Thin Film Solar Cell Technologies and Application: Review of Materials

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Abstract- *Thin film solar cells (TFSC) are a promising approach for terrestrial and space photovoltaics and offer a wide variety of choices in terms of the device design and fabrication. Thin film semiconductor materials have much higher absorption coefficient than silicon. Such versatility allows tailoring and engineering of the layers in order to improve device performance. In practical application, thin-film fabrication turn out to be complex and needs proper control over the complete process chain. In order to choose the right solar system for a specific geographic location, we want to understand and compare the basic mechanisms and general operation functions of several solar technologies that are widely studied. This paper not only gives a brief introduction about the fast developing solar technologies industry, but also may help us avoid long term switching cost in the future and make the solar systems performance more efficient, economical and stable.*

Keywords- Thin Film, Solar Cell, Nanomaterials, Solar Technology

I. INTRODUCTION

The sun is the most plentiful energy source for the earth and including sun, wind, fossil fuel, hydro and biomass energy have their origins in sunlight. Solar energy falls on the surface of the earth at a rate of 120 petawatts. This means all the solar energy received from the sun in one days can satisfied the whole world's demand for more than 20 years. We are able to calculate the potential for each renewable energy source based on today's technology. The thin film solar cells have been developed because of their potential for the reduction of manufacturing costs. Thin Film Solar Cell the crystalline silicon is normally referred to as the first generation photovoltaic technology. The second generation photovoltaic consists of thin film solar cell materials such as cadmium telluride (CdTe), amorphous silicon (a-Si), copper indium gallium diselenide (CIGS), and thin film crystalline silicon. Thin films have a long history in silicon photovoltaics (PV) as antireflection (AR) coatings due to their excellent optical properties and low deposition cost. This work explores several novel areas where SnO2, TiO2 thin films could be use to enhance silicon (Si) solar cell performance while reducing device fabrication costs. Its green energy and doesn't emit carbon dioxide during operation. The major material of photovoltaic panel which is the most commonly used today is silicon and is abundant and environmentally safe.

II. SOLAR ENERGY AND ENVIRONMENTAL ASPECTS

Amorphous silicon solar cells have been used in consumer products such as calculators and digital watches since the early 1980s and attempts have been made to launch outdoor power modules onto the market since the mid-1980s. Many companies, notably Kaneka and Mitsubishi of Japan, have supplied single junction a-Si power modules in appreciable quantities [1].

Sustainable and renewable generation of electricity by photovoltaic systems is being developed because the mismatch of supply and demand of energy. Storage of energy is often essential for these systems to become a competing technology for the conventional energy generation. One way to solve the problem of storage is the development of photochemical systems that use sunlight (photons) directly to drive reversible chemical reactions leading to products that can be used for energy storage. A new type of solar cell which is based on dye-sensitized nanocrystalline titanium dioxide has been developed by M. Grätzel and coworkers (O' Regan and Grätzel 1991; Nazeeruddin, et al. 1993). Remarkably high quantum efficiencies have been reported for this type of solar cell with overall conversion efficiencies up to 11 % [2]. The collection of solar energy and its transfer to electricity energy will have wide application and deep impact on our society, so it has attracted the attention of the researchers. Solar energy is the only choice that can satisfy such a huge and steadily increasing demand. Proper understanding of thin-film deposition processes can help in achieving high-efficiency devices over large areas, as has been demonstrated commercially for different cells. Research and development in new, exotic and simple materials and devices, and innovative, but simple manufacturing processes need to be pursued in a focussed manner. Which cell(s) and which technologies will ultimately succeed commercially continue to be anybody's guess, but it would surely be determined by the simplicity of manufacturability and the cost per reliable watt. We are able to calculate the potential for each renewable energy source based on today's technology. (Figure 1) Future advances in technology will lead to higher potential for each energy source. However, the worldwide demand for energy is expected to keep increasing at 5 percent each year.1 Solar energy is the only choice that can satisfy such a huge and steadily increasing demand.

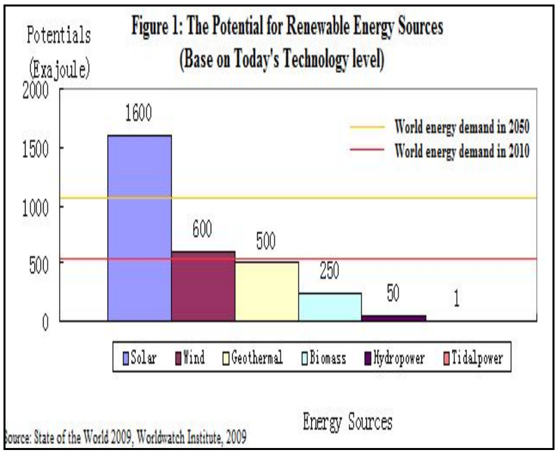

Fig. [1]

However, the application of solar energy technologies can be dangerous under several conditions. Multi-junction photovoltic cells (III–V), which can achieve relatively higher energy converting efficiency than commonly used silicon cells, are usually made with poisonous materials like gallium arsenide (GaAs) or cadmium telluride (CdTe), can cause harm to the environment if leaked. More study about the safety and materials recycling for these cells must be conducted if we want to adopt these techniques into our solar industry. For concentrated solar power techniques, coolant and lubricant can be a problem if leaked. If these drawbacks are avoided, we are able to conclude that solar energy is clean and safe.

1.3 SOLAR TECHNOLOGIES:

There are various type of solar techniques that are currently available. However, each of them is based on quite different concepts and each has its own advantages and disadvantages. Review of materials and different technologies will help us to know about solar technologies and applications at different set of conditions. Photovoltaic solar panels (PV) and concentrated solar power (CSP) are the two commercialized methods and expected to experience rapid growth in the future. Other important Solar techniques are Dye Sensitized Solar Cell (DSSC), Concenterated Photovoltic (CPV) and solar thermoelectricity.

First Generation Solar Cells are are produced on silicon wafers. It is the oldest and the most popular technology due to high power efficiencies. The silicon wafer based technology is further categorized into two subgroups named as: Single or Mono-crystalline silicon solar cell. Poly or Multi crystalline silicon solar cell. Polycrystalline Silicon Solar Cell (Poly-Si or Mc-Si) Polycrystalline PV modules are generally composed of a number of different crystals, coupled to one another in a single cell. The processing of polycrystalline Si solar cells is more economical, which are produced by cooling a graphite mold filled containing molten silicon. Polycrystalline Si solar cells are currently the most popular solar cells. They are believed to occupy most up to 48% of the solar cell production worldwide during 2008. During solidification of the molten silicon, various crystal structures are formed. Though they are slightly cheaper to fabricate compared to monocrystalline silicon solar panels, yet are less efficient ~12% - 14%.

The first thin-film solar cell candidates for large-scale manufacture were based on cadmium sulphide. Attempts to commercialise this technology in the mid-1970s and early 1980s were unsuccessful, attributed to stability issues with the cells and the appearance of amorphous silicon as an apparently superior contender at that point in time. How-ever, greater difficulties than originally anticipated in commercialising amorphous silicon provided opportunities for two related chalcogenide-based polycrystalline thin-film technologies discussed below.

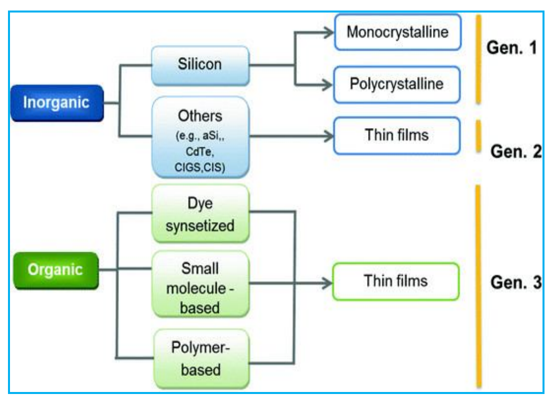

Fig. [2] Types of Solar Cells

Second Generation Solar Cells: Thin Film Solar Cells Most of the thin film solar cells and a-Si are second generation solar cells, and are more economical as compared to the first generation silicon wafer solar cells. Silicon-wafer cells have light absorbing layers up to 350 µm thick, while thin-film solar cells have a very thin light absorbing layers, generally of the order of 1 µm thickness [21]. Thin film solar cells are classified as; • a-Si. • CdTe. • CIGS (copper indium gallium di-selenide). 2.2.1 Amorphous Silicon Thin Film (a-Si) Solar Cell Amorphous Si (a-Si) PV modules are the primitive solar cells that are first to be manufactured industrially. The "amorphous" word with respect to solar cell means that the comprising silicon material of the cell lacks a definite arrangement of atoms in the lattice, non-crystalline structure, or not highly structured. These are fabricated by coating the doped silicon material to the backside of the substrate/glass plate. These solar cells generally are dark brown in color on the reflecting side while silverish on the conducting side.

Third Generation Solar Cells: Most of the developed 3rd generation solar cell types are Nano crystal based solar cells. 2) Polymer based solar cells. 3) Dye sensitized solar cells. 4) Concentrated solar cells. Nano Crystal Based Solar Cells are also known as Quantum dots (QD) solar cells. These solar cells are composed of a semiconductor, generally from transition metal groups which are in the size of nanocrystal range made of semiconducting materials. The structure of the QD solar cells are shown in Figure………….... With the advance of nanotechnology, these nanocrystals of semiconducting material are targeted to replace the semiconducting material in bulk state such as Si, CdTe or CIGS.

Polymer Solar Cells: (PSC) are generally flexible solar cells due to the polymer substrate. The first PSC were invented by the research group of Tang et al. at Kodak Research Lab. A PSC is composed of a serially connected thin functional layers coated on a polymer foil or ribbon. It works usually as a combination of donor (polymer) and a acceptor (fullerene). There are various types of materials for the absorption of sunlight, including organic material like a conjugate / conducting polyme.

Dye Sensitized Solar Cells (DSSC): Recent research has been focused on improving solar efficiency by molecular manipulation, use of nanotechnology for harvesting light energy. The first DSSC solar cell was introduced by Michel Gratzel in Swiss federal institute of technology. DSSCs based solar cells generally employ dye molecules between the different electrodes. The DSSC device consists of four components: semiconductor electrode (n-type TiO_2 and p-type NiO), a dye sensitizer, redox mediator, and a counter electrode. The DSSCs attractive due to the simple conventional processing methods like printing techniques, are highly flexible, transparent and low cost as well. However, there are certain challenges like degradation of dye molecules and hence stability issues. This is due to poor optical absorption of sensitizers which results 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 the cells.

Perovskite Based Solar Cell: Perovskite solar cells are recent discovery among the solar cell research community and possess several advantages over conventional silicon and thin film based solar cells. Perovskites are a class of compounds defined by the formula ABX_3 where X represents a halogen such as I^-, Br^-, Cl^- where A and B are cations of different size. Conventional Si based solar cells need expensive, multiple processing steps and require high temperatures (>1000˚C) and vacuums facilities. The perovskites based solar cells can have efficiency up to 31%. It can be predicted that these perovskites may also play an important role in next-generation electric automobiles batteries, according to an interesting investigation recently performed by Volkswagen. However, current issues with perovskite solar cells are their stability and durability. The material degrades over time, and hence a drop in overall efficiency. Therefore more research is needed to bring these cells into the market place.

Several energy storage devices are available in the market but those are highly expensive and a short life span. Recently, in 2014, Harvard University researchers developed a new type of battery based on organic molecules called Quinone. It is found in plants and is economical in a sense that it can store sunlight energy for a couple of days. The world's first solar cell energy storage is introduced by Wu and his co-workers at Ohio State University. This device not only can store energy but can also reduce the costs of renewable energy by 25%, relying on a new aqueous, rechargeable lithium-oxygen battery used in sunlight.

1.4 DISCUSSION AND CONCLUSION:

Topography of thin films ranges from very rough to atomically smooth and tailorability of various opto-electronic properties. GaAs, GaAlAs, GaInAsP, InAs, InSb, and InP are interesting solar cell materials. They have near-optimal band gaps and are extremely expensive. These materials have been only found applications in the space solar cells. So the performance of III-V Semiconductors is more important criterion than their costs. To some extent in concentrating systems where the active surface area of the cells can be reduced significantly, thus, expensive materials can be used. While energy conversion efficiencies exceeding 16% have been achieved with the photo electrochemical solar cells utilizing semiconductor photoelectrodes, instability by photocorrosion makes them have no practical importance. Thin-film solar cell modules are reaching the market in accelerating quantities, giving the opportunity for these potentially lower cost approaches to establish their credentials. Thin-film modules are finding application into MW-scale systems presently being installed in Germany and Spain. Potential future purchasers should soon have a much more extensive experience base with these technologies on which to draw. This may facilitate more widespread acceptance of thin-film technologies and stimulate the on-going investments required to reach production volumes and costs required to make global impact not only for thin-films, but for photovoltaics in general.

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