GaN as Semiconductor Material for Solar Photovoltaic: A Review

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Abstract: *Solar energy is seen as a potential alternate source of energy as it is available globally in abundant. The concern related to global energy crisis has drawn the tremendous attention of researchers towards the generation of electricity with help of solar Photovoltaic in the past years. Solar energy technologies are poised for the significant growth in the 21st century but the factors that pushed us behind are efficiency and installation cost of the solar photovoltaic. In this paper we will discuss about the path to achieve true energy and ways to increase the efficiency as well as to reduce the installation cost of solar photovoltaic by using gallium nitride instead of silicon which will also help in reduction of weight.*

Keywords: Gallium nitride, Sic, solar photovoltaic, transistor, silicon

1. INTRODUCTION

In the last decades, photovoltaic has evolved from a pure niche market of small scale applications towards becoming a mainstream electricity source. Most solar panels consist of crystalline silicon PV cells, which are 14-16% efficient in converting sunlight into electricity. A number of alternatives, however, are under investigation. Thin film cells can be made from a variety of materials. Although these are currently less efficient than standard PV cells, they are lightweight, flexible, and cheaper to manufacture. Multi-junction cells can achieve an efficiency of more than 43%. They are structured so that different parts of the cell are tuned to capture sunlight at specific wavelength ranges, rather than having a single receptor that misses a portion of the available energy. Solar photovoltaic cell use direct conversion of solar energy into electrical energy by the means of photovoltaic cells. The photovoltaic is defined as the generation of an electromotive force as a result of the absorption of ionizing radiation energy. These photovoltaic cells are made up of semi-conductors solar cells which do not need to operate at higher temperature.

2. NEW TECHNOLOGY EVOLVED

From the last many years we have been using silicon photovoltaic cells, but knowing that neither silicon nor SiC solutions would provide that required inverter performance, GaN transistors have been developed so as to meet the future demands of electricity. These are also compressed up into compact, lightweight design along with the improvement in the efficiency of the photovoltaic cells. These may provide up to 5 times better than the silicon carbide products and by enabling the inverter to be reduced to a significantly more compact package. The 650 V GaN transistors played an indispensable role in obtaining the desired operating ranges of plates. The system stability may also be enhanced across a wide range of power levels, aiding the higher level of inverter integration. It uses future-forward design paired with a disruptive level of system integration. With this approach, we may reduce the installed cost of solar power with battery storage by up to 50% .Using an intelligent design capable of compensating for diverse power environments, these photovoltaic cells have been integrated creating a new category of solar photovoltaic cells. These have built-in battery storages that can provide electricity with electrically -optimized power efficiency. These types of solar plates have also been integrated with the GaN Systems' gallium nitride (GaN) transistors in its newly developed inverters to increase power efficiency and reduce size and weight within the enclosed solar plates. Also for the additional power requirements, standard IEC power outlet may be used.

3. WORKING OF SOLAR PV

A typical silicon PV cell is composed of a thin wafer consisting of an ultra-thin layer of phosphorus doped (N-type) silicon on top of a thicker layer of boron-doped (P-type) silicon. An electrical field is created near the top surface of the cell where these two materials are in contact, called the P-N junction.

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Issue: 12 | Dec-2017 www.irjet.net p-ISSN: 2395-0072

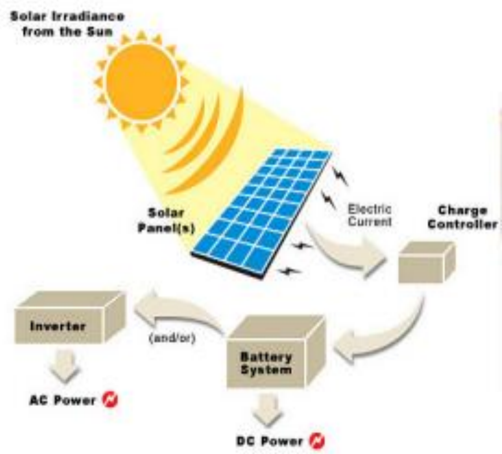

Fig – 1: Solar Basic Layout

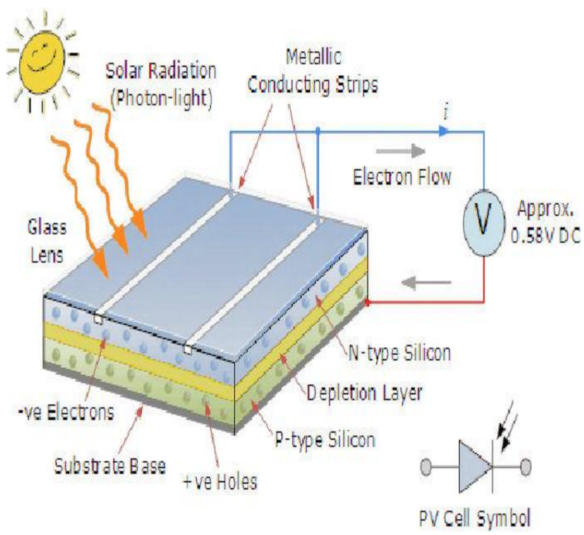

Fig -2: Cross sectional view of solar PV cell

When sunlight strikes the surface of a PV cell, this electrical field provides momentum and direction to light-stimulated electrons, resulting in a flow of current when the solar cell is connected to an electrical load. Regardless of size, a typical silicon PV cell produces about 0.5 – 0.6 volt DC under open circuit, no-load conditions. The current (and power) output of a PV cell depends on its efficiency and size (surface area), and is proportional to the intensity of sunlight striking the surface of the cell. For example, under peak sunlight conditions, a typical commercial PV cell with a surface area of 160 cm^2 (~25 in^2) will produce about 2 watts peak power. If the sunlight intensity were 40 percent of peak, this cell would produce about 0.8 watts.

4. MAXIMUM POWERPOINT

A solar cell may operate over a wide range of voltages (V) and currents (I). By increasing the resistive load on an irradiated cell continuously from zero (a short circuit) to a very high value (an open circuit) one can determine the maximum power point, the point that maximizes V×I; that is, the load for which the cell can deliver maximum electrical power at that level of irradiation. (The output power is zero in both the short circuit and open circuit extremes).

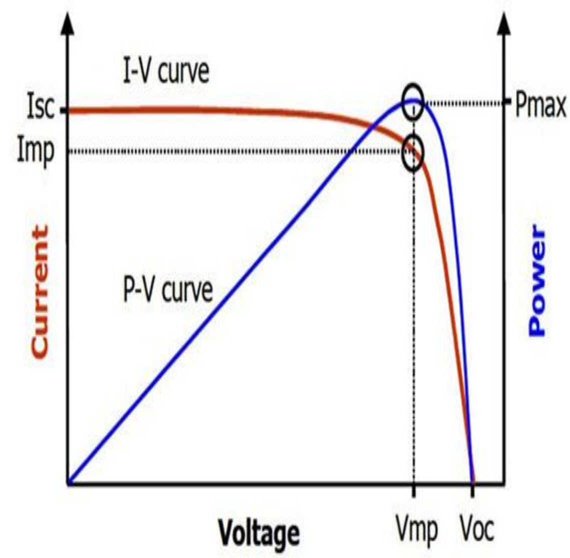

Chart -1: Maximum power point

A high quality, mono crystalline silicon solar cell, at 25 °C cell temperature, may produce 0.60 V open-circuit (V_{OC}). The cell temperature in full sunlight, even with 25 °C air temperature, will probably be close to 45 °C, reducing the open-circuit voltage to 0.55 V per cell. The voltage drops modestly, with this type of cell, until the short-circuit current is approached (I_{SC}). Maximum power (with 45 °C cell temperature) is typically produced with 75% to 80% of the open-circuit voltage (0.43 V in this case) and 90% of the short-circuit current. This output can be up to 70% of the V_{OC} x I_{SC} product. The short-circuit current (I_{SC}) from a cell is nearly proportional to the illumination, while the open-circuit voltage (V_{OC}) may drop only 10% with an 80% drop in illumination. Lower-quality cells have a more rapid drop in voltage with increasing current and could produce only 1/2 V_{OC} at 1/2 I_{SC}. The usable power output could thus drop from 70% of the V_{OC} x I_{SC} product to 50% or even as little as 25%. Vendors, who rate their solar cell "power" only as V_{OC} x I_{SC}, without giving load curves, can be seriously distorting their actual performance.

5. MATERIAL USED

Gallium nitride (GaN) is a wide band gap semiconductor material and is the most popular material after silicon in the semiconductor industry. The prime movers behind this trend are LEDs, microwave, and more recently, power electronics. New areas of research also include Spintronics and Nano ribbon transistors, which leverage some of the unique properties of GaN. GaN has electron mobility comparable with silicon, but with a band gap that is three times larger, making it an excellent candidate for high-power applications and high-temperature operation. The ability to form thin AlGaN/GaN hetero structures, which exhibit the 2-D electron gas phenomenon, leads to high-electron mobility transistors, which exhibit high Johnson's figure of merit. Another interesting direction for GaN research, which is largely unexplored, is GaN based micromechanical devices or GaN micro electromechanical systems (MEMS). To fully unlock the potential of GaN and realize new advanced all GaN integrated circuits, it is essential to integrate passive devices (such as resonators and filters), sensors (such as temperature and gas sensors), and other more than Moore functional devices with GaN active electronics. Therefore, there is a growing interest in the use of GaN as a mechanical material. This paper reviews the electromechanical, thermal, acoustic, and piezoelectric properties of GaN, and describes the working principle of some of the reported high performance GaN based components.

Gallium Nitride: There has been increasing research and industrial activity in the area of gallium nitride (GaN) electronics, stimulated first by the successful demonstration of GaN LEDs. This set the field of GaN electronics in motion, and today the technology is improving the performance of several applications including use in transistors and using them as semiconductor material in solar photovoltaic. These may provide up to 5 times better than the silicon carbide products Gallium Nitride is direct band gap semiconductor having Wurtzite crystal structure.

Formation: GaN crystals can be grown from a molten Ga melt held under 100 atmospheres of pressure of N2 at 750 °C. As Ga will not react with N2 below 1000 °C, the powder must be made from something more reactive, usually in one of the following ways:

$$2\,Ga + 2\,NH_3 \rightarrow 2\,GaN + 3\,H_2$$

$$Ga_2O_3 + 2\,NH_3 \rightarrow 2\,GaN + 3\,H_2O$$

6. APPLICATION OF SOLAR PV

1. Used to provide power supply to water pumping sets for micro irrigation and drinking water supply.

2. They provide power supply to radio beacons for ship Navigation at ports.

3. They provide power supply to cathode protection of oil pipe lines, for weather monitoring and battery charging.

7. CONCLUSION

One encouraging trend relating to the future of solar energy is that many of the world's greatest innovators are choosing to focus their talents and funds on improving alternative energy technology. Most solar panels based on silicon can convert around 15% of the sun's energy into electricity. More experimental photovoltaic panels, like GaN based panels, can convert 40% of incident solar energy into electricity. These panels utilize varying band gaps and mirror arrays and are used more for large scale solar power generation. It uses future-forward design paired with a disruptive level of system integration. With this approach, we may reduce the installed cost of solar power with battery storage by up to 50%.

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9. BIOGRAPHIES

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