4G Solar Photo-Voltaic Cells

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Abstract:

The solar power is one of the cleanest sources of power that is present on the earth to fight with the present global warming problem due to ever increasing use of fossil fuel which are producing green house gases. A significant amount of research and development work on the solar photovoltaic technology has been done since the 1970s. Many innovative systems and products have been put forward and their quality evaluated by academics and professionals. The recent boom in the demand for photovoltaic modules has created a silicon supply shortage, providing an opportunity for thin-film and other low cost new photovoltaic modules. The most popular solar materials in use today are silicon and thin films made of CdTe (cadmium telluride) and CIGS (copper indium gallium selenide). Thin-films have the potential to revolutionise the present cost structure of photovoltaic by eliminating the use of the expensive silicon wafers that alone account for above 50% of total module manufacturing cost. This article gives a review of the trend of development of the cell technology, in particular the advancements in recent years and the future work required.

1. Introduction:

After the Industrial Revolution of the 18th and 19th centuries, it was cleared that the availability and ease of production of energy has impacted the world economy and welfare hugely. If we analyse the Water-Food-Energy trio in the pre-industrialization era we can easily conclude that the availability and production of energy was not as essential as the conservation of food and water back then. Contrarily, in the present day scenario, if Water and Food were placed on one side of a coin, then the obvious other side would be Energy availability and production coupled with financial security and a 'better than yesterday' standard of living and hence, today, the overall growth of a nation is vastly dependent on the amount of energy resources it has. As all the day-to-day activities such as irrigation for agriculture, food processing and cooking, and transportation and like are constantly being pushed towards technological advancement, they are also becoming more and more energy intensive simultaneously. This exponentially increasing demand for energy has led to a plethora of environmental problems which are in turn affecting the social and economical conditions either directly or indirectly. The direct impact created due to an upsurge in the energy demand is firstly on theenvironment because it is the fossil fuels that are being tapped to meet the demand. Unfortunately, the rate of consumption is very huge in comparison to the rate of replenishment of these fossil fuels. Moreover, uncontrolled and irresponsible use of these fossil fuels releases harmful contaminants such as ash and various flue gases which prove to be adverse for various biomes, apart from being the cause for

Global Warming. Hence, as the guardians of Mother Earth, the human civilization must strive for the use of eco-friendly and economically sustainable technologies in the field of Energy Security for the nations and the globe as a whole. The need of looking up to the cleaner non-conventional or renewable energy sources such as solar, wind, geo-thermal and tidal energy has been the top most priority for the scientific community now, for the past 50 years because of the rapid burgeoning of the human population and the simultaneous shrinking of the fossil fuel reserves. Of all the non-conventional energy sources, Solar Energy coming from the Sun which is the very primary contributor for all the natural phenomena occurring on Earth is found to be promising for the energy security needed in contrast to other mentioned sources which indirectly depend upon solar energy itself.

The energy from the Sun has been very prominent for the emergence of life on Earth and also responsible for all the changes that occurred in the Earth's biotic and abiotic components. The Solar Energy has been in use since the dawn of civilization when ancient communities used it directly to dry grain bulk and indirectly in the form of wind power captured by the boat's sails to travel the seas. Plants, the building blocks of life on Earth, totally thrive upon the energy derived from the Sun through Photosynthesis. The season and weather cycle is also totally dependent upon the energy from the Sun. In present times, the Solar Energy is being successfully used for large scale industrial applications such as bulk cooking of food through Concentrating Solar Cookers and small scale applications like domestic space conditioning and water heating. The uses of Solar Energy mentioned above are dictated by processes which are heat centric but not work centric, owing to the technological limitations present in them. As the total Solar potential of the world is accounting to more than 100 GW (Gigawatts), one promising source of work centric output via Solar Energy is the Photovoltaic (PV) Technology. This technology involves the light from the sun causing the electrons in a layered-composite material to flow, thereby producing an electric current.

2. Photovoltaic effect:

The Photovoltaic effect involves the generation of electric current in a material upon its exposure to light. This effect can be termed to be physical and chemical property/phenomenon of/in the material.

The Photovoltaic effect is similar to the Photoelectric effect in which the electrons get excited and start to move due to the impinged light and produce electric current. The only difference between the two is that in the former, the excited electrons stay inside the material's lattice whereas in the latter, the excited electrons are ejected out of the material into vacuum. Another difference apart from this is that the former separates the electrons by diffusion whereas the latter separates them by ballistic conduction.

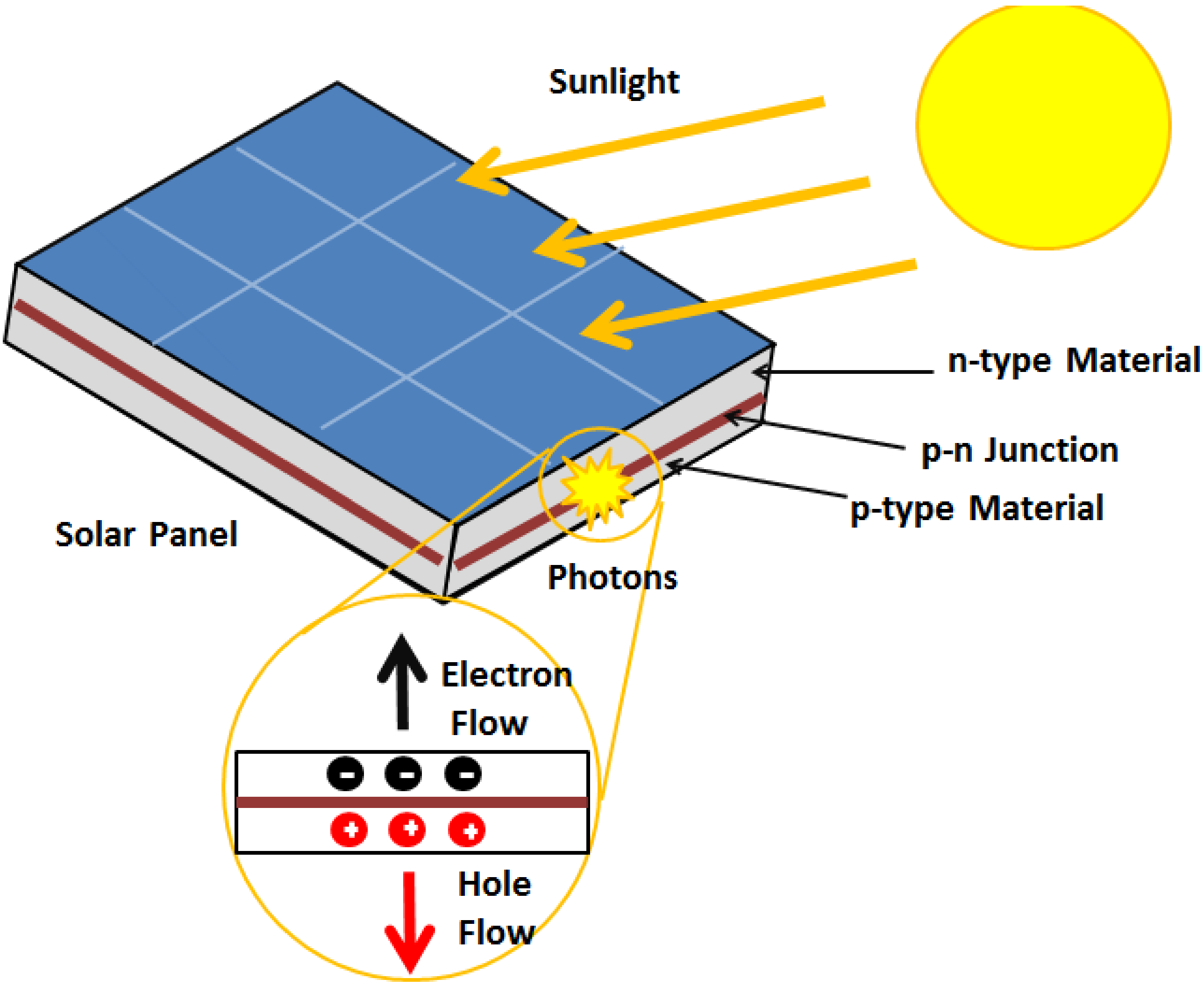

Fig.1.: Photovoltaic effect due to Sunlight

The Photovoltaic effect was first observed by a French physicist, Alexandre-Edmond Becquerel in the year 1839. Later on, the photodiodes have been developed as a means to produce electricity as they are illuminated by the light from any external source. A diode is a two terminal semi-conductor device that allows flow of current, as a result of excitation of electrons in one direction and restricts it in the other. The most common semi-conductor diodes available nowadays are the p-n junction diodes connected to two external terminals. The p-type semi-conductors have a deficiency of electrons, called as holes and the n-type semi-conductors have an abundance of electrons, owing to the extrinsic impurities added to the natural semi-conductors such as Silicon (Si) and Germanium (Ge).This difference in the concentration of charge carriers between the two semi-conductors makes them to travel from 'n' side to 'p' side through the p-n interface, thereby producing electricity in the opposite direction. In the case of a photodiode, the excitation of electrons is due to the illumination of the diode by the light from Sun as shown in fig.1. These photodiodes are normally referred to as Solar-Cells nowadays. The Solar-Cells help in the direct conversion of solar energy into electricity.

2.1.Advancement of Solar-Cells:

With the advancement in the technology and simultaneous increase in the demand for efficient generation of electricity through the Solar-Cells, newer designs have evolved in the course of time with their own advantages and limitations. Four generations of the Solar-Cells, have been classified on the basis of their advantages and shortcomingswith respect to ease of manufacturing, deployment, lifetime, conversion efficiency and versatility. The description of the 1G, 2G and 3G Solar Photovoltaic systems is not contextual to this article and can be referred for in the citations mentioned at the end.

3. Technological Development

3.1.Reflective dishes: The demand of solar energy has increased the demand for silicon, this has made researchers think of alternatives to silicon. A team of researchers at Israel's Ben Gurion University has found what they are calling a better alternative to silicon. The team has used gallium arsenide instead of silicon in their solar cells, which becomes more efficient when used with reflective dishes. This makes the system expensive than silicon solar panels, but the cost per watt is made comparable to that of a conventional power plant. The team has designed a reflector made of mirrors that collects and intensifies the light a thousand times over. A solar energy system built on 4.6 square miles in the Negev would produce 1,000 megawatts of electricity.

3.2.Spherical Solar Cells: Spherical Silicon Solar Arrays is the brainchild of Japan's Clean Venture 21 and is up to five times cheaper and uses up to five times less material and consumes half the energy to reproduce. With good optical properties these 1mm silicon cells are put into little reactors, measuring 2.2 to 2.7 mm in width. Since the cells are spherical and not rectangular, the sunlight is absorbed from all possible angles for generating power with better efficiency and flexibility.

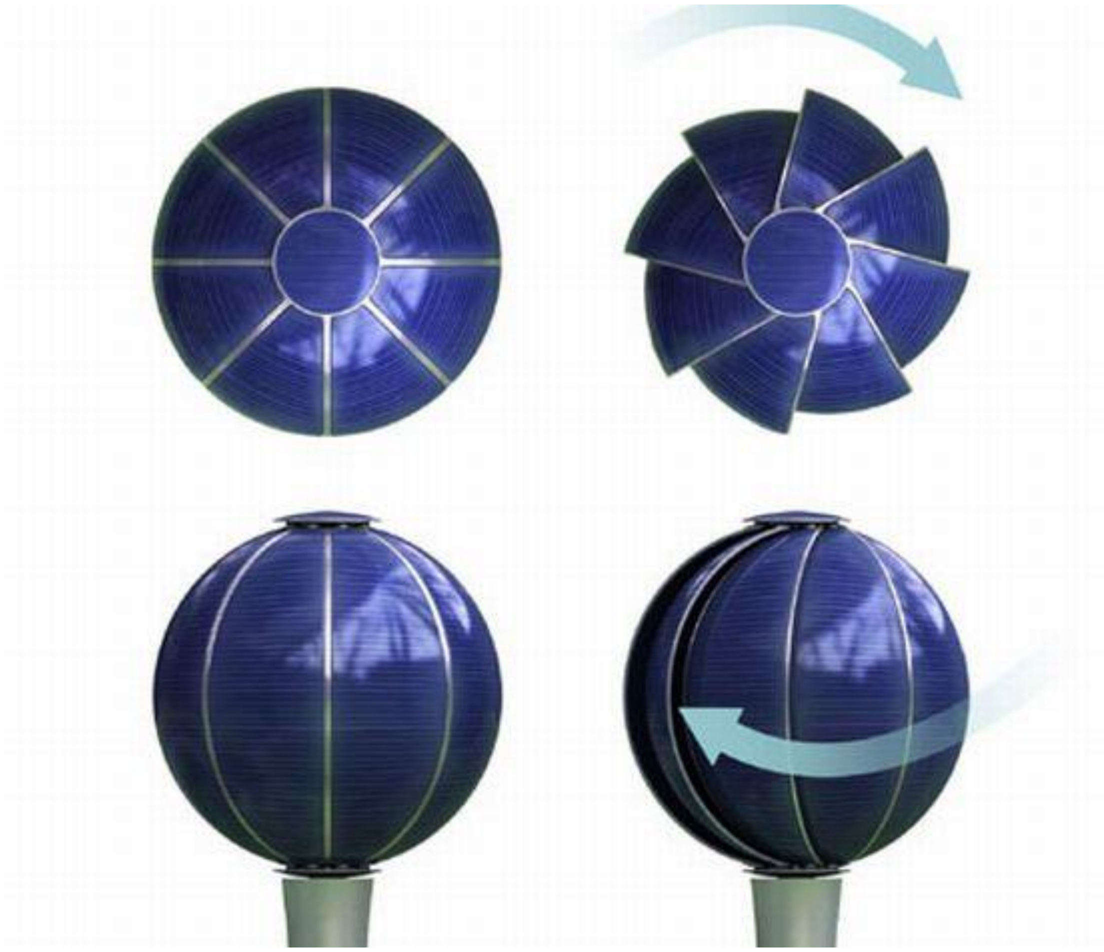

Fig.2. Spherical Solar Cells

3.3.Nanotechnology powered DSSCs: This technique was developed by the researchers at the Ohio State University. The cells dubbed Dye Sensitive Solar Cells (DSSC) developed by the researchers were not only cost-efficient, beautiful to look at but also converted more light into electricity. The key to all this was the use of a mixture of ruthenium and either titanium or zinc oxide particles that could absorb the incoming rays of the sun. To ensure that these cells not only consume the power of the sun, but also conducted electricity, researchers implanted nanowires in these cells which serve as connections.

3.4.Solar concentrators – Heliotube: The best way to improve the efficiency of solar cells is to increase the amount of sunlight that falls on the surface of solar cells. Solient Energy knew how to do that when they released an efficient solar panel dubbed the Heliotube. The panel made use of solar concentrators or mirrors that scan the sky and move the panel in the most profitable direction. This technique also lessens the amount of photovoltaic material required in the design, thereby reducing the overall cost of the panel by up to half. The company has also done well in releasing roof and parking lots optimized panels.

Fig.3. Heliotube solar cells

3.5.Paint on Solar Cells: Thinner solar cells mean that they can be embedded in places where no one ever thought of having them. This is what researchers at the New Jersey Institute of technology thought when they developed solar cells so thin that they can be painted on flexible plastic sheets, which can then take up the place of your normal glossy paints. These cells are based on the combination of carbon nanotubes and carbon Buckyball molecules to create a series of snake-like patterns which can conduct electricity. Researchers also expect that the technique will be much cheaper than what is being used today.

3.6. Carbon nanotubes: Researchers at University of Notre Dame, in Indiana, have demonstrated a way to significantly improve the efficiency of solar cells made using low-cost, readily available materials, including a chemical commonly used in paints.The researchers added single-walled carbon nanotubes to a film made of titanium-dioxide nanoparticles, doubling the efficiency of converting ultraviolet light into electrons when compared with the performance of the nano particles alone. A new material (represented by the dots in [b]) makes it possible to convert more of this light into electricity. Instead of reflecting back out of the solar cell, the light is diffracted by one layer of the material (larger dots). This causes the light to renter the silicon at a low angle, at which point it bounces around until it is absorbed. The light that makes it through the first layer is reflected by the second layer of material (smaller dots) before being diffracted into the silicon.

3.7.Star Solar: a startup based in Cambridge, MA, aims to capture and use photons that ordinarily pass through solar cells without generating electricity. The company, which is licensing technology developed at MIT, claims that its designs could make it possible to cut the cost of solar cells in half while maintaining high efficiency. This would make solar power about as cheap as electricity from the electric grid.

3.8.Cheap, Superefficient Solar: Technologies collectively known as concentrating photovoltaic are starting to enjoy their day in the sun, solar cell which absorb light and convert it into electricity, and the mirror- or lens-based concentrator systems that focus light on them. The technology could soon make solar power as cheap as electricity from the grid. Japanese electronics giant Sharp Corporation showed off its new system for focusing sunlight with a fresnel lens (like the one used in lighthouses) onto superefficient solar cells, which are about twice as efficient as conventional silicon cells.

3.9.Flexing silicon's power: Arrays of tiny silicon solar cells like the one in this photograph are assembled using a transfer-printing technique. These arrays are as efficient as conventional solar cells, which are bulky and rigid. Each microcell in the array is about 1.5 milli meters long and 15 micrometers thick. Arrays of these microcells are as efficient as conventional solar panels and may be cheaper to manufacture because they use significantly less silicon. Such cell can be rolled up like a carpet, transport them in a van, and unfurl them onto a rooftop.

3.10. Tubular solar: Cylindrical solar cells, which can be arranged in rows to make solar panels, are particularly suited for generating power atop commercial buildings.

3.11. The IBM solar cells: IBM solar cells could be an alternative to existing "thin film" solar cells. Thin film solar cells use materials that are particularly good at absorbing light. The leading thin film manufacturer uses a material that includes the rare element tellurium. Daniel Kammen, director of the Renewable and Appropriate Energy Laboratory at the University of California, Berkeley, says the presence of tellurium could limit the total electricity such cells could produce because of its rarity. While total worldwide electricity demand will likely reach dozens of terawatts (trillions of watts) in the coming decades, thin film solar cells will likely be limited to producing about 0.3 terawatts, according to a study he published last year. In contrast, the new cells from IBM could produce an order of magnitude more power.

3.12. 4G Solar Cells:

In contrast to the 1G, 2G and 3G Solar-Cells that are bulky and rigid, the 4G Solar-Cells are far more flexible as they are made up of polymer-thin films accompanied by the strength of novel inorganic nanostructures. The versatility of the Nanotechnology is harnessed to manufacture these Solar-Cells, which in turn improves the optoelectronic properties of the thin-film Photovoltaic systems. Other than the technological advantages they provide, the manufacturing of these Solar-Cells also proves to be cost-efficient. The manufacturing process for these cells involves the mixing of polymers with nanoparticles which helps in the unhindered movement of electrons and protons, thus producing better voltage and a Direct Current (DC) as a result of enhanced conversion efficiency. The 4G Solar-Cell technology may be termed as an 'Inorganics-in-Organics' concept that improves the convertibility of solar energy into electrical energy.

3.12.1. Advantages of the 4G Solar-Cells over others:

- ✓ High degree of Flexibility
- ✓ Very less weight than others
- ✓ Larger lifetime
- ✓ Lower manufacturing cost
- ✓ Customizability

3.12.2. Scope of 4G Solar Technology: The Present and the Future

India, as a global competitor in the field of Solar Photovoltaic energy has a long way to come into the group of the forerunners that include China, Germany, Japan, USA and Italy as reported at the end of the year 2015 by the Renewable Energy Policy Network for the 21st Century (REN21). However the use of 4G Solar Photovoltaic technology has not yet been domesticated in the leading countries also, owing to the already existing huge Solar Photovoltaic farms of the older generations. By appreciating the extent of advancement the photovoltaic technology has transcended as a result of curiosity imbibed in the nature and the human civilization's pondering for enhanced and sustainable life-systems, we can surely say that the future is sunny enough to realize the whole globe running on clean zero energy.

4. Summary:

The recent boom in the demand for photovoltaic modules has created a silicon supply shortage, providing an opportunity for technological advancement in Thin-film solar cell modules, use of material other than silicon and new ideas to improve the efficiency and to bring the cost of cell down are reaching the market in accelerating quantities, giving the opportunity for these potentially lower cost approaches to establish their credentials. Several distinct technologies are now available with their applications into MW-scale system.

5. Summary:

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