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The properties and advantages of the hybrid Solar Cell

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ABSTRACT

Most of the power generated nowadays is produced using fossil fuels, which emit tons of carbon dioxide and other pollution every second. More importantly, fossil fuel will eventually run out. In order to make the development of our civilization sustainable and cause less harm to our environment, people are looking for new source of substitute clean energy Because of the increasing demands in clean energy, the solar energy industry is one of the fastest growing forces in the market. Nowadays there are several major directions for hybrid solar technology development. For example, photovoltaic systems directly convert the solar energy into electrical energy. Today's most efficient technology for the generation of electricity from solar radiation is the use of multi junction solar cells made of III-V compound semiconductors. Efficiencies up to 39 % have already been reported under concentrated sunlight. Electricity is produced in solar cells which, as noted, consist of more layers of semi conductive material. When the sun's rays shine down upon the solar cells, the electromotive force between these layers is being created, which causes the flow of electricity. The higher the solar radiation intensity, the greater the flow of electricity. The most common material for the production of solar cells is silicon. Silicon is obtained from sand and is one of the most common elements in the earth's crust, so there is no limit to the availability of raw materials. To increase the efficiency and reduce the cost of a PV system, an introduction of combination of polymer and nanoparticles in cell design is fast replacing the silicon PV modules. An overview of this new technology confined to Amorphous silicon (aSi) Cadmium Tellurium (CdTe) , Copper indium gallium selenide (CIS, CIGS), CdSe and TiO_2 Hybrid Solar Cells is presented in this paper. The properties and the advantages of the hybrid solar cell have been discussed in detail.

Key words: Generations of PV cell technologies, Solar energy, Materials for solar cell.

INTRODUCTION

Solar energy is clean and renewable. It doesn't emit carbon dioxide during operation. The major material of photovoltaic panel which is the most commonly used today is hybrid solar. Silicon is abundant and environmentally safe.

The photovoltaic systems are commercially available and widely extended, further research and development of photovoltaic technology is essential to allow it to become a major source of electricity. Considering future directions in the research of solar photovoltaic cells, as far as crystalline silicon solar cells concern, a technology that has dominated since the beginning of photovoltaics developing, So far, the market is dominated by crystalline silicon cells, while an increasing share of thin film technology is expected in the future. Thin film technology enables significant savings in materials, more flexible installation of photovoltaic cells since they can be bent. Furthermore, thin film technology solar cells have a significantly shorter return of invested energy period, while, on the other hand, the effectiveness is somewhat lower. Silicon as base material is absolutely dominating, with a share of 98,3%, out of it mostly crystalline silicon technology with a 93,7% share in total production[1]. Until recently monocrystalline silicon production technology was predominant.The production of monocrystalline silicon is more expensive, but the cell efficiency is greater. Today this technology is losing a step in comparison with the technology of multicrystalline silicon (Mc Si). The advantages of multicrystalline silicon are lower capital investment for production of wafer (a thin slab of a semiconductor material), higher efficiency due to the use of square silicon wafers, which provide greater active surface of the module compared with a circular or quasi circular shape of monocrystalline wafer.

GENERATIONS OF PV CELL TECHNOLOGIES

PV cell technologies are usually classified into three generations:

First generation PV technologies: Crystalline Silicon cells:

First-generation PV systems (fully commercial) use the wafer-based crystalline silicon (c-Si) technology, either single crystalline (sc-Si) or multi-crystalline (mc-Si). Silicon is one of the most abundant elements in the earth's crust. It is a semiconductor material suitable for PV applications, with energy band gap of 1.1eV. Crystalline silicon is the material most commonly used in the PV industry, and wafer-based c-Si PV cells and modules dominate the current market. This is a mature technology that utilises the accumulated knowledge base developed within the electronic industry. This type of solar cell is in mass production and individual companies will soon be producing it at the rate of several hundred MW a year and even at the GW-scale [2]. First-generation solar cells dominate the market with their low costs and the best commercially available efficiency.

Crystalline silicon cells are classified into three main types depending on how the Si wafers are made. They are: Monocrystalline (Mono c-Si) sometimes also called single crystalline (sc-Si);Polycrystalline (Poly c-Si), sometimes referred to as multi-crystalline (mc-Si); and Thin film growth (EFG ribbon-sheet c-Si).

Second generation PV technologies: Thin film solar cells:

Second-generation PV systems are based on thin-film PV technologies and generally include three main families: 1) amorphous (a-Si) and micromorph silicon (a-Si/μc-Si); 2) Cadmium-Telluride (CdTe); and 3) Copper-Indium-Selenide (CIS) and Copper-Indium- Gallium-Diselenide (CIGS). After more than 20 years of R&D, thin-film solar cells are beginning to be deployed in significant quantities. Thin-film solar cells could potentially provide lower cost electricity than c-Si wafer-based solar cells. However, this isn't certain, as lower capital costs, due to lower production and materials costs, are offset to some extent by lower efficiencies and very low c-Si module costs make the economics even more challenging. Thin-film solar cells are comprised of successive thin layers, just 1 to 4 μm thick, of solar cells deposited onto a large, inexpensive substrate such as glass, polymer, or metal. As a consequence, they require a lot less semiconductor material to manufacture in order to absorb the same amount of sunlight (up to 99% less material than crystalline solar cells). Second-generation thin-film PV technologies are attractive because of their low material and manufacturing costs, but this has to be balanced by lower efficiencies than those obtained from first-generation technologies [3].

Third generation PV technologies:
Third-generation PV technologies are at the precommercial stage and vary from technologies under demonstration (e.g. multi-junction concentrating PV) to novel concepts still in need of basic R&D (e.g. quantum-structured PV cells). Some third-generation PV technologies are beginning to be commercialised, but it remains to be seen how successful they will be in taking market share from existing technologies. Third-generation technologies are yet to be commercialised at any scale. Concentrating PV has the potential to have the highest efficiency of any PV module, although it is not clear at what cost premium. Other organic or hybrid organic/conventional (DSSC) PV technologies are at the R&D stage [4]. They offer low efficiency, but also low cost and weight, and free-form shaping. Therefore, they could fill niche markets (e.g. mobile applications) where these features are required.

There are four types of third-generation PV technologies: Concentrating PV (CPV);Dye-sensitized solar cells (DSSC);Organic solar cells; and Novel and emerging solar cell concepts.

TYPES OF SOLAR PHOTOVOLTAIC CELLS

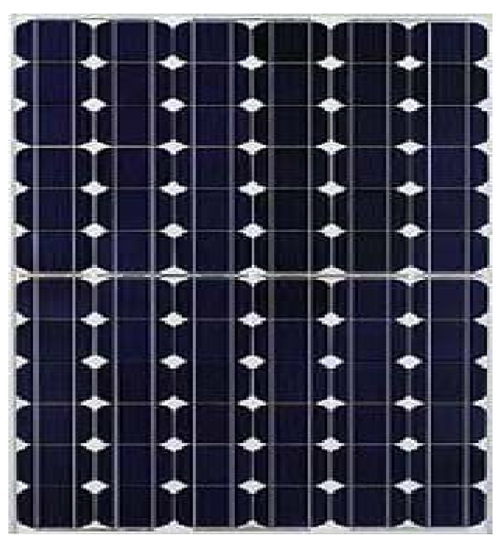
Electricity is produced in solar cells which, as noted, consist of more layers of semiconductive material. When the sun's rays shine down upon the solar cells, the electromotive force between these layers is being created, which causes the flow of electricity. The higher the solar radiation intensity, the greater the flow of electricity. The most common material for the production of solar cells is silicon. Silicon is obtained from sand and is one of the most common elements in the earth's crust, so there is no limit to the availability of raw materials.

Solar cell manufacturing technologies are:

- monocrystalline,
- polycrystalline
- thin film technology.

1. Mono crystalline Si cells:

Until recently monocrystalline silicon production technology was predominant, obtained by the so called Czochralski process or technology of the floating zone. The production of monocrystalline silicon is more expensive, but the cell efficiency is greater Monocrystalline Si cells: conversion efficiency for this type of cells ranges from 13% to 17%, and can generally be said to be in wide commercial use. In good light conditions it is the most efficient photovoltaic cell. This type of cell can convert solar radiation of 1.000 W/m2 to 140 W of electricity with the cell surface of 1m2. The production of monocrystalline Si cells requires an absolutely pure semiconducting material. Expected lifespan of these cells is typically 25 to 30 years and, of course, as well as for all photovoltaic cells, the output degrades somewhat over the years [5]. New technology charge controllers, which allow for a higher array voltage than the battery bank voltage, somewhat obviate the advantages of the monocrystalline panels.



Mono-Crystalline Silicon PV Cell

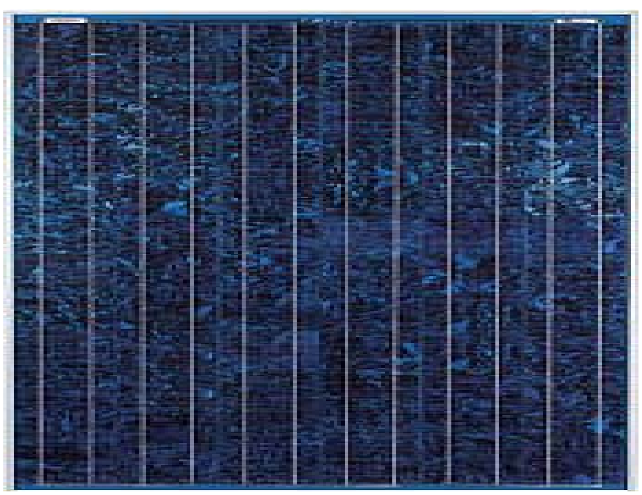
2. Multi crystalline Si cells:

Multicrystalline Si cells: this type of cell can convert solar radiation of 1.000 W/m2 to 130 W of electricity with the cell surface of 1m2. The production of these cells is economically more efficient compared to monocrystalline. Poly-crystalline silicon cells are made from sawing a cast block of silicon first into bars and then wafers. This technology is also known as Multi crystalline technology. Poly-Si cells are less expensive to produce than single crystal silicon cells as the energy intensive process for purification of silicon is not required. They are less efficient than single crystalline cells. The efficiency of polycrystalline silicon cells ranges from13-14% and can often be purchased at a lower cost per watt than monocrystalline silicon panels. This type of panel sees the widest use in polar applications [6]. The advantages of multicrystalline silicon are lower capital investment for production of wafer (a thin slab of a semiconductor material), higher efficiency due to the use of square silicon wafers, which provide greater active surface of the module compared with a circular or quasicircular shape of monocrystalline wafer. Liquid silicon is poured into blocks, which are then cut into slabs. During the solidification of materials crystal structures of various sizes are being created, at whose borders some defects may emerge, making the solar cell to have a somewhat lower efficiency, which ranges from 10% to 14%. The lifespan is expected to be between 20 and 25 years.

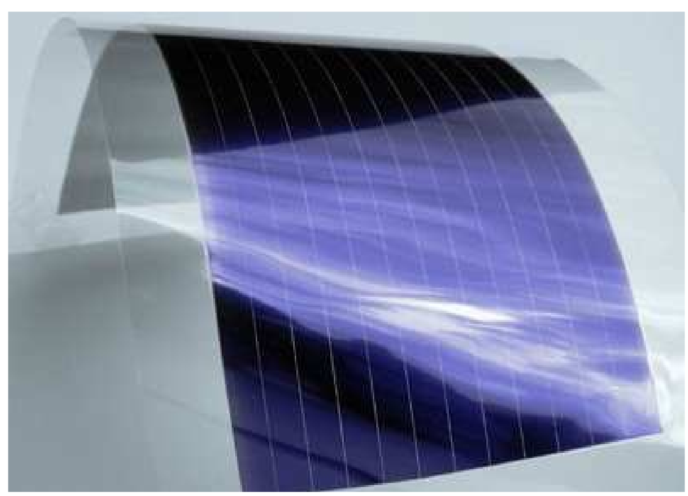
3. Thin film technology

In Thin Film Solar technology, a very thin layer of chosen semiconductor material (ranging from nanometer level to several micrometers in thickness) is deposited on to either coated glass or stainless steel or a polymer substrate. Various thin-film technologies are being developed to reduce the amount of light-absorbing materials required to construct the solar cell. The process of generating modules in thin film technology has resulted in reduced production costs compared to crystalline silicon technology, which is somewhat more intense. Today's price advantage in the production of a thin film is balanced with the crystalline silicon due to lower efficiency of the thin film, which ranges from 5% to 13%. Lifespan is around 15 to 20 years. The main advantages of thin films are their relatively low consumption of raw materials; high automation and production efficiency; ease of building integration and improved appearance; good performance at high ambient temperature; and reduced sensitivity to overheating [7]. Thin film technologies are growing rapidly. In recent years, thin film production units have increased from pilot scale to 50 MW lines, with some manufacturing units in the gigawatt (GW) range. As a result, thin films technologies are expected to increase their market share significantly by 2020.

There are four types of thin film modules (depending on the active material) that are now in commercial use:



Poly-Crystalline Silicon PV Cell



Thin flim PV

3.1. Amorphous silicon (aSi):

Amorphous Si Cells: Cell efficiency is around 6%, a cell surface of 1m2 can convert 1.000 W/m2 of solar radiation to about 50 watts of electric energy. Progresses in research of this type of module have been made and it is expected a greater efficiency in the future. If a thin film of silicon is put on a glass or another substrate it is called amorphous or thin layer cell. The layer thickness is less than 1 microns, therefore the lower production costs are in line with the low cost of materials. However, the efficiency of amorphous cells is much lower compared to other cell types [8]. It is primarily used in equipment where low power is needed (watches, pocket PCs) or, more recently, as an element in building facades.

3.2. Cadmium Tellurium (CdTe):

Cadmium tellurium (CdTe) cells: Cell efficiency is around 18%, a cell surface of $1m^2$ can convert solar radiation of 1.000 W/ m^2 to 160 W of electricity in laboratory conditions. Cadmium teleurid is a fusion of metal cadmium and tellurium semimetal. It is suitable for use in thin photovoltaic modules due to the physical properties and low technology manufacturing. Despite these advantages it is not widely used due to cadmium toxicity and suspected carcinogenicity

3.3: Copper indium gallium selenide (CIS, CIGS):

CIS cells have the highest efficiency among the thin-film cells, which is about 20%. This cell type can convert solar radiation of 1.000 W/m^2 to 160 W of electricity with the cell surface of 1 m^2 in laboratory conditions.

3.4: Thermo sensitive solar cells and other organ cells (DSC):

The development of these organic cells is yet to come, since it is still testing and it is not increasingly commercialized. Cell efficiency is around 10%. The tests are going in thedirection of using the facade integrated systems, which has proven to be high-quality solutions in all light radiation and all temperature conditions [9]. Also, a great potential of this technology is in low cost compared to silicon cells. There are other types of photovoltaic technologies that are still developing, while others are to be commercialized. Regardless of the lifespan, the warranty period of today's most common commercial photovoltaic modules is 10 years at 90% power output, and 25 years at 80% power output.

HYBRID SOLAR CELLS:

To overcome the problems of the conventional Si based solar cells, hybrid solar cells were developed. These cells are a combination of a polymer and nano organic or inorganic semiconductor. Hybrid solar cells combine the excellent electronic properties of inorganic molecules with the reduced cost and flexibility of amorphous substrates . In order to achieve high hybrid solar cell performance, the electron and hole mobility's should be balanced and optimized. CdSe is a promising photovoltaic material because of its high absorption coefficient and nearly optimum band gap energy for the efficient absorption of light and conversion into electrical power[10,11]

CdSe based hybrid solar cells:

Hybrid solar cells are similar to conventional solar cells, but in this case, nanoscale CdSe acts as the electron receptor while P3HT acts as the hole receptor. P3HT was chosen due to the fact that it has the highest hole mobility in conducting plastics available today, while the inorganic semiconductor CdSe has a high electron mobility. High mobilities ensure fast charge transport and separation of the electron-hole pair, reducing current losses due to recombination and increasing the efficiency of the cell. Electrons and holes are exchanged at the interaction surface between CdSe and P3HT. Since an electron's position and direction can only be described by a probability, or wave function, the particular path that an electron will take is indeterminate. In an effort to direct the electron's path, the shape of the CdSe is long and narrow, like a wire, providing a directed, low-resistance path for the electron to follow. The nanorods may also be tuned to absorb different frequencies of light [12,13]

TiO_2 Hybrid Solar Cells:

Recently, nano crystals has paved a new route for photovoltaic application due to its high surface area to volume ratio and tunable light absorption. One such application of nano crystals is titanium dioxide (TiO_2) nano particle based solar cell. This cell utilizes high surface-area-to-volume ratio TiO_2 nano crystals to increase the exciton dissociation area. These are n-type semiconductors that have a strong absorption peak in the ultraviolet, but are transparent to visible light. They have a wide band gap of 3.05-3.5 eV. Single crystal titanium dioxide TiO_2 has a resistivity of about 1013 Ωcm at room temperature and about 107 Ωcm at 250◦C. Additionally, TiO_2 nanostructures may be cheaply synthesized in a modest chemistry lab via sol gel processing. TiO_2 nanoparticles are also effective photo catalysts for treatment of air and water pollutants. Inorganic semiconducting nanoparticles are preferred in photovoltaics because of improved light gathering properties as compared to conventional thin film PV cells. Several researchers have shown interest in the optical properties and low cost of TiO_2 nanoparticles for use in photovoltaic systems. The functional properties of TiO_2 films, powders and ceramics are strongly dependent on the phase of the material. For many applications, the size of crystals that are present also alter the behaviour of the film [14,15]. The properties of TiO_2 are: High Electrical resistance, High durability, High refractive index, Good chemical resistance and high chemical stability

The application of titanium dioxide solar cell requires only a low power output, since this is easier to achieve. The device had an efficiency of 7.1% under full sunlight which increased to 12 % under diffuse lighting. This solar cell has a large potential market due to reduced fabrication costs and higher conversion efficiencies compared to amorphous silicon solar cells. This increases the absorption properties of the device in the visible spectral region. Spray-deposition techniques have been used for depositing the nano crystalline TiO_2 films and the highly porous, Chemical Vapour Deposition (CVD) deposited films could potentially be used for this type of solar cell. Therefore, the application of hybrid solar cells will improvise the efficiency and the cost can be reduced compared to the conventional Si based solar cells.

CONCLUSION

This paper explored the features of solar cell using hybrid materials which is a combination of inorganic semiconductors and conjugated polymers. The significant progress made in the development of hybrid solar cells has resulted in improved efficiency compared to the conventional Si solar cells. Therefore major breakthrough in technology of solar cells is still needed to meet the fundamental cost requirement. As a result, Mono crystalline Si cells, Multi crystalline Si cells, Thin film technology, Hybrid solar cells, CdSe and TiO_2 hybrid solar cells have been dealt in this paper which will be used to develop efficient and cost effective solar cells. The sun delivers its energy to us in two main forms: heat and light. There are two main types of solar power systems, namely, solar thermal systems that trap heat to warm up water, and solar PV systems that convert sunlight directly into electricity.

Advantages

- It is an abundant Renewable Energy
- This technology is Omnipresent and it can be captured for conversion on a daily basis
- It is a Non-polluting technology, which means that it does not release greenhouse gases
- It is a Noiseless technology as there are no moving parts involved in energy generation
- This technology requires Low-maintenance because of lack of moving parts
- It can be installed on modular basis and expanded over a period of time
- Most viable alternative for providing electricity in remote rural areas as it can be installed
- where the energy demand is high and can be expanded on modular basis.

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