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EFFECT OF GRAPHENE IN SOLAR CELLS- A REVIEW

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Abstract - Graphene-based nanocomposites have a significant deal of potential for energy storage and conversion due to their distinctive characteristics, simplicity in production, and functionalization. High carrier mobility, a rapid rate of recombination, and long-term stability are just a few of the fantastic properties of these hybrid materials. The most current developments in various photovoltaic solar cell combinations, as well as applications of graphene and its composites in the areas of material choice, fabrication method and properties, energy storage, and conversion (Solar cells), are outlined in this article. The significance of materials based on graphene in solar cells is highlighted in this article. Future studies to create fresh procedures for the design and synthesis of nanocomposite based on graphene are also suggested.

***KeyWords*:**Graphene, solarcell, nanocomposites, Photovoltoic.

1.INTRODUCTION *(Size 11, Times New roman)*

Fossil fuels currently report for more than 84% of the world's energy needs, however they are limited and will eventually run out from an environmental and human health perspective. Up to 2050, it appears that the world's energy will have increased to double. As a result of the urgent energy and environmental crises, wind energy, water energy, and solar energy for the development of renewable energy have drawn an increasing amount of attention from all countries. Solar energy is abundant, affordable, and clean, so the research and development of solar cells must go quickly. Here, a self-assembling method was used to create a bio-nanocomposite made of natural plants and including CuO, graphene oxide, and porphyrins. For PSCs, it served as the first bio-nanocomposite HTMs. [1]

The most widely used and readily available substance is carbon. Due to their environmental friendliness, the use of carbon-based products has significantly increased. Due to its distinct properties, which can be attributed to its honeycomb crystal lattice with one atom of thickness, graphene has received a lot of attention. Due to its exceptional properties, graphene-based materials have demonstrated excellent usage in a number of biosensing and bioelectronics applications.

Due to its ability to electrostatically retard molecules by applying strong van der Waal's forces and particle intera ctions, graphene has received a lot of attention.Due to th e fact that graphene absorbers' absorbance rate is indepe ndent of light wavelength and that it is possible to use th em to absorb any type of laser light, which saves money and energy, they are very advantageous.[2]

A great substance with many examples to its credit is gr aphene.It is the thinnest substance known to humankind and the most stable approximation ever made.Despite its short history, and despite the fact that one can be certain of the truth of uses only when business items show up, t his carefully twodimensional material exhibits unusually high gem and electronic quality. Graphene no longer ne eds additional confirmation of its significance with regar d to major physical science.[3]

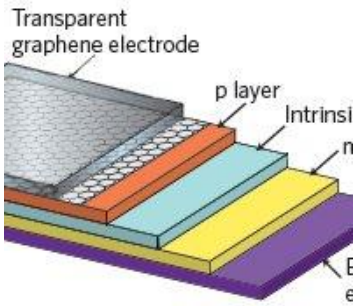

Figure-1: Graphene electrode in solar

Graphene-based solar cells may be produced in industrial quantities using the direct growth plasma-enhanced chemical vapour deposition (PECVD) method. The need for great transparency in order to pass more photons while maintaining low sheet resistance presents another hurdle for graphene-silicon junction solar cells. Another type of directly generated graphene has been taken into consideration in this study to avoid a trade-off between conductivity and transmittance. Direct PECVD

growth of graphene nanowalls or vertical graphene nanohills (VGNH) on any substrate is possible.

In comparison to planar graphene, these VGNH have a substantially lower sheet resistance and higher transmittance because of their vertical morphology. It is important to regulate the graphene to achieve a high carrier density, an open-circuit voltage, and built-in potential since the work function of the material is reliant on a number of layers. The precise control of VGNH's layer count, however, presents another difficulty. Bi et al. also attempted to create a graphene-based solar panel using ambient pressure chemical vapour deposition (APCVD), however this method required a high temperature of 1200 °C to form a few layers of graphene. To be cost-effective, such high temperatures are not desired, and many substrates, including glass, cannot withstand them.**[4]**

2. Why do you favour Graphene?

The advancement of material science and composite tec hnology is driven by the demand for lightweight solutio ns to numerous engineering challenges.Utilising a porou s material as the substrate layer has various advantages, such as energy conversion and storage, lower electrical a nd thermal conductivity, and is a better way to meet the l ightweight criteria of the solar cells.[5]

Unlike most 3-d materials, graphene possesses peculiar chemical and physical properties. Another name for intrinsic graphene is a zero semiconductor or semi-metal. The fact that Graphene possesses a straight band gap allows it to absorb more photons in a smaller volume than indirect band gap semiconductors like Si, which have almost two times the electron mobility of Graphene. Graphene can be employed as transparent electrodes and interconnects between two sub cells in tandem solar cells because it also has good optical characteristics. One atom thick C-sheet made up of six condensed ring members is called graphene. A hexagonal 2D lattice is created by the sp2 bonds between the C-atoms.

The carrier mobility of a perfect graphene sheet is on the order of 10 at room temperature. This suggests that graphene can be used as a substitute for silicon in nanotechnology since it outperforms the carrier mobility of silicon by an order or two. Graphene offers exceptional mechanical strength in addition to its exceptional electrical qualities. The band gap of graphene can be adjusted. Graphite is understood to be 3D Graphene. It is the thinnest material with the greatest strength, as well as the most transparent and highly conductible. This makes using graphene to create transparent electrodes for solar cells a wise decision.**[6]**

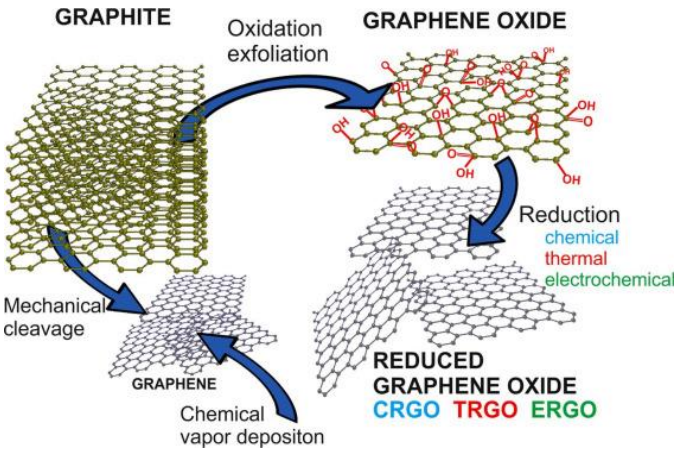

Figure-2: Structure of graphene synthesis

Through a selfassembly process, a bionanocomposite inc luding CuO, graphene oxide, and porphyrins was created using natural plants.It served as the first bionanocompos ite HTMs for PSCs, enabling them to be reasonably pric ed, environmentally responsible, and economically viabl e.

The findings of experiments investigating the efficiency of cooling using graphene nanofluids (GNP) as the primary Cooling Media through micro-sized tubes that were positioned to be in direct contact mode on the back of a PV solar panel. The combination of these techniques is anticipated to lower the surface temperature of the PV solar panel and boost output effectiveness**.[7]**

3. The qualities of graphene are as follows:

i. Strength

Graphene is incredibly strong than diamond, in fact. Without breaking, we can stretch it by 20–25% of its original length.

ii. Electronic Property

The ability to control the flow of electrons that carry electricity makes graphene more intriguing. Similar to photons, electrons travel through graphene at speeds that are nearly as fast as light.

iii. Optical Properties

Graphene has a flat transmittance spectrum from the ultra violet (UV) region to the long wavelength infrared region (IR), and it transmits light at a rate of 97-98%.**[6]**

4. Solar cells-Energy

A PV solar panel's solar-to-electricity energy conversion mechanism is frequently accompanied by the production of byproducts, or waste heat on the PV solar panel's surface. Due to the negative inversely proportional relationship between PV temperature and output efficiency, the undesired heat energy produced will result in a decrease in the total effective output of electrical parameters. Therefore, in order to maximise the output efficiency, it is crucial to reduce the temperature of the PV panel.

Due to its low weight, ability to be mass produced using roll-to-roll technology, and use of more environmentally acceptable materials, organic solar cells (OSCs) have gained more and more attention from both academia and industry. These thin-film devices are created by sandwiching two electrodes, at least one of which is transparent to allow light to enter the device, between two organic photoactive layers**.[1]**

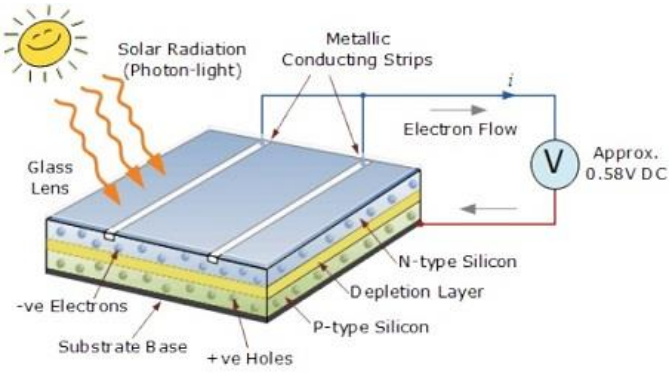

Fig 2. Struture of solar cell

5. Material selection

Due to its increased thermal conductivity and electron mobility, graphene has been regarded as one of the most widely employed materials in a variety of applications. By doping a few defects and functional groups onto the basal carbon plane, it can be used as a precursor for numerous derivative materials, including fluoro-graphene, and nano-composites, and this sparks widespread applications.[2]

We bought ethanol, potassium hydroxide, ferric chloride , and ferrous chloride from SigmaAldrich.In this experi ment, reagentgrade compounds were utilised without ad ditional purification.[4]

Materials for the DSSC, including FTO Coated Glass Substrates (2 mm, 7 /seq), N3 Dye, TiO2 Paste, Electrolyte Z-50, and Pt-Paste, were purchased from Solaronix in Switzerland. Grafen Chemical Industries Co. in Turkey is where the graphene powder was purchased. Graphene's sheet thickness is 8 nm, but its surface area per gramme is 100 m^2.[7]

From Sringeri, Sringeri taluk, Chikkamagaluru district, Karnataka, India, areca seeds were extracted. The gathered seeds are washed several times in distilled water, dried, ground to a size of 100 mesh, and then stored at room temperature.[8]

All of the chemicals were of the analytical reagent grade and were used directly. Sigma-Aldrich provided the graphene oxide powder, acetic acid, ethanol, and titanium (IV) isopropoxide (TIP) (99.999%, 4-10% edge-oxidized).[9]

6. Preparations of working electrodes

Various studies have been conducted to examine the broad properties of high-performance graphene-based materials. In the beginning, single-layer graphene was produced using a simple graphite taping technique. Graphene is now produced using procedures like reduction in GO, micro-mechanical exfoliation, liquid phase exfoliation (LPE), and epitaxial growth. Heat treatment was, by far, the most environmentally friendly technique used. GNPs are created via chemical modification and are viewed as colloidal suspensions inside aqueous solutions. It was concluded that the production of 2D materials based on graphene has a significant impact on the functionality and potential applications of bioelectronics**.[2]**

200 mg of freshly produced potassium tantalate nanoparticles were added after 100 mg of graphene oxide was dispersed for 30 min in distilled water. This solution was then placed in a hot air oven for hydrothermal reaction at 180 °C for 24 hours after being sonicated for 10 minutes. Following the reaction, the suspension was left to dry for 24 hours at 70 °C. Consequently, the solid composite that was formed was crushed with a pestle and mortar and kept for analysis**.[8]**

At room temperature, titanium tetra isopropoxide (TIP) was combined with ethanol and acetic acid in the following molar ratios: 0.5: 4.5: 0.05. This titanium precursor solution was then agitated for 2 hours.Separately, the graphene oxide (GO) solution was made by sonicating 5 ml of graphene oxide monolayer powder (graphene sheets) for 20 minutes.In a 1: 0.2 ratio, the TIP and GO solutions were combined and swirled for 30 minutes.After cleaning the glass substrate using standard cleaning techniques, the solution was applied dropwise using the spin coating process while the substrate was rotated at a speed of 3500 rpm for 30 seconds**.[9]**

The modified Hummers' method was briefly described. It involved mechanically dispersing 5 g of graphite powder in 200 mL of 95–97% H_2SO_4 in a 1000 mL volumetric flask. Next, 5 g of $NaNO_3$ was added to the solution, which was then maintained in an ice bath (0–10 ºC) for 3 hours while being continuously stirred. Then, 15 g of $KMnO_4$ were gradually added while maintaining a reaction temperature below 10 ºC and mixed for 2 hours. After removing the ice bath, the reaction mixture was placed to a glass reactor, and 900 mL of distilled water was slowly added. For 12 hours, the reaction was heated to 50 ºC. The resulting brown precipitate was then washed with 200 mL of HCl (10%) after 5 mL of H_2O_2 (30%) was added.**[9]**

After being sputtered onto FTO glass, a thick ZnO buffer layer was submerged for 12 hours at 95°C in an aqueous solution comprising $Zn(NO_3)_26H_2O$ and NH_4OH. The ion-layer adsorption and reaction (SILAR) technique was used to sensitise ZnO nanowire (NW) electrodes with CdSe. For this, the electrodes were submerged in an aqueous solution of $CdSO_4$ for 30 seconds, washed with deionized water for 30 seconds, then submerged in an aqueous solution of Na_2S for 30 seconds. Then, employing chemical bath deposition from an aqueous solution containing $Cd(CH_3COO)_2$ (as a Cd ion source), 2.5 mM of Na_2SeSO_3.Then, CdSe QDs were in situ deposited on CdS/ZnO NWs by chemical bath deposition using an aqueous solution containing $Cd(CH_3COO)_2$ (as a Cd ion source), 2.5 mM of Na_2SeSO_3 (as a Se ion source), and NH_4OH (as a complexing agent).[10]

7. Fabrication of electrodes

The 2.5×2.5 cm^2 squares of unaltered graphene and BI-doped graphene films on PET substrates were cut out. Sharp edges were created on the graphene layer by patterning it with laser ablation (Fibre Laser Controller PL-20). The next step was to feed the graphene layer into a thermal evaporator for the deposition of 1.5 mm ×25 mm Ag bus bars to lower contact resistance. Commercial ITO on glass anodes were bought from Xin Yan Technology Ltd, cleaned in an ultrasonic bath for 15 minutes each with Alconox, deionized water, acetone, and 2-propanol, dried for 10 minutes at 120 ºC, and then treated with UV-ozone for 30 minutes. After that, the thermal oxidizer was loaded with the Ag-bar graphene and ITO substrates**.[1]**

A solution of water and ethanol (1:1) is added, and it is then sonicated for 10 minutes with uniformly scattered KT NCs. The solution was then sonicated after receiving 0.90 µl of Nafion. A nickel foam approximately 1.5 cm in height and 1 cm in breadth was coated with this solution. Ni foam was coated by adding the solution drop by drop while removing the top part. The electrode was then utilised once it had fully dried. Additionally, KT-rGO NCs is coated in the same manner and used for electrochemical research**.[8]**

A modified version of Hummer and Offeman's method was used to produce graphene oxide from natural graphite powder. After stirring for an hour in an ice bath, 8 g of graphite powder (Sigma Aldrich), 8 g of NH_4NO_3, and 368 ml of 98% H_2SO_4 were added. A steady addition of 40g of $KMnO_4$ was made to the mixture while stirring for an hour, until the solution turned green. The mixture was then placed in a water bath heated to 35 °C. To create a thick paste, the fluid was churned for one hour. 640 ml of double-distilled water should be added to the paste after it has been agitated at 90 °C for an hour to develop a brown colour. 48 ml of H_2O_2 (30%) and 1600 mL of water were used to dilute the solution.[11]

The scotch tape cleavage method gained popularity, however it only produces a tiny quantity of piles of sheets or a few isolated sheets. The highly reduced graphene oxide (HRG) is a term used to describe the defective graphene-like materials that may be produced in vast quantities using consecutive oxidation-reduction processes. Bottom-up and top-down approaches are two general categories into which the synthesis of graphene is divided. The Scotch tape method, which uses atoms or molecules of a range of precursors other than graphite through chemical reactions, is a good alternative to the mechanical exfoliation of graphite and produces a relatively higher yield of graphene. Epitaxial growth on

single-crystal SiC and chemical vapour deposition on metal foil surfaces are two examples of these techniques.**[12]**

8. Characteristics of Materials

Raman spectroscopy was used for the structural examination. To prevent laser-induced damage to the VGNH, a tiny spot size of around 0.8 mm and low input power of 1 mW were used. All data were measured at many locations on a substrate under the same circumstances to ensure measurement accuracy. Energy dispersive x-ray spectroscopy (EDX) was used to map the elements while field emission scanning electron microscopy was used to investigate the surface morphology of vertically growing graphene. An atomic force microscope (AFM, Nanofocus Ltd.) was used to measure the thickness, surface roughness, and work function of VGNH. The same AFM was used for KPFM imaging, and a cantilever with a silicon tip coated in platinum/iridium was employed. The sheet resistance, the carrier concentration, and the p-type behavior. [4]

Philips X'pert PRO diffractometer was used to determine the phase of the synthesised material.BET surface area calculations are performed using the Quanta Chrome Nova 2200e Surface Area & Pore Size Analyzer Nova station A. Utilising a high-resolution transmission electron microscope (HRTEM), morphology at the surface was studied. Software called VESTA was used for the structural analysis. Different electrochemical measurements of the material were made using a CH 660E potentiostat (CH Instruments, USA) and cyclic voltammograms (CV). These measurements were made by using a three-electrode system with a working electrode (Ni foam), counter electrode (platinum wire), and reference electrode (calomel electrode).**[8]**

Shimadzu's XRD-6000 X-ray diffractometer was used to analyse the structure using X-Ray Diffraction (XRD), which uses a Cu-K radiation source. The films' transmittance T and reflectance R spectra were measured using a computer-aided double-beam spectrophotometer (Shimadzu 3150 UV-VIS-NIR) with a resolution of 0.1 nm at normal incidence at room temperature. A VeecoDektak 150 profilometer's stylus displacement was used to calculate the layer thickness. Surface Electron Microscopy (SEM) (Shimadzu Superscan SSX-550) and Atomic Force Microscopy (AFM; VeecoCP-II) in contact mode with Si tips at a scan rate of 1 Hz were used to examine the surface morphology of the layers. EDX technology with scanning was used to determine the microstructure of the films.**[9]**

Shimadzu UV-2450 spectrophotometer was used to measure the absorption spectra, while Shimadzu RF-5301PC spectrofluorometer was used to measure the fluorescence spectra. Using the KBr pellet method, the JASCO spectrometer 4100 performed Fourier transform infrared (FT-IR). Shimadzu 6000-XRD X-ray diffractometer was used to conduct the X-ray diffraction (XRD) patterns using Cu Kα radiation. Images taken using a JEOL 2100 microscope operating at a 200 kV accelerating voltage were obtained using transmission electron microscopy (TEM). Surface area & pore size distribution (BET) Nova LX3 and Brookhaven zeta potential performed the thermogravimetric (TGA) Shimadzu Zeta potential results. He-Cd laser, 325 nm, max. 200 mw, Synapse CCD camera, KIMNON CO, LTD, Japan; photoluminescence (PL). Explaining cyclic voltammetry using the Volta lab PGZ100 and solar-powered Current-Voltage (I-V) measurements.[11]

A high-resolution transmission electron microscope (HRTEM, Tecnai G2 F20 S-TWIN) and a field emission scanning electron microscope were used to examine the morphological properties of the eVG. Thermo Fisher Scientific's DXR 532 Raman spectrometer was used to collect the Raman spectra at a 532 nm excitation wavelength. MATLAB software was used to run image processing methods to determine the statistics of edge parameter values. To produce binary images that clearly reveal the edge profiles, the processing required a number of operations, including negative transformation, contrast enhancement, Wiener filtering, Gaussian low-pass filtering, and thresholding, among others.**[13]**

9. CONCLUSION

The comprehensive study of graphene for various materials offers a significant potential to address issues with energy conversion and storage, as it was stated here. There have been many discoveries regarding the fundamental properties of graphene, but there are still many discoveries to be made regarding the properties of materials based on graphene and its solar applications. Graphene-based nanocomposites have a significant deal of potential for energy storage and conversion due to their distinctive characteristics, simplicity in production,

and functionalization. These various pairings of photovoltaic solar cells and materials based on graphene are excellent for long-term endurance. In order to create new graphene-based nanocomposites and to better understand their characteristics as well as associated phenomena, it is therefore interesting to investigate graphene.

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