low-cost material and do not need to elaborate on manufacturing equipment.

Recently researchers have been focused on improving solar efficiency by molecular manipulation, use of nanotechnology for harvesting light energy [39]-[42]. DSSC can be coated on flexible sheets, but its conversion efficiency and the absorption coefficient is low [18]. Recently researchers have been focused on improving solar efficiency by molecular manipulation, use of nanotechnology for harvesting light energy [39]-[42]. DSSC can be coated on flexible sheets, but its conversion efficiency and the absorption coefficient is low [18].

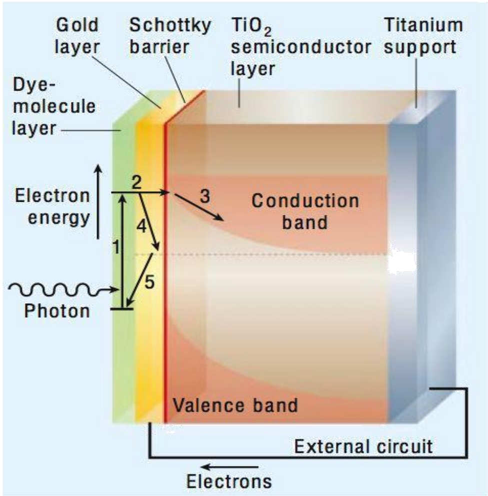

Fig: Schematic Dye-sensitized solar cell [53]

These cells generally employ due molecules between the different electrodes. The DSSC device consists of four components: a semiconductor electrode (n-type TiO_2 and p-type NiO), a dye sensitizer, a redox mediator, and a counter electrode (Carbon or Pt) [38]. Typically a Ruthergum Metal-organic dye (Ru-centred) is used as a Monolayer of light-absorbing material. The Dye-sensitized solar cell depends on a mesoporous layer of nanoparticulate Titanium dioxide to greatly amplify the surface area (200-300m^2/g TiO_2, as compare to approximate 10m^2/g of the single flat crystal). The photogenerated electrons from the light-absorbing Dye are passed on the n-type $TiO_{2,}$ and the holes are absorbed by an electrolyte on the other side of the Dye. The circuit is completed by a redox couple in the electrolyte, which can be liquid or solid. The Dye-sensitized solar cell attractive due to simple conventional processing methods like printing techniques are highly flexible, transparent, and as well as low cost. There are certain challenges like degradation of dye molecules, and hence stability is also a big issue. This occurs due to poor optical absorption of sensitizers, which result in poor conversion efficiency. The dye molecules generally degrade after exposure to ultraviolet and infrared radiations leading to a decrease in the lifetime and stability of a cell. Coating with a barrier layer may also increase the manufacturing more expensive and lower the efficiency. The novelty in the DSSC solar cells arrives due to the photosensitization of nano-grained TiO_2 coating coupled with the visible optically active dyes, thus increasing the efficiency greater than 10%. The first commercial shipment of DSSC solar modules occurred in July 2009 from G24 Innovations.

G. Concentrated Solar Cell

The word concentrated here means the concentration of solar energy. The main principle of the solar cell is to collect a large amount of solar energy onto a solar region over the PV solar cell. For this purpose, the principle of options is used by using large mirrors and lenses arrangements to focus sunlight onto a small region on the solar cell. Thus the converging of solar light radiations produce a large amount of heat energy. After that, this heat energy is driven by a heat engine controlled by a power generator. A concentrated solar cell is the newest technology in solar cell research is development. It is classified in lower medium and high concentrated solar cells depending on the power of the lens system. These types of solar cells have a PCE of more than 40%. Other advantages of these types of solar cells are no moving parts, no thermal mass, speedy response time can be scalable to a range of sizes.

H. Transparent Solar Cell

Sunlight is available for free everywhere, but the guarantee of using this light for solar power is restricted to solar farms and rooftop panels. Recently, transparent solar cells caught the attention of scientists due to their variety of possible applications in our daily lives. Transparent solar cells are already in use for these applications in some countries, while others are for the far future, once their efficiency is improved. Transparent solar cells can transform crowded cities from exclusively power consumers into power plants. Building-integrated photovoltaics, also known as BIPV, is the nearest application for transparent solar cells. If all the buildings with 90% glass on their surface used transparent solar cells printed on the surface of the glass, the solar cells have the potential to power more than 40% of that building's energy consumption. Another application of transparent solar cells is in automobiles and electronic devices. If these applications used TSC in their glass surfaces, people could have cars that do not need fuel or devices that can be self-charged from the sun. Solar-powered vehicles are a desired application of TSC, with cars, airplanes, trains, and boats potentially being powered with solar energy. TSC has the potential to power all the electronic devices that we use in our daily lives, from tablets, MP3 players, cell phones, and e-readers to laptops and other portable devices—from some years before Transparent solar materials and semi-transparent materials started to be developed. Some companies have implemented transparent solar cells with reasonable efficiency but not enough to compete with silicon solar panels. However, this invention has a high potential of turning every glass surface in the advanced world into a solar panel. Researchers are now working to improve the efficiency of transparent solar cells without sacrificing transparency; this is expected to be achieved in the next years.

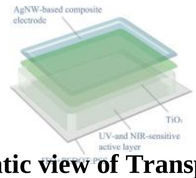

Fig: Schematic view of Transparent Solar Cell

There are approximately nine technologies that apply to the fabrication of transparent solar cells, and they are a focal point of current research due to market demand and the potential applications of transparent solar cells (TSC). The centers of research that report some success with TSC are in Japan, Germany, the USA, and India. It should be noted that 90% of these technologies use an FTO or ITO conductor on glass, which has a layer with almost 10Ω/sq resistance, using a thin film with a thickness of less than 20nm [43, 44]. Before the deposition of any other materials, combined with intrinsic optical losses of the glass itself, these layers reduce the transparency by approximately 15–20%. So, the best transparency achieved till now is less than 80% [45].

I. Perovskite Solar Cells

This is the latest technology on which so much researches are going on. Perovskite is a class of compound defined by the formula ABX_3 where A and B are cations of different size and X represent a halogen such as I^-, Br^-, Cl^-. An active layer or Perovskite structured material is used. Mostly, this is a solution-processed hybrid organic-inorganic tin (Sn) or Lead (Pb) halide based material. Here group A consists of methyl Ammonium ($CH_3NH_3^+$) or Mamidinium $CH(NH_2)_2^+$ while group B consist of lead (Pb^{++}), Tin (Sn^{++}). The metal halogen octahedral are joined together to form a stable three-dimensional network structure. The researches show more interest in the research of this solar cell increased from 5% to 20% in 2014 [46, 47]. These solar cells are considering as extremely cheap solar cells. Although till now, the use of Perovskite solar cells have not commercialized while so many researches are going on to achieve it.

These solar cells possess several advantages over conventional silicon-based solar cell need expensive multiple processing steps and require high temperature greater then 1000^0c and vacuum facilities [48, 49]. These solar cells have an efficiency maximum of up to 31% [50]. These Perovskite-based solar cells may be best used in next-generation electric automobiles batteries, according to an investigation recently performed by Volkswagen. However, their stability is a big issue among the researchers because its materials degrade over time, and hence overall efficiency drops.

Conclusion

All the types of technologies that are used previously and also which are developing currently are discussed here. From the discussion, we can see that solar energy is green and clean, a promising energy resource for the future. There are so many challenges in front of the use of solar energy as its high Initial Cost, occupying more space, and also lack proper disposal method. Solar cell efficiency is also a big challenge. Since solar energy is not available for 24 hours, all these equipment of PV solar cells may not work at night (and also not in the rainy season), and a lot of electricity will go unused [51]. Therefore energy storage is an important consideration in the case of PV solar cells. There are so many storage devices are available, but these devices are costly and have a short life. This also increases the initial cost of solar cell technology, which is the main challenge among all in the use of solar energy. There are also so many researches that are going on in developing an efficient storage device, e.g., Harvard University researchers developed a battery based on organic molecules in 2014. These organic molecules are found in plants, and these can store energy for two days. The world's first solar cell energy storage device was introduced by Wu and his co-workers at Ohio State University. This device was storage and cost-efficient and reduced the cost of renewable energy resources by 25% [52].

Solar power generation has several advantages over another form of energy like petroleum products and fossil fuel due to its eco-friendly nature and its promising and consistent nature to meet the high energy requirements for the future. The method of receiving solar energy is also quite simple, but efficient and durable solar cell material is also needed. This time mostly, researchers are focusing on developing the nanoscale solar cell material and transparent solar cell material due to their high energy conversion efficiency, and also these require lesser space. The polymer-based solar cells are also a viable option, but their degradation over time is a serious concern. There are so many challenges for the solar industry, including lowering the cost of production, public awareness, and the best infrastructure. So now we can conclude that solar energy is the need of the day, and new research on solar cells can make a change worldwide.

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