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Review Article

A REVIEW ON GRAPHENE BASED SOLAR CELLS

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ABSTRACT

Over the past few decades, the photovoltaic industry has grown rapidly following the improvements in the efficiency and the demand for alternative energy resources. Commercial silicon photovoltaic with a power conversion efficiency of more than 20% plays a dominate role, but the high manufacturing cost is still a major issue for large-scale implementation. Many efforts have been made to reduce the cost of photovoltaic devices. There are huge demands for developing new electrode materials with lower cost and comparable performance. To date Graphene and Graphene-derived materials have created an immense research interests due to its extraordinary physical and chemical properties, which delineated Graphene as an outstanding material for future electronics, optics, and energy-harvesting devices. This paper analyzes some of these properties of graphene & investigates whether graphene or graphene based materials can be a potential replacement for conventional materials used in solar cells or not. Graphene is a single atom thick two-dimensional material thus exhibit ~97.7% transmittance during the entire visible light spectrum. Graphene has unusual electronic transfer properties which follows the characteristic of 2D Dirac fermions, quantum hall effects. Electro catalytic actions of grapheme play a key role enhancing the efficiency of electro chemical solar cell like dye-sensitized solar cell (DSSCs), where the liquid/solid interface acts as a pathway for transfer electrons.

INTRODUCTION

Two of the most serious issues that we face today are Energy Crisis and Global Warming. The supply for each of these originates from fossil fuels. Fossil fuels are unit fuels shaped by decomposition of dead organisms like coal, fossil oil or gases. Generally, they have supplied almost the whole world energy needs for the last two centuries because of their high energy density. But, this development of fossil fuels gave rise to the two afore-mentioned issues. The harmful gases discharged into the atmosphere owing to the burning of fossil fuels which harmed the atmosphere for many years that gave rise to global warming. There are completely different suggestions on what will replace fossil fuels as a source of energy etc. The most promising solution to each of the afore-mentioned issues is alternative energy. Most of the renewable sources of energy trace their origin to the sun, like solar or photovoltaic cells, wind energy; bio fuels etc. [1] Out of these energy sources solar cells are the best source of energy because it directly converts daylight to electricity without polluting the environment. A comparison has been given between different solar cell designs utilizing graphene to examine which design of solar cell can be best replacement to current Silicon based solar cell in future.

Background on Existing Solar Energy

The use of Solar/Photovoltaic cell to convert sunlight to electricity has been in practice for over a century now. Photovoltaic effect was first observed by French physicist Edmond Becquerel in 1839 when he discovered that when two brass plates were exposed to light, after immersing in a liquid, they produced current. In 1883 Charles Frits first developed a Selenium based solar cell with 1% efficiency. In 1954, Bell Labs in USA invented the first Silicon based solar cells with 6% efficiency. Till now, it is the most popular material used to fabricate Solar Cells. In 1980-81 Multifunction Solar Cells first came into use. [2]

Some of the constraints of using solar energy via solar cells are:

- Solar energy is not predictable as Sunlight is not predictable throughout the day.
- The installation of solar or PV modules is very expensive.
- Till now only around 30% efficiency has been achieved by solar cells.

The basic principle of a solar cell is photons in electrons out. Electromagnetic waves or light waves are absorbed by the solar cells which excites the electrons in the valence band to the

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conduction band leaving a hole in the valence band & which in turn results in charge flow. This charge is collected at the two contacts & electricity is generated. This is generally how conventional solar cell works. However, over the years different types of solar cells have been developed namely Multijunction solar cells, organic solar cells, organic-inorganic hybrid solar cells, Dye sensitized solar cells etc. [2]

Single Junction Solar Cell

In a single junction electric cell the highest tip layer is created of glass or clear plastic as shown in fig 1. This layer permits daylight to enter the electric cell, protects the cell & is capsulate by a metal frame for support.

This layer permits sunshine to enter the electric cell, protects the cell & is capsulated by a metal frame for support. The cell core is formed of n-doped semiconductor that produces electrons that mix with the holes generated within the p-doped semiconductor region. [3]

They're separated by a p-n junction which is that the absorption region of the core & together wherever the electrons from the n region meet with the holes from the p-region. [3]

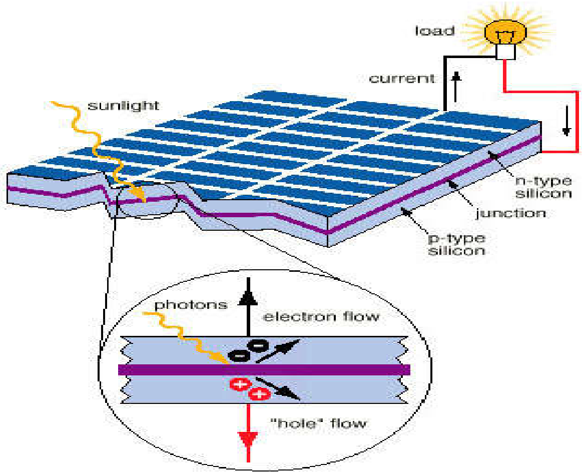

Fig 1 Single Junction Solar Cell

Multi Junction Solar Cell

To increase the efficiencies of the traditional solar cells bicycle or Multi junction solar cells are beginning to be developed. The essential plan of the Multi junction solar cells is that multiple sub cells composed of materials having

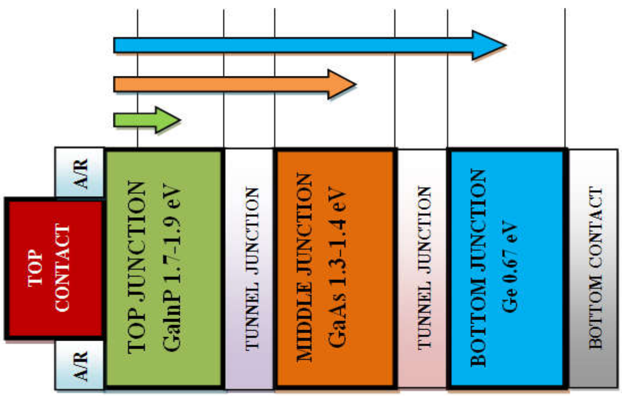

Fig 2 Schematic Diagram of Multi Junction Solar Cell [4]

completely different band gaps area unit stacked on high of one another connected along by heavily doped tunnel junctions as shown in fig 2. As a result, a bigger portion of the solar spectrum is being absorbed & used to get electricity. This will increase the potency of the solar cells. [4]

1. As a result large portion of the solar spectrum is being absorbed and utilized to generate electricity.
2. In these, photovoltage is neither sacrifice nor losses created as in single junction cells.

Dye Sensitized Solar Cell

This is another variety of organic cell, however, whose style is somewhat totally different from the standard solar cell as shown in fig 3. It typically consists of a clear cathode, an extremely porous semiconductor layer with a soaked layer of dye, A N solution answer containing oxidation reduction pairs and a counter conductor. The essential working rule of those solar cells is dye molecule harvests daylight and is happy in order that it injects negatron directly within the physical phenomenon band of TiO_2 that is that the porous semiconductor. The injected negatron then moves to the clear anode & through the external circuit to the cathode. The dye molecule takes one negatron from iodine within the solution by oxidizing it to electron tube. The electron tube recovers its missing negatron from external disseminative circuit by disseminative to the counter conductor. The highest efficiency reported by such a solar cell is around 12.3% which is much lower than the silicon solar cells but due to their low cost & easy fabrication these are a popular subject of research. [5]

1. The highest efficiency reported by such a solar cell is around 12.3% which is much lower than the silicon solar cells but due to their low cost & easy fabrication these are a popular subject of research.
2. Parameters that affect the performance of a solar cell which will be discussed in this paper are band gap, conductivity of electrodes & transparency of the electrodes.

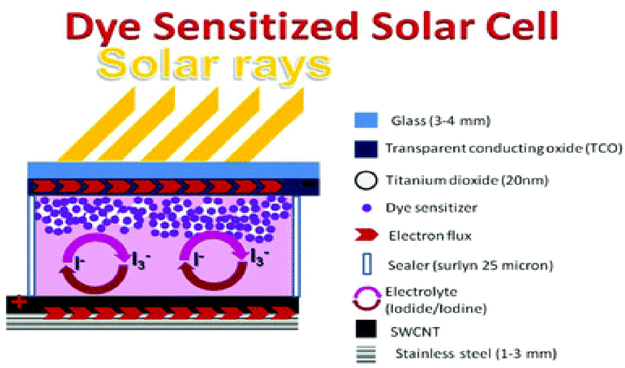

Fig 3 Dye Sensitized Solar Cell [6]

Table 1 Comparison of the bandgap of popular semiconductors

Material	Bandgap	Reference
Si	1.11	[7]
Ge	0.67	[7]
GaAs	1.43	[7]

Table 1 shows comparison between Si, Ge, and GaAs. Si has a greater band gap than Ge and almost equivalent band gap as

GaAs. Also, Si is easily found in nature as from the extraction by the reduction of carbon Whereas Ge and GaAs are not so easily available in nature that's why Si is better semiconductor material used as a substrate in solar cell.

Why graphene?

Graphene has different chemical, physical properties from most 3-d materials. Intrinsic Graphene is also known as a zero-gap semiconductor or semi-metal. Si has electron mobility almost two times less than of Graphene thereby making it super conducting, since it has a direct band gap it can absorb more photons in a much slender area as compared to indirect band gap semiconductors like Si. Graphene also has excellent optical properties & therefore can be used as translucent electrodes & interconnects between two sub cells in tandem solar cells. Graphene is a C-sheet one atom thick comprises of condensed six member rings. The C-atoms are sp^2 bonded in Graphene & create a hexagonal 2D lattice. An ideal Graphene sheet has a very high carrier mobility on the order of 10^5 cm^2/ (V s) at room temperature. This goes over the carrier mobility of Si by one or two orders suggesting that Graphene can be utilized as a replacement for Si in nanotechnology. Besides its outstanding electrical properties, Graphene also has very high mechanical strength. Graphene also has a tunable band gap. 3D Graphene is known to be Graphite. It is the slimmest material with maximum strength; it is also highly crystal clear & highly conducting. This makes Graphene a smart choice to make translucent electrodes in solar cells. Graphene can be modified in each and every dimension e.g., 1-D, 2-D and 3-D. as shown in fig 4. [8]

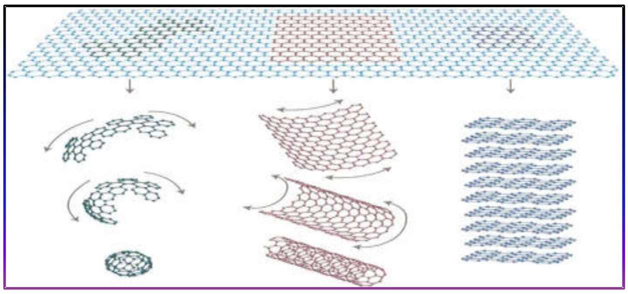

Fig 4 Structure of Graphene Synthesis [8]

The following properties of graphene are:

Strength

- Graphene is super strong–even stronger than diamond.
- We can stretch 20-25% of its original length without it breaking.

Electronic Property

- Graphene is more interesting to manipulate the flow of electron that carries electricity.
- Electron move through graphene a bit like photon, at speed close enough to the speed of light.

Optical Properties

- Graphene transmit about 97-98% light.
- Graphene has a flat transmittance spectrum from the ultra violet (UV) region to the long wavelength infrared region (IR)

Graphene Based Solar Cell Design

Graphene Based Electrodes

Graphene is used to create flexible, translucent, conductive electrodes by taking the benefit its tremendously high optical clearness & electrical conductivity. Graphene has a superior transmission coefficient than other translucent oxides used like ITO (Indium Tin Oxide) in the high-wavelength area of the incident photons. Also, since graphene is transparent, it decreases the losses due to outline of the grid electrodes. Chemical doping of Carbon nanotubes (CNTs) or graphene outcomes in significant increase in its conductivity, promoting charge transfer. Both Single walled Carbon Nano-tubes (SWCNT) & Multi walled Carbon Nano-tubes (MWCNT) are being seen as basic factors to make the electrodes of the solar cells & research is being carried out on how to implement them to better enhance the efficiency of the solar cells. A solar cell with electrodes based on CNT is discussed in fig 5.

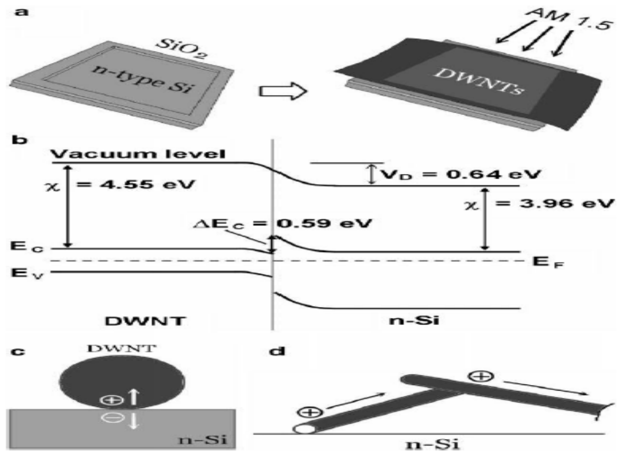

Fig 5

Fig 5: DWNT-Si heterojunction and multifunctionalities of the DWNTs. a) Illustration of coating a patterned Si/SiO_2 substrate (Si window: 7mm _7mm) with a DWNT film in cell fabrication. The DWNT film serves as a transparent electrode for light illumination (AM 1.5) and charge collection. b) Band scheme diagram of the DWNT-Si heterojunction. c) Illustration of the charge separation occurred at the interface between a DWNT and the Si substrate (cross-section view). d) Illustration of charge transport through a percolated DWNT network. [9]

SWCNT Based Photoactive Device

A p-n junction carbon nanotube (CNT) due to its defect free diode structure shows ideal diode behavior. In this design SWCNTs were nanowelded across two asymmetric metal electrodes with high & low work functions which established a strong built in electric field along the length of the tubes as shown in fig 6. The SWCNTs are vertically aligned which enhances the photo absorption properties of the device as photons not absorbed by a tube is likely to be reflected or transmitted towards another tube having a different bandgap. Also, the photo absorption is maximized when electric field of incident light is parallel polarized to the tube axis. The tubes are arranged such that higher band gap tubes absorb the shorter wavelength photons. [10]

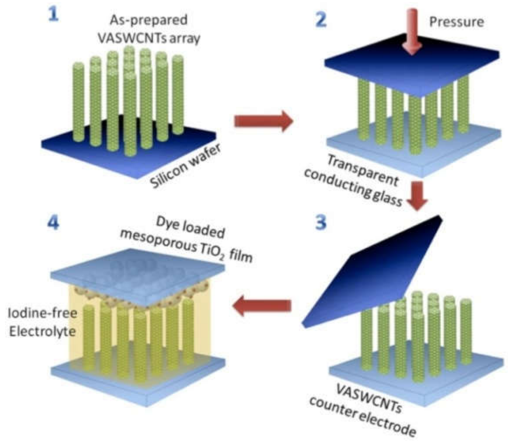

Fig 6 PV device with vertically aligned SWCNTs as photoactive material connected between two metal electrodes.

Challenges of Swcnt Based Photoactive Device

1. Due to their exceptional properties of superior carrier mobility, direct band gap characteristics & low scattering & recombination losses theoretically it looks a viable photovoltaic device to generate electricity but, the implementation of this device is quite difficult.
2. These devices to function properly the diameter & chirality of SWCNTs need to be carefully maintained but till now, the growth of SWCNTs with accurate diameter & chirality control has been difficult.
3. Multi junction designs of these photoactive devices are difficult to realize. Even if it's implemented experimentally construction of large solar grids with multiple panels of photoactive device like this might be difficult to implement.

CONCLUSION

These solar cells can be built up to replace conventional solar cells which would provide analogous efficiencies. A combination of all the applications of graphene in a solar cell might offer a better solution to this problem & provide better efficiencies.

Currently, research is going on many other regions on using graphene in solar cells to enhance the efficiency & reduce the costs of the solar cells so that they can be a probable source of energy in future & can substitute fossil fuels in different applications.

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