Superiority of CIGS solar Cells over single Crystal Solar Cells

Mukul Kishore

Dept. of Physics, Hindu College,Moradabad-
244001 (U.P.)

Abstract:- Photovoltaic is now a billion dollar industry. The growth of the solar power industry in the last 15 years is amazing and can not be ignored. Solar technology is not just growing; it is becoming more competitive in terms of price also. Solar panel prices have fallen considerably in last few years and another 50% price drop would make solar more competitive with oil and gas. Silicon was the main raw material in 90% of solar PV cells till 2005. But this share has reduced to 60% due to the shortage of high quality silicon. This shortage of silicon has done a number of things. It has shown the growth of Solar technology and increase in the price of silicon solar cells. It has also led the solar industry to invest in solar research, primarily focused on thin-films. In this paper we discuss about copper-indium-gallim-diselenide (CIGS) thin film solar cells as an alternate of silicon solar cells.

Introduction: The supply and demand of energy determine the course of global development in every sphere of human activity. Sufficient supplies of clean energy are intimately linked with global stability, economic prosperity and quality of life. Finding energy sources to satisfy the world's growing demand is one of the foremost challenges for the next half-century. The importance of this pervasive problem and the perplexing technical difficulty of solving it require a concerted national effort marshalling our most advanced scientific and technological capabilities. Now a question arises-why

photovoltatics? In fact it is not a difficult question to answer. The Sun is the champion of energy sources. It delivers more energy to Earth in an hour than we use in a year from fossil, nuclear, and all other renewable sources combined. Its energy supply is inexhaustible in human terms, and its use is harmless to our environment and climate. Despite the Sun's immense capacity, we derive less than 0.1% of our primary energy from sunlight. Initially, fossil fuel was apparently without end, and the Earth's environment also appeared resilient.

But later the situation changed. The photovoltaic (PV) industry was based on the various applications of powering satellites in remote locations. However, the tide has changed dramatically with the growing recognition of the environmental impact of non-renewable energy sources and the economic volatility that came from the dependence upon oil. The current PV market consists of a range of technologies including wafer based silicon and a variety of thin film technologies. Three "generations" of photovoltaics have been envisaged that will take solar power into the mainstream. The range of current technologies and possible future options have been grouped from the first generation to the third generation technologies by Green Martin[2].

Crystalline Silicon Solar Cells: Current PV production is dominated by single junction solar cells based on crystalline silicon including single crystal (c-Si) and multi crystalline silicon (mc-Si). This type of single junction, silicon devices are now commonly referred to a the First Generation (1G) technology, the majority of which is based on screen printing based device similar to that shown in Figure-1

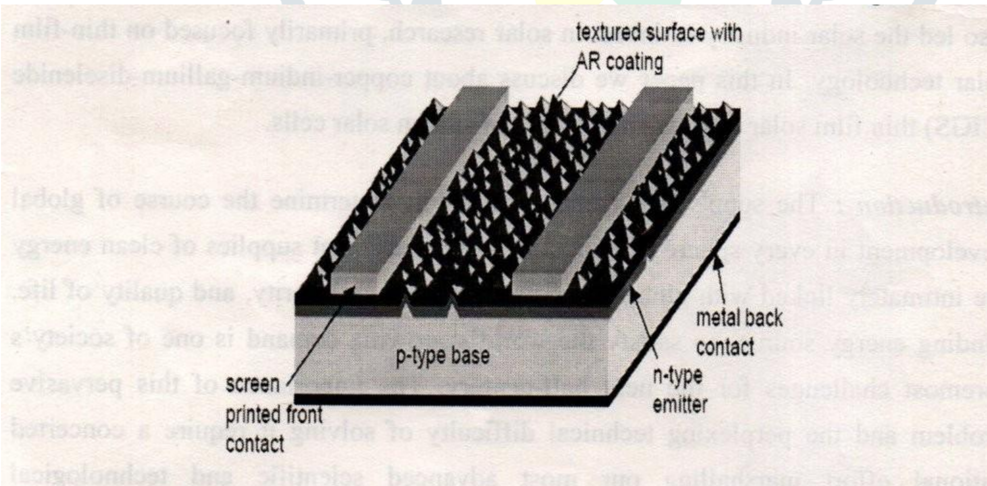


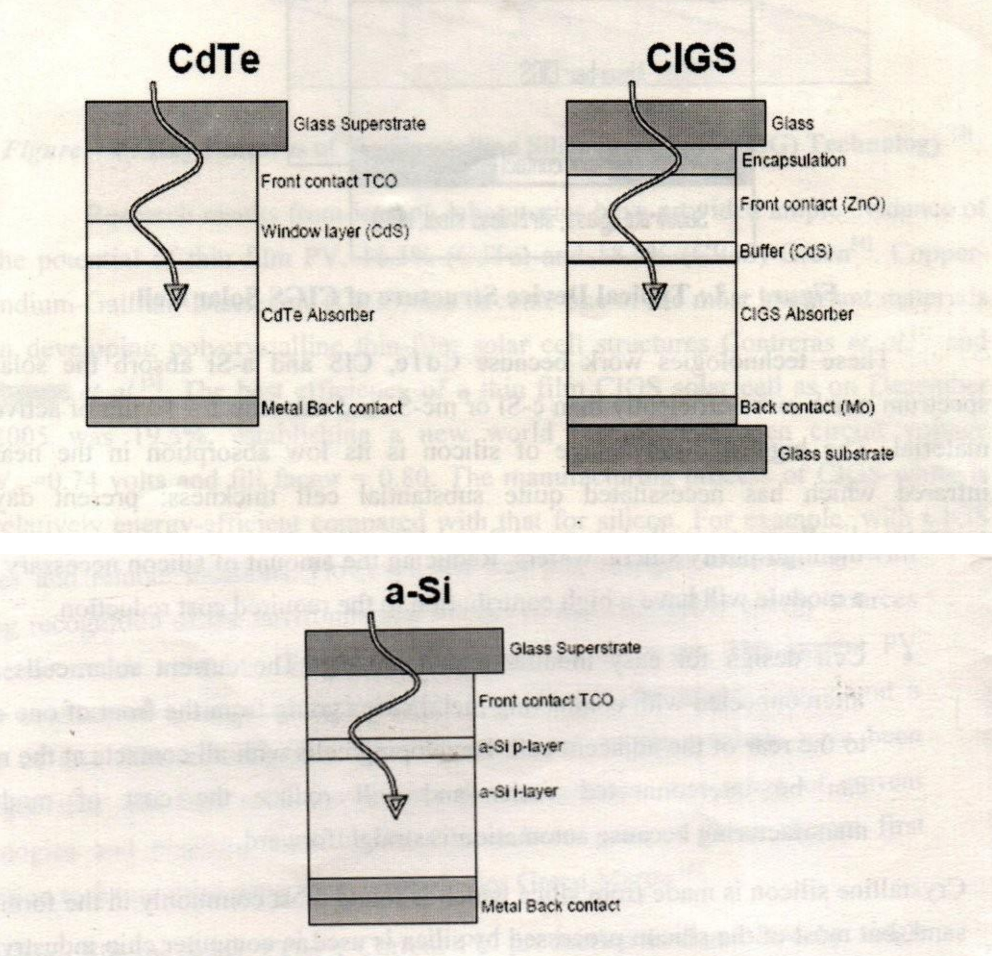
Figure – 1 : **Schematic of a Typical Screen-Printed Single-Crystal Solar Cell**

The band gap of crystalline silicon is 1.1. Historically, crystalline silicon (C-Si) has been used as the light absorbing semiconductor in most solar cells, even though it is a relatively poor absorber of light and requires a considerable thickness (several hundred microns) of material. Nevertheless, it has proved convenient because it yields stable solar cells with good efficiencies (11-16%, half to two thirds of the theoretical maximum), The manufacturing costs of a crystalline silicon PV module are about 2 Euro/Wp. For large scale introduction of solar electricity generation, it is needed to reduce these cost to 1Euro/Wp, and on the long term even to below 0.5 Euro/Wp. The solar cell process can contribute to the cost reduction by:

- Developing processes that can be applied on much thinner substrates, called wafers. About 50% of the current costs of a PV module can be assigned to the high purity silicon wafers. Reducing the amount of silicon necessary for module will have a high contribution to the required cost reduction.
- Cell design for easy module manufacturing: The current solar cells are interconnected with conducting metal strips going from the front of one cell to the rear of the adjacent cell. Developing cells with all contacts at the rear can be interconnected easier and will reduce the cost of module manufacturing because automation is straightforward.

Crystalline silicon is made from silica which is found most commonly in the form of sand, but most of the silicon processed by silica is used in computer chip industry as chip requires high grade silicon. Consequently the rejected silicon from the computer chip industry can be utilized in solar cells. The shortage of silicon has slowed down the growth of solar industry by raising the price of silicon solar cells. It has also led the solar industry to invest in solar research, primarily focused on low cost thin-film solar technology i.e. Second Generation (2G) technology.

CIGS Solar Cells: The obvious next step in the evolution of Pv with reduced cost is to remove the unnecessary material from the cost equation by using thin-film devices. Second Generation (2G) technologies are single junction devices that aim to use less material whilst maintaining the efficiencies of 1G PV. (2G) solar cells use amporphous-Si (a-Si), Copper-Indium-Gallium- Diselenide(CIGS),Cadmium Telluride (CdTe) or polycrystalline-Si (p- Si) deposited on low-cost substrates such as glass (Figure-2).



CdTe, CIGS and a-Si Thin Film PV Devices

***Figure – 2 :* Schematic Diagrams of Thin Film**

A typical device structure of CIGS solar cell is shown in figure -3 CIGS solar cells are almost designed in the substrate configuration from soda-lime glass, stainless steel or polymer material. The back contact is typically sputtered Mo and forms a non-blocking contact with CIGS.

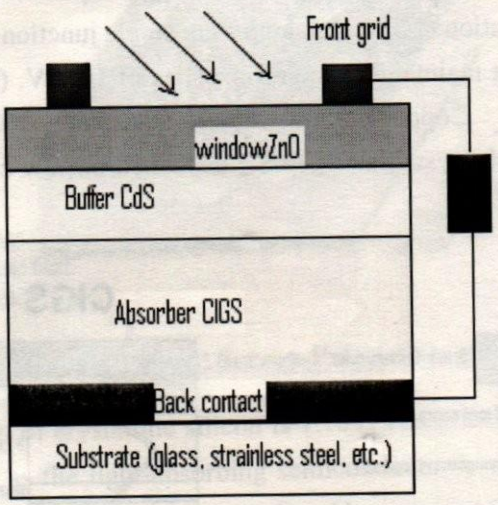


***Figure – 3 :* Typical Device Structure of CIGS Solar Cell**

These technologies work because CdTe, CIS and a-Si absorb the solar spectrum much more efficiently than c-Si or mc-Si and use only 1-10 µm of active material. The biggest disadvantage of silicon is its low absorption in the near infrared which has necessitated quite substantial cell thickness: present day commercial cells are typically between 1/3 and 1/2 millimeter.

This leads to large demand of very high quality semiconductor material. Meanwhile a very promising work has been done in light trapping in the yester years Green et al [3] and Andreani et.al. [6] Light trapping involves the increase of the optical path length of the light inside the solar cell. Results show that optical structures designed to improve the absorption of the near-infrared can lead to a significant reduction of the amount of high quality material, and ultimately to a corresponding reduction of the cost of solar cells. By light-trapping, applied to a cell of 5 micrometer thickness leads to the same absorption as a 100 micrometer cell without light trapping. Figure -4 shows very efficient light trapping achieved by strongly

excited right-moving diffracted wave couples only weakly to the zero-order outgoing wave.

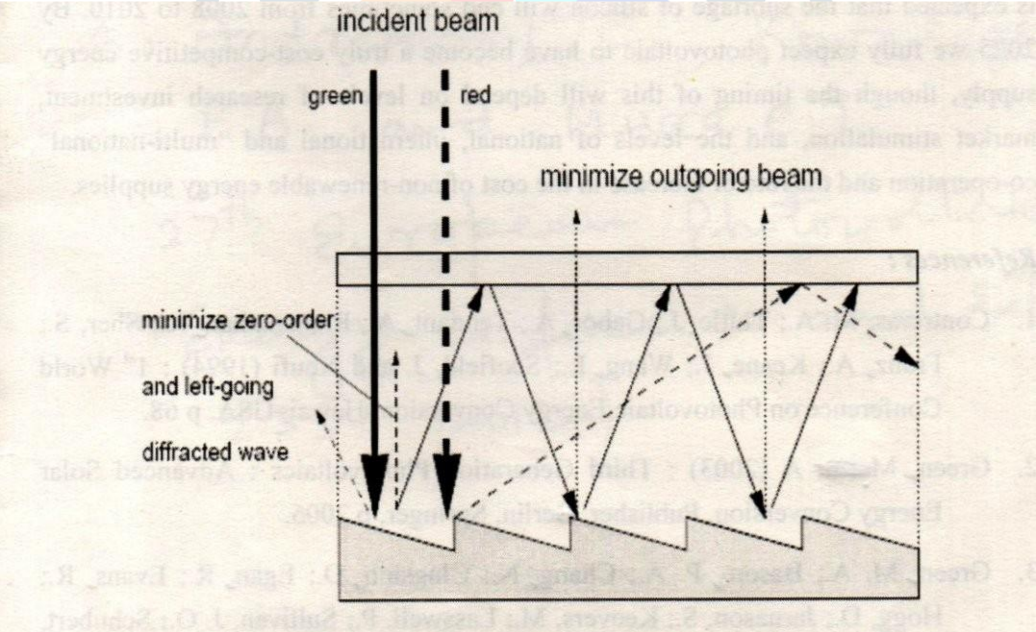


***Figure – 4 :* Key Features of the Crystalline Silicon on Glass (CSG) Technology [3]**

Research results from leading laboratories have provided ample evidence of the potential of thin film PV, 16.5% (CdTe) and 18.4% (CIGS) Green [4]. Copper Indium-Gallium-Diselenide (CIGS) has become one of the most important materials in developing polycrystalline thin-film solar cell structures, Contreras et al.[1] and Karang et al. [5]. The best efficiency of a thin film CIGS solar cell as on

June 2015 was 23.4% establishing a new world record [7]. The manufacturing process of CIGS is relatively energy efficient compared to that of silicon. For example, with CIGS there is no need to melt, cast and finally slice the semiconductor into thin wafers, as is done with some forms of silicon. Also, CIGS manufacturing processes have advanced to the point where the material is now routinely produced semi-continuously as a “coating” on long strips of suitable substrates. As a result, the cost of CIGS module has steadily decreased and is now reportedly lower than polycrystalline silicon, the most common solar cell semiconductor.

Conclusion:- Results show that optical structure improves the peformance of silicon solar cells near infrared region. It reduces the requirement of high quality material and ultimately reduces the cost. But still CIGS solar cells look more competitive than silicon solar cells due to the shortage of high quality silicon. But is is expected that the shortage of silicon will end in the coming years. By 2025 we fully expect photovoltaic to have become a truly cost competitive energy supply, though the timing of this will depend on the levels of research investment, market stimulation, and the cooperation at national, international and multinational levels and also the rate of increase in the cost of non renewable energy supplies.

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