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Analysis and Fabrication of Graphene Embedded Hybrid Photovoltaic Cells by Increase in the Current Output

S.Lakshmi Narashiman
Student at Department of Mechanical Engineering
SRM Institute of Science and Technology
Chennai, India

Ravi Manish
Student at Department of Mechanical Engineering
SRM Institute of Science and Technology
Chennai, India

V.Kumar
Assistant Professor at Dept. of Mechanical Engineering
SRM Institute of Science and Technology
Chennai, India

M. Kamatchi hariharan
Assistant Professor at Dept. of Mechanical Engineering
SRM Institute of Science and Technology
Chennai, India

A.Sengolerayan
Assistant Professor at Dept. of Mechanical Engineering
SRM Institute of Science and Technology
Chennai, India

Abstract—Silicon being the obvious choice for years, for all the photovoltaic systems but couldn't produce much energy output as needed. Silicon is preferred because of its abundance, stable cell efficiencies, and non-toxic nature. There has been a lot of research and development on the solar cells but these solar cells are not able to generate energy as required. The upper limit of the efficiency of the Silicon Solar Cells is restricted to 29%, which is higher than the upper limit of laboratory usage 25%, and commercial panels which have the efficiency of around 24%. On the other hand, Graphene, the wonder material is today, repeatedly tested in different fields because of its wide properties like flexibility, conductivity, and strength. This paper will try to combine both the technologies at the structural level thereby increasing the efficiency of the Silicon solar cell.

Keywords—Graphene; Solarcell; efficiency; conductivity; Silicon; Graphene Oxide; p-type; n-type

I. INTRODUCTION

Solar cells are used to produce electricity by transducing light energy to electrical energy, and this transduction process is due to Photovoltaic effects. Graphene technology is gradually fading now but still there is not a significant contribution of this technology towards the science. As computer technology grows, the need for miniaturized electronic devices grows too, which contributes to more stress on small Silicon devices. The need for Silicon-based electronic devices in the nanometer level has reached a limit of around 50 nm for the electric channel and the width of Graphene layer is only a few nanometers which may be used as the small devices such as transistors or other small electronic devices. One of the application of Graphene in silicon based devices is it supports the miniaturization of silicon based solar cells. It was doubted earlier that the synthesis of two dimensional crystals was not possible because of, namely due to a theorem called Mermin-Wagner theorem. This theorem states that if there is any 2D layer synthesized and fitted on to a device due to heat they lose their long range order and melt, deteriorating the structure and thus making it not feasible. Graphene is truly the first 2D crystal structure. Further the electrons in Graphene could be visualized as massless charged fermions which could never encounter 3D world. The electron movements inside the Graphene could be more understood by the modern physics rather than classical physics.

II. COMPONENTS

A. *Graphene*

Graphene was discovered in 2004, formally known as “wonder material”. It consists of carbon atom bonded to each other in a perfect hexagonal lattice. It is an allotrope of carbon, which has two double bonds and two single-bonded atoms for strong and rigid structure. It is an atom thick by which it acquires all of its remarkable abilities. It is stronger than diamond, flexible and due to its thickness, transparent. It has extraordinary photoelectric properties, best conductor of heat and electricity due to which it has great scope in manufacturing super-capacitors. Graphene is so thin it only absorbs 2% of the light illuminated on it. This makes it almost invisible to the naked eye. Its thickness also contributes to its unique properties to be extremely light and efficiently conduct electricity. It is a semi metal. Each carbon atom is bonded to three other carbon atoms leaving a one electron free for electronic conduction. It has tensile strength of 132 GPa and weight of 0.77 sq. metre. Even though Graphene is a good conductor of electricity it has difficulties in collecting and holding electrical charges produced inside solar cells. One of the better methods is to use Graphene oxide which is a slightly less conductive but an overall good collector of charge.

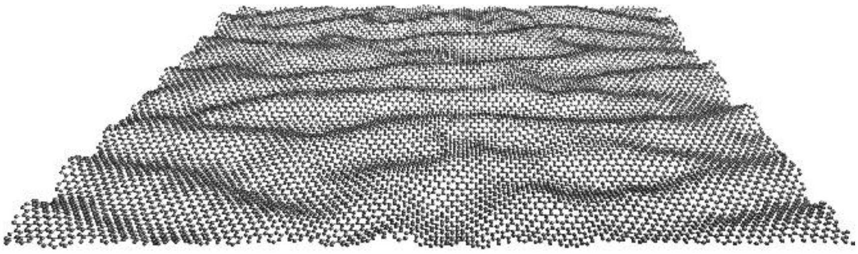

Fig. 1 – Graphene Structure

B. *Solar Cell*

The Solar cells are devices which give electrical energy from light energy. It works on the principle of photoelectric effect. It undergoes a physical and chemical reaction. Radiation illuminated on a metal affects its resistance, current generated and voltage produced varying with the intensity of light. The solar cell absorbs light of a certain frequency and thus an electron hole pair is generated in the semiconductor. A potential difference is given in order to separate these opposite charges and these separated electrons are transported to an external circuit.

Chemical properties of silicon are what make it more feasible and possible to generate electricity. Silicon has an atomic number 14, with 3 shells and of electronic configuration 2, 8, and 4. Due to the half-filled outermost shell it always tries to make up for lack of stability by readily sharing its four lone electrons with neighboring atoms. Thus, forms a crystalline structure. The only drawback with this structure is that it has no free electrons to move about to give electricity thus acting as a poor conductor. This is rectified by adding an impurity such as phosphorous or boron with 5 electrons in their outermost shell. These impurities are added in the ratio of a million to one. It bonds with silicon in such a way that four of its electrons are bonded with silicon, acting as a neighbor and leaving a free electron to roam by creating an electron hole pair for conduction of electron.

When heat is given to the silicon atoms few of them get excited and move to excited state, leaving behind a hole each. These electrons free to move due to their extra energy try to find another hole to fit in and carry current along. However, lacking very much in number they are not at all useful. But when phosphorous is doped into the silicon it is a completely different story. When an impurity is added to this setup it takes relatively very less energy to knock off the extra electron in the phosphorous atom. This in turn creates a chain reaction as a result most of the atoms of silicon do break free, providing lot more carriers (electrons) than in pure silicon. This type of silicon is called N-type (negative type) due to the presence of excessive electrons.

Now boron can also be added instead of phosphorous. This contains exactly 3 electrons in its outermost shell. So what happens in this is the excessive number of positive charge carriers. This leads to the forming of P-type (positive type).

These semiconductors separately aren't very useful. But when they are brought in contact with each other, that is when they exhibit exquisite properties. The electrons from the n side and the holes from the p side hurry to each other at the junction. They form a stable environment here which is called the barrier or junction. As this happens it goes on becoming increasing in width and making it harder for the electron and hole pairs from each side to attract. An electric field is produced due to their charge difference but not strong enough to break the bonds at the barrier. When the sun rays fall on the diode if the radiation is of appropriate frequency, an electron breaks free from the barrier and thus also leaving a hole.

Now if these free electron and hole come close to the electric field they disrupt the stability of the N-type and also P-type. Now, if an external flow is provided the electrons from the negative will flow towards the positive side attracted towards holes. This movement produces current, the electric field present gives voltage and these two combined give power. There are other components involved in making a solar cell truly work to its full potential. An anti-reflective coating is given on the cells. As the silicon chips are very shiny they reflect back most of the sun rays. As silicon is weak and very reactive to varying weather conditions, a layer of glass is placed on it to protect it and also allow sun light to penetrate through it.

Consider a 140W solar panel at standard conditions, has the specifications as 17 volts of voltage and 8.2 amperes of current. This can charge a 10 volt/100Ah battery, Ampere hour states that the battery was discharged at 20 amperes for 5 hours which is basically the standard. As the battery requires only 10 volts to be charged the remaining 7 volts is wasted. The power used by the battery is 10*8.2= 82watts. While the panel is producing 140 watts only 82 watts is used up to charge it. The efficiency is dropped by 41% solely because of this. This will take almost 12 hours to charge the batter from 0.

Fig. 2- Solar cell Apparatus

III. Photoelectric Effect

Photoelectric effect is the phenomenon of ejection of an electron from its ground state by illuminating radiation that is material specific. Incident light consists of energy in packets called "Quanta". Based on the duality of matter it is suggested that when light wave strikes a metallic surface, that is matter, it exhibits its particle nature by transferring its energy on to the electron. Every metal has a threshold frequency until which it will not eject any electrons.

When a radiation of specific wavelength and frequency is beamed upon a metal the electrons in their ground state get excited and gain enough energy to cross the threshold frequency. The band gap is the main criteria for determination of threshold frequency of a material. If the band gap is too big of a metal and the light incident is not that powerful the electron goes half way through the band gap and falls back into its previous shell. In semiconductors, these are not totally conductors or insulators; instead they have a band gap that is the space between the ground state and the excited state.

When the electrons are not properly excited they do not have sufficient energy to cross the band gap, similarly the atoms that are above band gap should loose enough energy to come to the ground state. This is the effect that later led to the conclusion to the understanding of "dual nature" of photons.

IV. DESIGN OF THE HYBRID CELL

On an average a solar cell of unit area with an efficiency of 20% will produce an output of 200W/day at standard conditions. However, areas with higher insolation produce relatively higher power output. Insolation is the amount of solar power that will be received by earth per unit area in the form of solar radiation. Places that receive insolation up to 5.5 kW-hr/day produce around 440kW per year. The efficiency of a multi-crystalline solar cell is around 14-16%.

Potential Induced Degradation is a phenomenon that negatively affects the cells of PV modules. Just after a few years of installation, sulphur in the glass somehow due to weathering and aging, gains the ability to create a negative potential towards the solar cells, which entirely obstructs the path of the current produced. This lowers the efficiency up to 20%. Efficiency varies abruptly with numerous factors such as reflectance, thermodynamic efficiency, charge carrier separation, conduction, and other such factors. These problems can be accommodated with the following proposal that is cost effective and higher conversion efficiency rate from solar radiation to usable electricity. Main drawbacks of solar cells are that they are very less efficient. They produce heat inside their own system so as to restrict the flow of electrons in such a way that the hole that get detached from electron after a photon strikes them does not cross the barrier and gets pulled back into the corresponding semiconductor.

V. **Conclusion**

That is why a layer of Graphene to be grown on top of the N type semiconductor on which the sunlight directly falls on. This Graphene will in turn act as a weather protector and also give rigidity and toughness to the system. It acts as an anode on top that helps in effective transport of electrons without any power loss. This anode made up of Graphene oxide which is further connected to highly conductive carbon nanotubes. The positive electrode that rests on the other side on the junction connected to the P-type semiconductor is made using a more electro positive material compared to Graphene oxide. The difference in electronegativity of cathode and anode should be significant so that the electrons are able to penetrate through the Graphene Oxide layer. It also conveniently releases few electrons when Graphene oxide is utilized to do the same function. The intricate connections between solar cells in the solar panels are fabricated using Graphene. This provides the electrons a path with minute hindrance so that there are no obstructions due to heat.

This technique also eliminates the potential induced degradation problem as there would no longer be needed a transparent strong body to protect the silicon cells as the Graphene itself takes up that task. As the impedances due to thermodynamic, intermolecular and frictional aspects decrease, the current in hybrid cell increases exponentially making it more efficient and feasible. This also increases the total lifespan of the photovoltaic panel drastically.

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