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A Review: Comparative studies on different generation solar cells technology

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Abstract

In recent years solar cell technology has achieved tremendous growth as sustainable source of energy. The timeline of solar cells begins in the 19th century when it is observed that the presence of sunlight is capable of generating usable electrical energy. Solar cells have gone on to be used in many applications. They have historically been used in situations where electrical power from the grid is unavailable. For the developments of renewable energy technology invention of solar cell played an important role. Solar cells give us the easier way to utilize the enormous source of renewable energy. From the beginning of solar cell history its reliability, durability and price is a highly considering issue. In these studies, we showed a statistical comparison among the solar cell generation of different era. The comparative study is done by the material used in different generation solar cell, shape of the cell, durability, reliability and price variation of different era.

INTRODUCTION

The Earth receives an incredible supply of solar energy. The sun, an average star, is a fusion reactor that has been burning over 4 billion years. It provides enough energy in one minute to supply the world's energy needs for one year. In one day, it provides more energy than our current population would consume in 27 years. In fact, "The amount of solar radiation striking the earth over a three-day period is equivalent to the energy stored in all fossil energy sources." Capitalize from this huge amount solar energy people were struggling since 18th century by introducing the solar thermal collector. The first ever solar thermal collector was invented by A Swiss scientist, Horace de Saussure. [1]

Producing the electricity directly from the solar energy was the second discovery. This technology was discovered by Alexander Edmond Becquerel, who was a French physicist at the year of 1839. This was the beginning of the solar cell technology. [2]

Solar cells are usually divided into three main categories called generations up to recent years. The first generation contains solar cells that are relatively expensive to produce, and have a low efficiency. The second generation contains types of solar cells that have an even lower efficiency, but are much cheaper to produce, such that the cost per watt is lower than in first generation cells. The term third generation is used about cells that are very efficient. Most technologies in this generation are not yet commercial, but there is a lot of research going on in this area. The goal is to make third generation solar cells cheap to produce.

DIFFERENT GENERATIONS OF SOLAR SELLS

Generally 1st generation's solar cells include a. Single Crystal Solar Cells b. Multi Crystal Solar Cells. This are the oldest and the mostly common used technology type due to high efficiencies. 1st generation solar cells are produced on wafers. Each wafer can supply 2-3 watt power. To increase power, solar modules, which consist of many cells, are used. As seen in the list, generally there are two types of first generation solar cells. They differ by their crystallization levels. If the whole wafer is only one crystal, it is called single crystal solar cell. If wafer consist of crystal grains, it is called multicrystal solar cell. Anyone can see the boundaries between grains on the solar cell. Although efficiency of mono crystal solar cells is higher than multicrystal solar cells, production of multicrystal wafer is easier and cheaper. So they are competitive with monocrystals. 2nd generations solar cells focused on a. a-Si thin film solar cells b. mc-Si solar cells c. CdTe solar cells d. CIS and CIGS solar cells.

Their efficiencies are less than 1st generation, their costs are also less than 1st generation. In addition they have an advantage in visual aesthetic. Since there are no fingers in front of the thin film solar cells for metallization, they are much more applicable on windows, cars, building integrations etc. These thin films can also be grown on flexible substrates. As an advantage of thin film solar cells, they can be growth on large areas up to 6 m^2. However wafer based solar cell can be only produced on wafer dimensions. The second generation solar cells include amorphous Si (a-Si) based thin films solar cells, Cadmium Telluride/Cadmium Sulfide (CdTe/CdS) solar cells and Copper Indium Gallium Selenide (CIGS) solar cells.

3rd Generation solar cells considers a. Nanocrystal based solar cells b. Polymer based solar cells c. Dye sensitized solar cells d. concentrated solar cells.

These are the novel technologies which are promising but not commercially proven yet. Most developed 3rd generation solar cell types are dye sensitized and concentrated solar cell. Dye sensitized solar cells (DSSC) are based on dye molecules between electrodes. Electron hole pairs occur in dye molecules and transported through TiO_2 nanoparticles. Although their efficiency is very low, their cost is also very low. Their production is easy with respect to other technologies. Dye sensitized solar cells can have variable colors. Concentrated PV solar cell is another promising technology. Main principle of concentrated cells is to concentrate large amount of solar radiation on to a small region where the PV cell is located. The amount of semiconductor material, which might be very expensive, is reduced in this way. In this system a perfect optical system should be integrated. Concentration levels starts from 10 sun to thousands suns. So, total cost can be lower than conventional systems. CPVs are promising technologies for near future.

EFFICIENCY, PRICE, ENVIRONMENTAL IMPACT, DIFFERENT GENERATION SOLAR CELL

Efficiency- 1st generation solar cells lab based efficiency was 24.7% and module based 22.7%. 2nd generation solar cells lab based efficiency 18.4% and module based 13.4%. 3rd generation solar cells has very high efficiency >30% [4].

Table 1. Best efficiencies reported for different types of solar cells. [5]

Solar cell type	Efficiency	Laboratory/Institution
Crystalline Si	24.7	University of New south Wales
Multi Crystalline Si	20.3	Fraunhofer institute of solar energy system
Amorphous Si	10.1	Kaneka
HIT cell	23	Sanyo Corporation
GaAs cell	26.1	Radboud University Nijmegen
InP Cell	21.9	Spire Corporation
Multi junction cell	40.8	National Renewable Energy Laboratory
CdTe	16.5	National Renewable Energy Laboratory
CIGS	19.9	National Renewable Energy Laboratory
$CuInS_2$	12.5	Hahn Meitner Institute
DSSC	11.1	Sharp
Organic solar cell	6.1	Gwangju Institute of Science and Technology

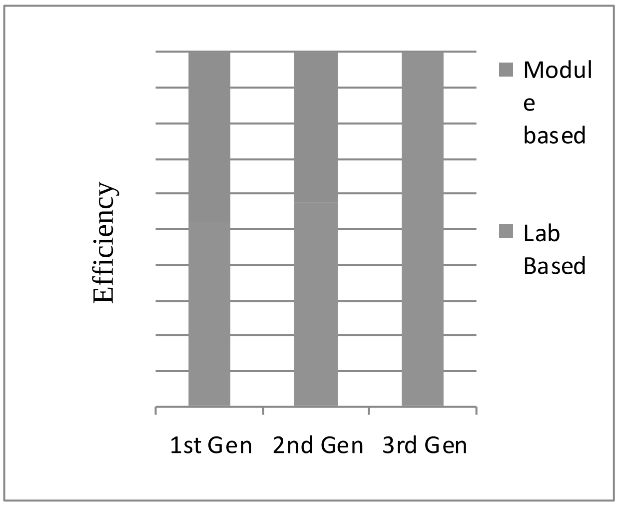

Fig. 1. Efficiency variation among the solar cell generation.

Price- There is three generation of solar cells. On a diagram which measures efficiency as a function of cost one can clearly see where those 3 generations are situated. [6]

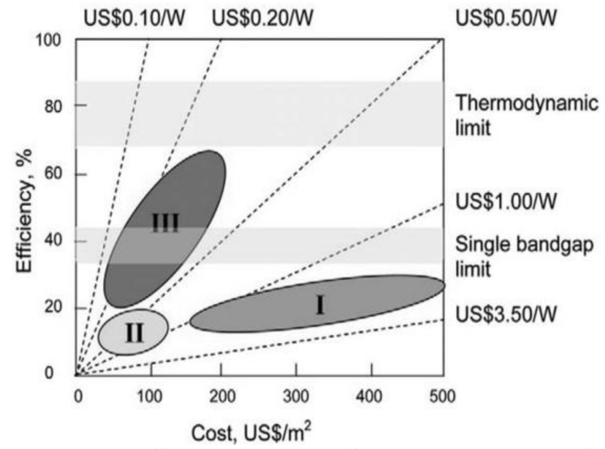

Fig. 2. Price Vs Efficiency among the different generation's solar cells.

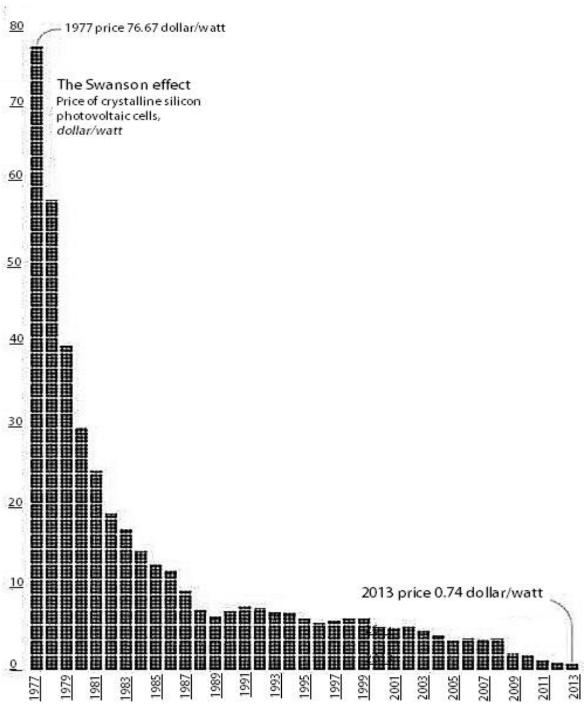

Fig. 3. Price variation of solar power generation from the year of 1970s to 2013. (Source: http://cleantechnica.com/2014/04/05/future-solar-solar-power-surge-2014/)

From the Fig. 1, this is clearly illustrated, 2nd generation solar cells per watt peak price is lower as well as efficiency with respect to other generation technology. It is also shown, 3rd generation solar cell technology has more efficiency as well as low price than the 1st generation solar cells. Between 1977 and 2013, the overall cost associated with solar power dropped an amazing 99%.

Environmental Impact- Solar cell technology played always an ideal role in the case of green energy / sustainable energy developments. So no can imagine production of solar cell can pollute our environment as well as disposal of this solar cell might be hazardous for our environment. Recent day's rapid growths of solar cell manufacturing industry are the responsible for this pollution increment. Some toxic chemicals, like cadmium and arsenic, are used in the PV production process. [7]

Environmental engineer Vasilis Fthenakis, a senior scientist at Brookhaven National Laboratory in Upton, N.Y., and his colleagues examined the four most common types of PV cells: multicrystalline silicon, monocrystalline silicon, ribbon silicon and thin-film. (Other contenders, such as amorphous silicon or superefficient multijunction cells were excluded for lack of data or lack of widespread application to date.) Even taking into account the low efficiency of thin-film solar cells or the energy needed to purify silicon for the other types of PV, all proved to entail significantly fewer emissions in their entire life cycle than the fossil fuels needed to produce an equivalent amount of electricity. In fact, most of their dirty side derived from the indirect emissions of the coal-burning power plants or other fossil fuels used to generate the electricity for PV manufacturing facilities. And even the most energy-intensive to produce—monocrystalline silicate cells with the highest energy conversion efficiency of 14 percent—emit just 55 grams (1.9 ounces) of globe warming pollution per kilowatt-hour—a fraction of the near one kilogram (2.2 pounds) of greenhouse gases emitted by a coal-fired power plant per kilowatt-hour. Even though thin-film solar PVs employ heavy metals such as cadmium recovered from mining slimes, the overall toxic emissions are "90 to 300 times lower than those from coal power plants," the researchers write in Environmental Science & Technology. The energy benefits of solar photovoltaics will only improve as the technology continues to boost its efficiency at converting sunlight to electricity or proves to last longer than the 30 years anticipated by manufacturers. "There is no reason for this not to last a lot more than 30 years," Fthenakis says. If solar energy begins to power its own production—a so-called PV breeder cycle, in which PV-generated electricity goes to produce more PV cells—the outlook is even sunnier. "I think 30 percent of the energy consumption in the [manufacturing] facilities is easily met from the land they have available [on] the roof and in the parking lot," Fthenakis says. [8]

LIMITATIONS OF DIFFERENT GENERATION'S SOLAR CELLS

For renewable energies, like solar energy, to compete with fossil fuels, there are two challenges to be met:

a. increase efficiencies
b. reduce production costs

Generally 1st generations solar cell based on Silicon (Si) solar cell. Though this technology has high conversion efficiency but the availability of Silicon is intricate because of its high cost. Also the fabrication process of the silicon based solar cell is complex. Several issues affect the efficiency of solar cells:

- The energy of the photons hitting the solar cell is less than the band gap, so the light cannot be converted into electricity and is lost.
- The energy of the incoming photons is greater than the band gap, so the excess energy is lost as heat.
- The Fermi levels of both n-type and p-type silicon are always inside the band gap of silicon so the open-circuit voltage is smaller than the band gap. [9]

2nd generation solar cells based on thin film solar cells. Some advantages are illustrated below.

- It has high absorption co-efficient
- It can occupy both vacuum and non-vacuum process.
- Lower cost in comparison of Si based solar cell.
- Low cost substrate (Cu tape)[4]

Disadvantages are:

- Environment Contamination starts from fabrication process.
- Materials are hard to find.

Advantages of 3rd generation solar cells are (polymer):

- Raw materials are easy to find
- Easier fabrication process rather than other two technology
- Cost is minimal

Disadvantages of 3rd generation solar cells (organic):

- Liquid electrolyte (low temperature)

High cost, Ru (dye) and Pt (electrode)

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