Challenges of Semi-Conductor Material Used For Thin Film Photovoltaic Cell: A Review

Nimisha Neog

Research scholar, Dept. of Physics

Dibrugarh University, Dibrugarh, Assam, India.

Abstract : Photovoltaic cells are slowly occupying the global market now a days as a form of renewable energy. For our future and sustainable energy development, solar cell has utmost importance. Various types of semiconductor materials are available which shows photovoltaic effect but very few have commercial interest. Different thin film technologies like Amorphous Silicone, CdTe technology, CIGS solar cell technologies are used for construction of photovoltaic cells. DSC, Organic PV, Quantum dots and Perovskite solar cells are next generation materials for thin film photovoltaic technology. Though the efficiencies of thin film solar cell is gradually increasing in last few years, there is still some challenges like insufficient efficiency, low stability, hazardous toxic materials forming during manufacturing, low availability, less cost effective. It will be certainly a major revolution for the current condition of the global energy demand, if these challenges can be overcome.

IndexTerms **– Challenges, Photo Voltaic cell, thin film.**

I. INTRODUCTION:

As global warming continues to threaten our environment photovoltaic cells are becoming more important as form of renewable energy. Most of the energy we use comes from fossil fuel like oil, gas and coal which are gradually running out. Again using these fuels causes air pollution and CO_2 the gas most responsible for global warming. The sun has enough fuel on board which we can use for 5 billion of years and solar panels can turn this energy into an endless convenient supply of electricity. Due to its various advantage solar cell has entered the market with 1.7% (2) of world electricity.

Some special materials are used for the construction of photovoltaic cell called semi –conductor. The most commonly used semiconductor materials for the construction of photovoltaic cells are Silicon. Several forms of Silicon are used for the construction; they are single crystalline, multi crystalline and amorphous. The best single crystal Si solar cells have efficiency of highest. For higher efficiency the purity of the material has utmost importance. The purity of Silicon at this state is from 99.99999% to 99.9999999%. So, the cost is highest for higher efficiency. On the other hand multi-crystalline silicon is normally less expensive to produce as well it has lesser efficiency. Amorphous silicon can absorb 40 times more solar radiation than single crystal silicon. But amorphous silicon has lower efficiency and light induced degradation (10). Another form of solar cells which have potential for low cost production has now entered the market for their advantage over traditional silicon photovoltaic cell (3) which is called "Thin Film Solar Cell".

II. CRITERIA OF SEMI-CONDUCTOR MATERIALS TO BE USED IN THIN FILM PHOTO VOLTAIC TECHNOLOGIES:

There are various types of semiconductor materials are available which shows photovoltaic effect, but very few of them are of commercial interest because they must follow constraints for minimizing thickness and wide availability (6).

a) Must have bandgap between 1 eV to 1.8 eV.
b) It must have higher optical absorption (~ 10^{-5}/cm).
c) It must have higher electrical conductivity.
d) It must be able to form a good electronic junction (homo/hetero/ schottky) with suitable materials.
e) The raw materials must be available in abundance and the cost of the material must be low.

For higher electricity production the absorber layer of solar cell must have high optical absorption co efficient which in turn the thickness of the absorber layer should be thin since the optical absorption co-efficient is inversely proportional to thickness (6).

Also thin film solar cells are favourable because of their minimum material usage and rising efficiencies. They have certain advantage compared to conventional silicon photovoltaic (18).

- Lower consumption of materials.
- Independence from shortages of silicon supplies.
- Fewer processing steps.
- Simplified materials handling.
- Process lends itself to automation.
- Integrated, monolithic circuit design; no assembly of individual solar cells into final products.

III. DIFFERENT THIN FILM TECHNOLOGIES THAT ARE COMMERCIALLY AVAILABLE ARE-

- Amorphous Silicon
- CdTe technologies
- Copper Indium Gallium Diselenide solar cell technologies

i. Amorphous Silicon:

Amorphous solar cells were first fabricated in 1976.The initial conversion efficiency was 2.7%. Since then, various progresses have been taken place to increase the efficiency. Now it has reached 14% in best lab cell. But amorphous Silicon is plagued with low efficiencies and light induced degradation, so it is almost extinct in terrestrial application [10], which can be seen in the Fig. 3.

ii. CdTe technologies:

CdTe is suitable material for photovoltaic cell as it has direct band gap of 1.45 eV, which is well within optimum range of 1 eV to 1.8 eV for maximum photovoltaic energy conversion. Because of high optical absorption co-efficient (~10^5/cm), only a few micrometers of CdTe is sufficient to absorb 90%of the incident light, thus minimizing the material cost. The best lab efficiency cell versus model is 18 and 21 % respectively as we can see from Fig. 1.

iii. Copper Indium Gallium Diselenide solar cell technologies:

Thin film of photovoltaic technology based on Copper Indium Gallium Diselenide is another option for thin film PV cell. CIS thin film has direct band gap of ~0.95 eV, when gallium is added to CIS the band gap increases to ~1.2 eV depending on the amount of gallium added to the CIGS film.CIS or CIGS modules are usually produced using co-evaporation or co-deposition technique. Copper, Indium, Selenide and sometimes Gallium are deposited on to the substrate at different temperature to mix together.

IV. MARKET OVERVIEW OF CURRENT THIN FILM TECHNOLOGIES AND ITS EFFICIENCIES:

As we know Si based solar cell (mono, poly crystalline silicon) were the first PV technology commercially available, still they occupy most of the market share that is more than 55% of the world installed capacity today[10].Another technology which are commercially available and main rival to that of crystalline Si ar CdTe,CIGS,a-Silicon and perovskite (new material) cells as they are cheaper; provide better mechanical properties, allowing for flexible usages at lower efficiencies risk [2].

First of all what is efficiency of a solar cell -it is simply the amount of electrical power coming out of a cell divided by the energy from sunlight coming in. The amount of electricity produced from PV cells depends on the quality (intensity and wave lengths) of the light available and multiple performance characteristics of the cell.

The efficiencies of best module and cell of each major technology are compared in the Fig.1

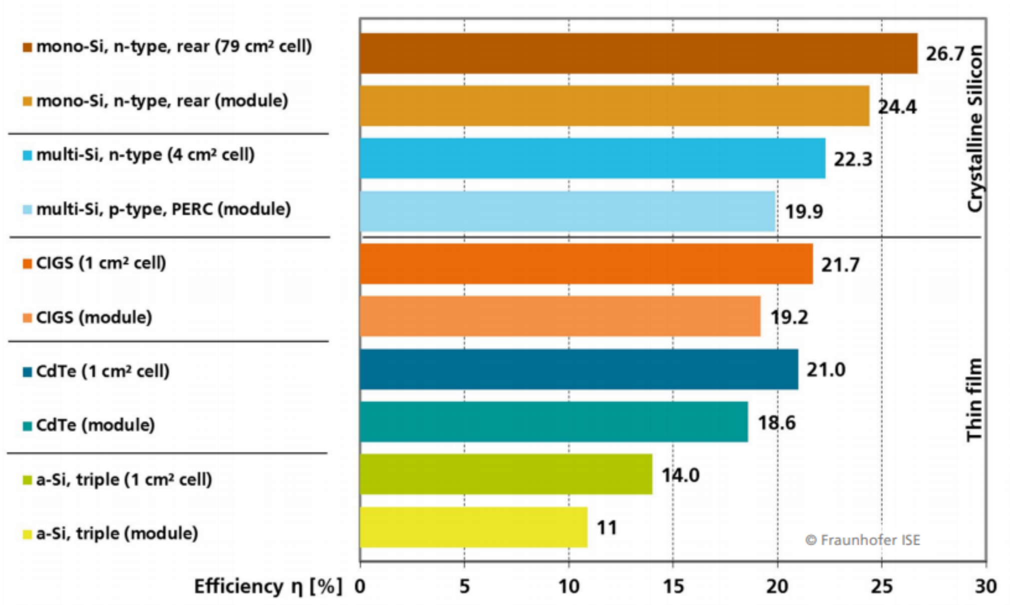

Fig.1 Efficiency comparison of technologies [8] (Source: Green et al: Solar cell efficiency tables (Version 51), Progress in PV; Research and applications 2018)

As there is a difference between cell efficiency and module efficiency that shows that how much could be gained by improving the transfer of laboratory prototypes into integrated system.

Crystalline silicon has the highest efficiencies of 26.7% for mono crystalline and 22.3% for multi crystalline. For thin film CIGS PV's it is 23.4% and for CdTe it is 21%.The new technology Perovskite have efficiencies of 20.9%.

The efficiencies of PV cells are increasing rapidly from last few years as we can see from the graph maintained by the National Renewable Energy Laboratories (Fig. 2).

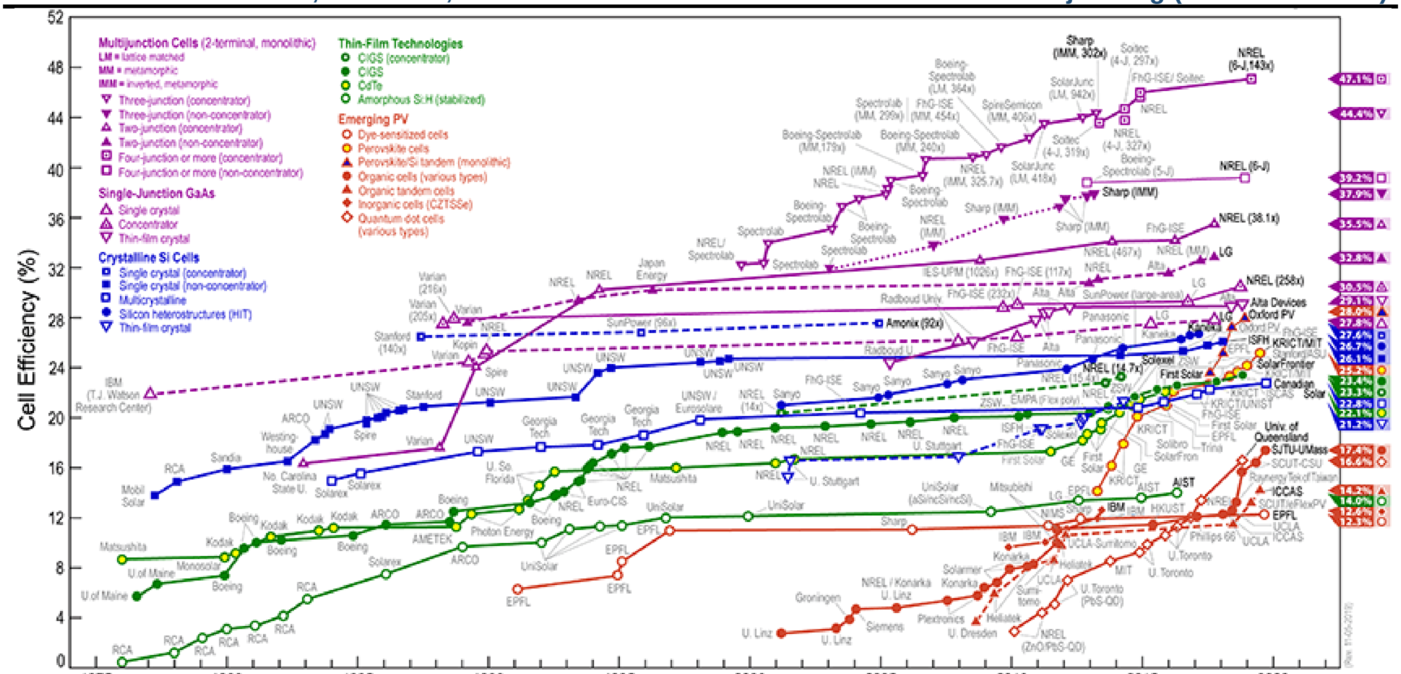

Fig.2 Best research cell efficiencies [13] (Source: NREL http://www.nrel.gov/ncpv/)

Thin film market share over the years are shown in Fig.3 which shows percentage of total global PV production from year 2000 to 2017.

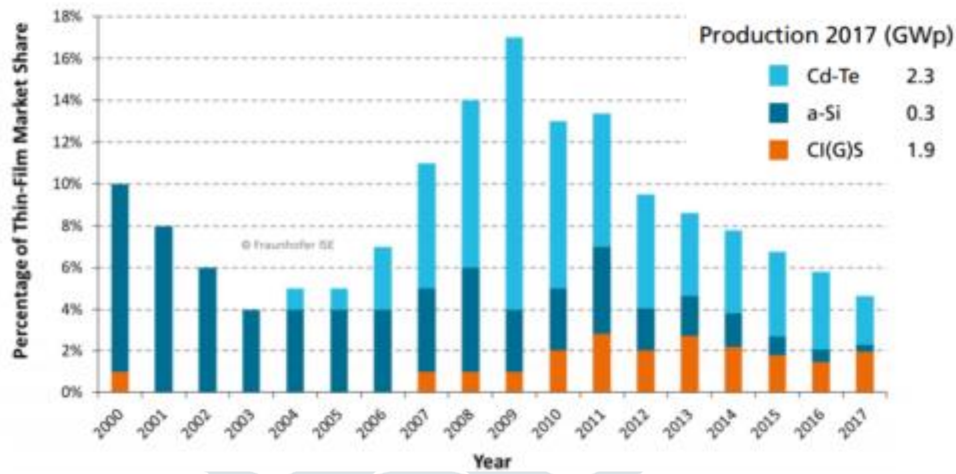

Fig.3: Market share of different thin film technologies [7] (Source: Fraunhofer institute of solar energy system, Data from 2000-2010 Navigant, from 2011: HIS, Graph: PSE GmbH 2018)

V. NEXT GENERATION MATERIALS FOR THIN FILM PV TECHNOLOGY:

There is continuous search for new material to increase the efficiency and to lower the cost. Average efficiencies still lie before 30% .If solar power is to take off in coming century, serious improvement in their efficiency need to be realized. Some of the recent research which hold good efficiencies then present thin film solar cell and some of them has various advantage, these are called next generation solar cell.

Some of the next generation solar cells are –

- **Dye sensitizer (DSC):** Dye sensitizer solar cell is regarded as one of the most promising PV devices, and has high theoretical efficiencies [2], low cost, semi flexible, semi-transparent and it is simple to make by conventional roll printing technique. In recent years continuous effort have contributed to the significant advances in DSC performance [12]. DSC devices employing a Zinc porphyrin based co-sensitized system have shown an efficiency record of 13% using liquid electrolytes, which may limit their outdoor applications [11].
- **Organic PV:** Another popular topic in individual research is organic PV, which shows some interesting opto-electronic properties along with mechanical and processing properties of polymer/ plastic material [14]. Significant effort has been devoted to increase the power conversion efficiency from <3% [14)] to current 13%. Highest efficiency for single junction cell [19] while it is still less efficient than other cell technologies. The organic solar cells are the only photovoltaic device that uses molecules to absorb photons and convert them to electric charges without the need of inter molecular transport as electronic excitation. It is also the only sure solar cells that separate the two functions of light harvesting and charge carrier transport, whereas conventional photovoltaic devices perform both operations simultaneously.

- **Quantum dots:** Quantum dots are semi- conductor nano-particles, which show unique optoelectronic properties due to quantum confinement effect different from those of bulk materials such as size dependent emission and optical absorption bands [15, 1].These properties of quantum dots attract attention of many fields. Colloidal quantum dots can be dispersed in a solution and are useful active materials for LED [4], solar cell [9], biosensor and biomask[3]. In last few decade QDSC have attracted significant interst because of their perceived benefit over some alternatives. Solar cells in terms of high light, thermal and moisture stability, tunable absorption range,high absorption co-efficient, multiple exciton generation possibility; solution processibility as well as their facile fabrication and low cost availability. Quantum dot solar cells have the potential to produce high efficiencies with a relatively cheap cost to construct them [5].
- **Perovskite solar cells:** Perovskite solar cells have grab attention recently due to its low cutting cost and high power conversion efficiency (PCE), which have reached more than 22% in laboratory scale devices within very short period of time [17]. However, the main challenges for thin film technologies, including perovskite solar cells, are their stability and toxicity involved in the manufacturing process. As all higher perovskite solar cells have lead as key constituent to tackle that scientists have been working on developing lead free perovskite solar cells. Also, the poor reproducibility in device fabrication and lack of uniformity of the PSC performance is a major challenge in obtaining highly efficient large scale PSC device [17].

Following Fig. 4 is showing the efficiencies improvement of Perovskite solar cells compared to other solar cell technologies.

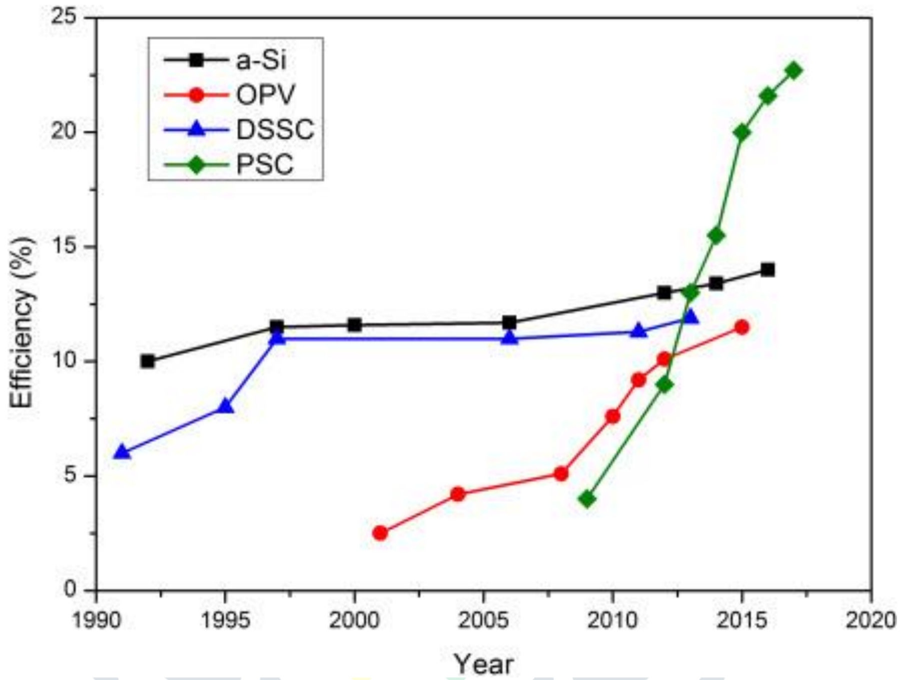

Fig 4: Comparing the rate of increase in perovskite solar cell efficiencies with the other thin-film PV technologies [16].

VI. Challenges:

Though the efficiencies of thin film solar cell is gradually increasing in last few years, there is still some challenges before photovoltaic technology become significant fraction of the overall energy production:-

- Efficiencies are still not sufficient for current energy demand of the market. Also, still significantly below those obtained from thermodynamics.
- Stability of the thin film solar cell is low as well as lifetime is short as compared to crystalline silicon solar cell.
- Thin film solar cell manufacturing process involves toxic materials which are hazardous for health.
- Low availability of some element in the present commercially available PV technologies.
- Thin film PV cell should be cost effective.

VII. Conclusion:

Thin film solar cells are ultimate solution for current demand of global energy. For thin film solar cells the materials should have some criteria such as band gap, higher optical absorption, higher electrical conductivity, ability to form good electric junction and low cost. Despite the increasing efficiencies thin film solar cell, there are still some challenges before photovoltaic technology. If these above challenges we can overcome then it will surely be major breakthrough for the current situation of the global energy demand.

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