



Carbon/ZnO Nanostructures Hybrids as An Electron Transport Layers in Perovskite Solar Cells.

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ABSTRACT

The development of a cost-effective and easily scalable energy system for harvesting renewable solar energy is an attractive proposition for the future. The perovskite solar cell has been fabricated by graphene/ZnO nanostructures as an electron transport layer. This work presents a facile synthesis of ZnO nanostructures with different morphologies simply providing different solvating conditions in the hydrothermal process, the preparation of graphene by hammer's method, the synthesis of graphene/ZnO nanostructures by thermal method for their subsequent use in Perovskite solar cell device. In this work the effect of varying the graphene concentration in the G/ZnO 2% wt of Graphene with ZnO nanostructures Films from 0.5% to 2.0%wt on the photovoltaic performance of perovskite solar cell. Among the different nanostructure morphologies, 2% wt Graphene/ZnO nano prisms showed superior performance reaching the maximum conversion efficiency. We attribute this to its large surface area, better conductivity, and enhanced dye absorption of nano prisms.

Keyword: Renewable Solar energy, Zno nanostructures, ZnO Graphene, Thermal method

1. INTRODUCTION

1.1 Background

The risk of energy insecurity is reduced by renewable energy. The easiest and most affordable way to solve the global energy crisis is through the use of solar energy, and the increasing consumption of energy, global warming, disruptions in the energy trade, and fluctuations in the price of fossil fuels are all seen as major threats to the world's energy security. There is a pressing need to choose the best location for a renewable energy project, including wind, solar, and hybrid projects. Despite developments in technology, 1.2 billion people on the earth would not have access to power by 2030, mostly owing to population growth. (Iram et al., 2021).

Recently oil and gas prices has increased and people raised the issue and preferred and demanded energy supply. In 20th century energy demand went up about 16 times because of the overpopulation. In worldwide to sustain the life style of 6.5 billion people there is a 13 terawatt of energy is currently required. To maintain our currently lifestyle by year 2050 we will need an additional 10 TW of clean energy. There are three main categories through which we can utilize nanostructures that can design of solar energy conversion devices. First is donor, second is acceptor and third is the nanostructures semiconductor based solar cells. During the process of photosynthesis light energy is converted into chemical energy through green plants. On the study of donor-acceptor system has a specific interest to containing Chla and porphyrins that can quoted the photoinduced electron transfer process of natural photosynthesis. Energy transfer, radiative and non-radiative excited state decayed during the process of light absorption, simultaneously electron transfer, proton coupled electron transfer. For energy conversion catalysis are important in designing molecular assemblies. (Kamat, 2007).

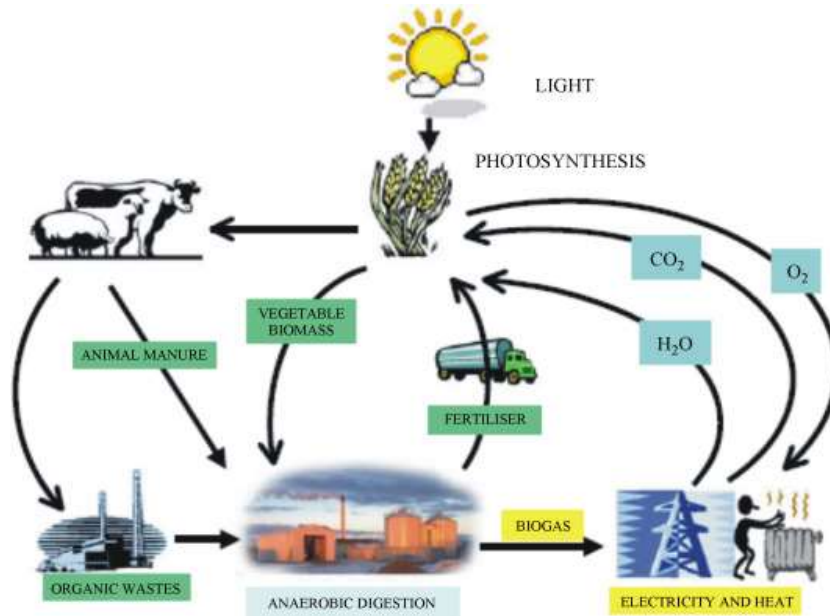


Figure 1: Role of renewable energy sources in environmental protection

1.2 Solar Energy Potential in Pakistan

Renewable energy development and effective use in growing in Pakistan. Pakistan is one of those countries where the sun shines almost all the year and has a significant solar power producing potential. Average solar radiations through the country remains 136.05W/m² to 287.36W/m². More of the period of the year sun shines for 10 hours a day that could result in 45-83MW power per month from just 100m² area. From March to October, the intensity of solar radiation stays favourable across the country. From February to October in Sindh, from March to October in Baluchistan, from April to September in the NWFP, Northern regions and Kashmir region, and from March to October in Punjab the radiation intensity remains greater than 200W/m². Throughout the year, solar energy has a promising potential in the most portions of southern region of Pakistan are above 5kWh/m²/day, which is ideal for photovoltaic technologies.(Shaikh et al., 2013).

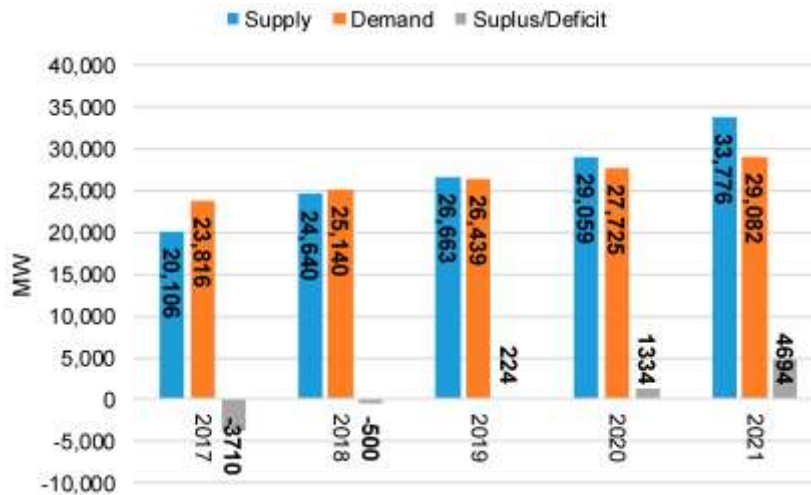


Figure 2: Projected electricity demand and supply during 2017-2021

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1.3 Harvesting Techniques

Solar energy can be harvesting by three techniques

1. Solar Fuel
2. Solar Thermal
3. Electricity

1.3.1 Solar Fuel

Solar energy into hydrogen generation via a splitting of water is supposed to be an aspirant fuel in future is supposed to be an aspirant fuel in future as it is a clean ,green and sustainable approach to elevate the global energy and alleviate environmental problems .Although numerous technologies have been established and are using for hydrogen production only a few can be considered eco-friendliest fundamental process of natural photosynthesis for sunlight to chemical energy conversion which further constitutes the bio building blocks of all living organisms provide the best baseline idea for hydrogen production in an intermediate process .Since natural systems are unamendable and the hydrogen is produced in sporadic concentration, research progress focus on imitating photosynthesis artificially.

Researchers have been striving to assemble an “artificial leaf” that efficiently captures, convert and stores solar energy as high energy chemical fuel. Artificial photosynthesis believed to be a promising technology not only in terms of efficient, eco-friendly and sustainable energy setup but also the formation of viable energy laden fuels through water splitting and CO₂ sequestration.

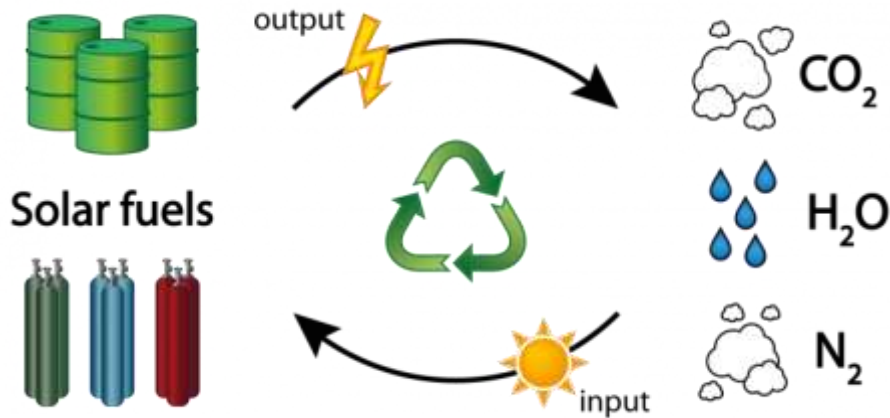


Figure 3: Solar fuels and electrochemical process

1.3.2 Solar Thermal

Solar energy is converted into thermal energy for usage in homes and business, such as drying, heating and cooling. Solar flat plate and collectors are used for such purposes where high temperature is not required, while for high temperature applications concentrated systems are used. To minimize serious damaged to the environment and living beings, solar thermal energy is also employed for saline removal and wastewater treatment.

1.3.3 Electricity

Electricity generation is further divided into two categories

- Solar Thermal power generation
- PV Technologies

1.3.3.1 Solar Thermal Power Generation

Electricity is generated using concentrated solar power technology. High magnification mirrors are used to concentrate solar energy at a point where water is converted into steam. Similarly, Fresnel mirrors, solar dish and power towers used to concentrate solar energy into a receive tube, a single point and reflector above the ground level respectively for high temperature applications. Power used the array of thousands of reflecting mirrors.

1.3.3.2 PV Technologies

PV technologies involving the semiconductor to convert sunlight into electricity. Solar photons have the ability to drive an electron across a semiconductor's bandgap, resulting in an electron-hole pair at p-n junction interface. Generated electrons move in one direction while hole in other which in results creates a potential difference equal to bandgap.(Kabir et al., 2018)

1.4 Properties of Semiconductors

- Internal semiconductors are pure materials that exhibit semiconductor properties.
- The number of free electrons in the conduction band equals the number of holes in the valence band.
- It has a low electrical conductivity.
- Its electrical conductivity is solely determined by temperature.

1.5 Solar Cells

A solar cell is a device that converts light energy directly into electrical energy via the photovoltaic effect.

1.5.1 Working of Solar Cells

A solar cell is made up of n-type and p-type silicon sandwiched together. It generates electricity by using sunlight to create electron holes across the junction between the various silicon flavours.

- Photons (light particles) bombard the cell's upper surface when sunlight falls on it.
- Photons (yellow bulbs) transport energy through the cell.
- In the lower p-type layer, photons give up their energy to electrons (green bulbs).
- This energy is used by electrons to jump across the barrier into the n-type layer and escape into the circuit.
- As electrons flow through the circuit, they light up the lamp.(N. A. Mohamed et al., 2021)

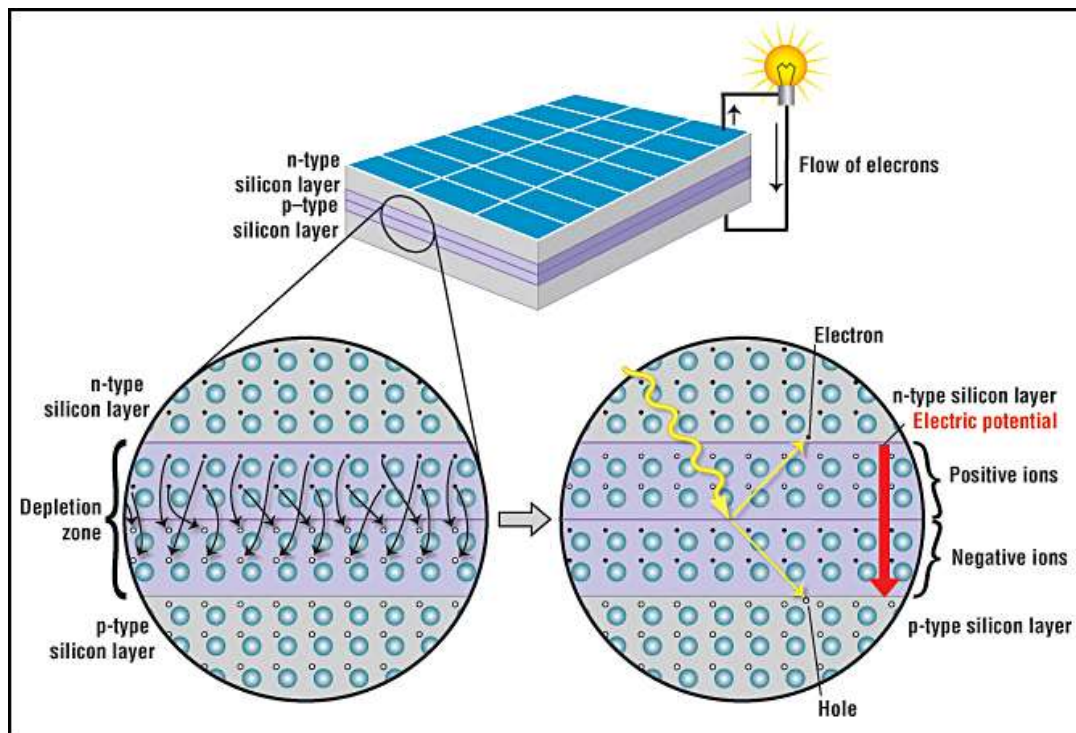


Figure 4: Principle of solar cell

2. Perovskite solar cell (PSC)

In 1839, a French physicist named Becquerel discovered the photosynthetic phenomenon. When sunlight hits a semiconductor substance in 1876, British scientists Adams et al discovered electricity. In 1883, Fritts created the world's first semiconductor material solar cell, which had a Germanium piece coated in a thin coating of gold. Solar cells were revolutionised in 1954 with the creation of the Pearson et al. crystalline silicon solar cell, which achieved solar efficiency of 4.5% at the time. All solid-state photovoltaic cells with 9.7% conversion efficiency were discovered by Kim et al. for the first time. Perovskites had gotten a lot of interest from scientists because of how inexpensive they are and how effective they are. In 2016 the power conversion efficiency was 22.1% recorded by National Renewable Energy Laboratory(NREL).(Zhou et al., 2018).

In 2020, power conversion efficiency was 25.5% recorded including tuneable bandgap, high charge mobilities and high photoelectric properties.

2.1. Structures and Principles of Perovskite Solar Cells

It shares a chemical composition with titanium Oxide, which has ABX_3 as its molecular structure. Because of the cubic lattice, unique, optical and electromagnetic properties, they have attracted wide attention to the researchers. Perovskite materials are used in solar cells like hybrid compound (organic - inorganic) with a perovskite structure like Methylammonium, $CH_3NH_3^+$, Formamidinium or MA^+ in group A are located in the face centered cubic lattice also as well in the metal cation B (Pb^{2+} , Sn^{2+} etc.) and halogen anions X (Cl^- , Br^-) and I occupy the core and apex of the octahedral respectively.

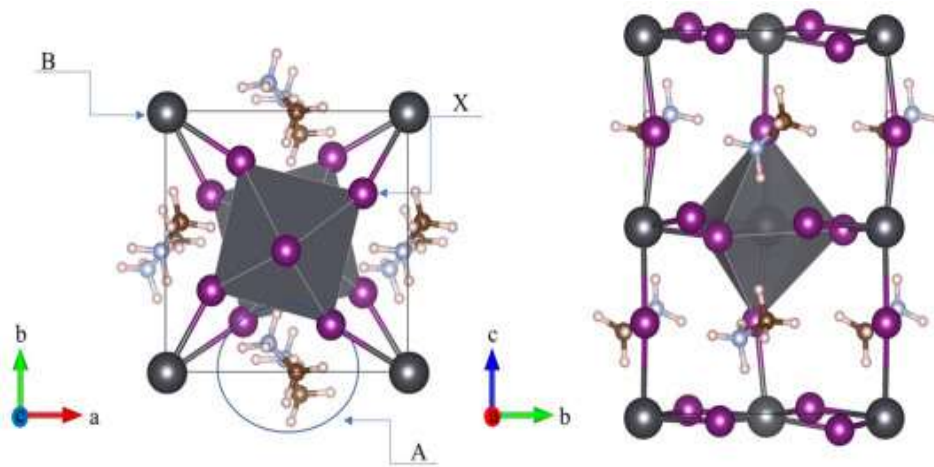


Figure 5: Structure of perovskite solar cells

These materials have four characteristics with such structure. In addition to their superior photoelectric characteristics, low excitation binding energy, and strong optical penetration, these materials also feature low excitation energy. Perovskite, on the other hand, is a light-absorbing layer that can efficiently absorb solar electricity. Third, a higher dielectric material may simultaneously transport and absorb electron - hole pairs. As a final result, electrons and holes may be transmitted simultaneously over a distance of up to 100nm or one metre.

These properties contribute to high open circuit voltages and fault current initial concentration when used to solar cell devices.(Zhou et al., 2018).

There are four basic steps through which perovskite solar cell can be described.

Firstly, Photon's absorption and exciton formation. Secondly, Exciton's diffusion. Thirdly splitting charge transmission and lastly charge collection.

2.2 Components of Perovskite solar cells

2.2.1 Hole Transport Layers (HTL)

Electron Transportation substantial and hole conveyance substantial are complex components of perovskite solar cells because they transmitted charges selectively within device, they are low cost, and they have efficient device stability and control photovoltaic parameters. According to the processing method and form hole transport material and efficient charge extraction the thickness of hole transport material is critical for all. For an optimal p-type semiconductor the Opto-electric device is require. For successful results perovskite solar cells used these p-type materials, the hole transport materials HOMO should be less powerful than the VB (valance band) of the perovskite solar cells. Owing to the change in fermi levels these holes transfer takes place. As well the hole conductor should display abundant hole mobility around ($>10cm^{-3} cm^{-2} V^{-1} s^{-1}$) and be comfortable under the multi environmental factors. Infact they have highly hole mobility, low cost as well they have attractive characteristics the inorganic hole transport materials (CuI, CuSCN, MoOx, CuOx, and NiO) used in perovskite solar cells because of these features. Polymeric materials have some downsides Purification, compound identification due to the unknown molecular weight, and imperfect penetration through the nanomaterial have all contributed to an increase in the effort necessary to manufacture tiny organic compounds like the HTMs..(Mahajan et al., 2022).

2.2.2 Electron Transport Layers (ETL)

The electron transport layer extracts and transports photo generated electrons from the perovskite layer to the cathode or anode. Simultaneously, the ETL modifies the interface among the perovskite coating and the conductor, reducing charge recombination. (Zheng et al., 2019).

2.2.2.1 Electron Transport materials in Perovskite Solar Cell

Furthermore, a one-dimensional nanorod ETL allows for rapid charge transport in a photovoltaic cell. Excellent pore filling achieved by manipulating the gaps between the nanorods and nanosheets was discovered to be beneficial in terms of increasing the fill factor (FF) and PCE. A variety of metal oxides, including TiO_2 , ZnO , SnO_2 , SiO_2 , and ZrO_2 , can be used as ETL or scaffold material. Each material has distinct advantages that help to increase the PCE. PSC has been manufactured using two different types of solution processes. Perovskite was deposited in one step, resulting in an average PCE of 8.19 percent from rutile-perovskite solar cells and 7.23 percent from anatase-perovskite solar cells. Nanova et al. predicted that an optimal porosity and an optimal perovskite over layer are required to control the shunt resistance and series resistance. (Mahmood et al., 2017).

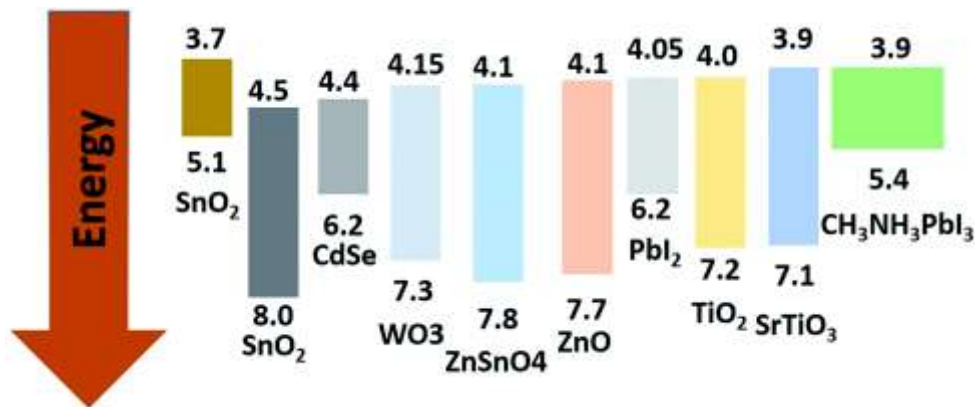


Figure 6: Metal oxides ETM for perovskite solar cells

Furthermore, the goal is to reduce electron-hole interaction at the interface and increase carrier separation. The efficiency of solar cells is enhanced by ETL properties such as reference speed, energy states alignments, trapping states, contact, and surface shape. Consequently, charge movement is quite high. Efficient perovskite solar cells rely on effective charge absorption and transmission, as well as limiting recombination process at the interface, thanks to ETL's role in this process. One such component that contributes to perovskite performance of the device is the matching of energy state. By aligning the ETL with the absorber layers, extraction and transportation of electron becomes considerably more efficient. Increase the device's open-circuit voltage and the short-current density (J_{sc}), as well as the fill factor (FF) (V_{oc}). Perovskite solar cells with high efficiency are defined by characteristics such as charge absorption, transportation, and combination at the interface. The electron carriers' layer and productivity of photoelectric perovskites may be improved through interface engineering. The ETL's surface morphologies can also be improved in order to increase the device's performance. A device's qualities are influenced by all of its components. ETL-free devices claimed to have a conversion efficiency of more than 13%, although the integration of electron carriers' channels still had a dominating performance and stability. As a result, strong electron mobility, a broad band gap, and a suitable energy level are all required for successful electron carriers layers. This has been common practise to construct highly efficient PSCs using broad band gap organic semiconductors because of their inexpensive cost and strong charge mobility. At this point in time, ETLs consist of binary or ternary titanium oxide and certain chalcogenides. (Rai et al., 2020).

2.3 Why ZnO Used in Electron Transport Layer

It is common knowledge that TiO_2 has a higher PCE than other ETLs, but its poor conductance and electron affinity are both undesirable for electron collecting and transport qualities. Furthermore, they feature surface and grain boundary defects, such as oxygen - containing functional groups and metal interstitials that make these less effective and volatile. There are several ways to enhance the conductivity of ETLs, however doping is one that has been shown to boost ETL conductivity and optimise the energy level match between ETLs and the polycrystalline film. Improved perovskite solar cell system performance and decreased hysteresis have been achieved as a result of the high conductivity, good electron recovery, reduced trap-state density and high electron mobility and transport process. (Lema et al., 2021).

ETL is a crucial component in perovskite solar cells, as it aids in the extractions and transport of photo generated electrons. Different materials are used for electron transport layer such as TiO_2 , WO_3 , SnO_2 . Because of its advantages such as low cost and ease of manufacture, good band gap and long electron lifespan, TiO_2 is commonly used in perovskite solar cells. However, TiO_2 is unstable in the ultraviolet area and requires a high temperature. However, in this proposed work ZnO would be used due to its greater electron mobility and greater conductivity magnitude than TiO_2 . ZnO has a well-suited band gap and can be manufactured easily at low temperatures, ZnO also has been widely documented in ETL, resulting in interfacial recombination. (Han et al., 2020).

2.4 Carbon nanotubes

Carbon has the atomic number 6 and six electrons that occupy the $1s^2, 2s^2$, and $2p^2$ atomic orbitals. Hybridization is possible in the sp , sp^2 , and sp^3 types, respectively. Graphite, fullerenes, and nanotubes, all of which have sp^2 carbon bonds, have sparked interest in this topic. The preponderance of carbon nanotubes' physical features is owed to graphene. When it comes to carbon atoms, the hexagonal honeycomb pattern in graphene provides a framework for allotropes like fullerene and carbon nanostructures, which are all based on the hexagonal honeycomb pattern. According to theory, a carbon fibre is just a tube produced from graphite sheet that's been folded up.

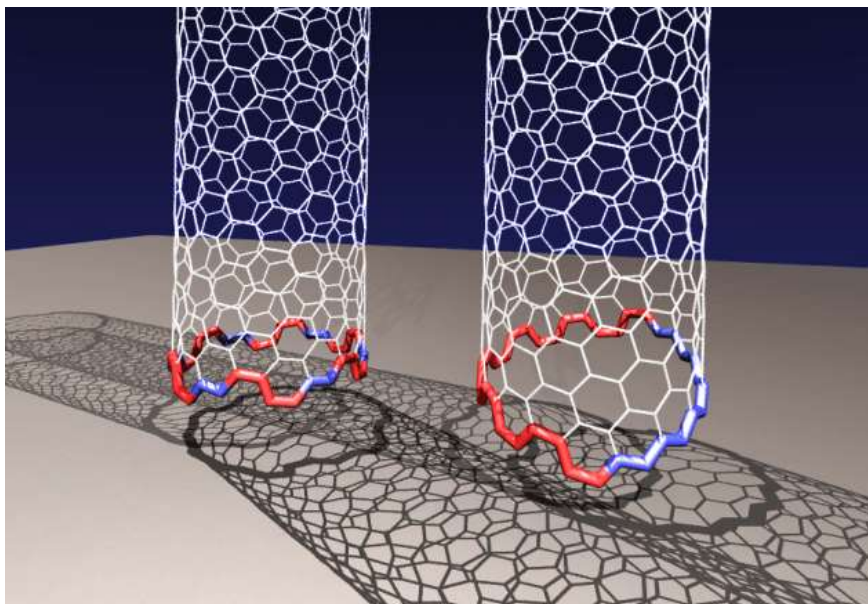


Figure 7: Representation of Carbon nanotubes

Carbon nanotubes' elasticity is yet another remarkable attribute. However, elasticity is a limited property of nanotubes and it is conceivable to momentarily distort the nanotube's shape under extremely physically significant pressures pressing. This is because nanotubes have a very high elasticity and may bend, twist, kink and eventually buckle without hurting them. If the carbon bonds are rearranged or there are atomic vacancies in the nanotube's structure, this might weaken the nanotube. (Eatemadi et al., 2014).

2.5 Incorporation of Carbon nanotubes in ZnO nanocomposites

Conductivity enhancement is accomplished by incorporating CNTs into the target material, resulting in a synergistic effect that improves the material's electrical conductivity.

To improve the electrical conductivity of materials carbon nanotubes are used because of their excellent electrical properties. By joining the carbon nanotubes to the target materials, the electrical conductivity can be enhanced. So, carbon nanotubes have been incorporated with ZnO nanostructures to improve its electrical conductivity. (Abdulhameed et al., 2021)

3. EXPERIMENTAL AND METHODS

Glassware and instrumentation

Glassware used for the nanoparticle's fabrication were beakers, disposable pipettes, specula, magnetic stirred, glass samples, bottles, centrifuged tubes, nitrile gloves and mask. Ph meter was used for the identification of pH. Hot plate, oven, and autoclave were used for the preparation of white precipitants of ZnO catalyst. BSA224S Sartorius microbalance were utilized for weighing chemicals. The centrifuge was used for the centrifugation of different morphology of ZnO nanocomposites. Further for the synthesis of carbon nanotubes CNT microwave oven, cylindrical quartz and rotary pump tubes were used.

For the incorporation of Carbon nanotubes with ZnO composites same instruments are used including sonicate and microwave oven.

3.1 Incorporation of graphene with ZnO nanocomposites

To manufacture the carbon/ZnO nanocomposites solvent thermal method was used. During the synthesis of carbon with ZnO nanocomposites, 0.9975g of ZnO was dispersed in 20ml of ethylene glycol in beaker and 20 ml of graphene about 0.5wt%, 1wt%, 1.5wt%, and 2wt% were dissolved in separate beaker then sonicated for one hour. Graphene solution was kept under stirred and 20 ml of ZnO solution was added on to graphene solution. Under

continuous stirring process 0.1 M of NaOH in 5ml of DI water was mixed with solution. After 30 minutes of stirring the mixture was transfer to autoclave under 160 for 48 hours. The solution was centrifuged and washed several times with ethanol then dried at 60°C for 24 hours.(M. M. Mohamed et al., 2019).

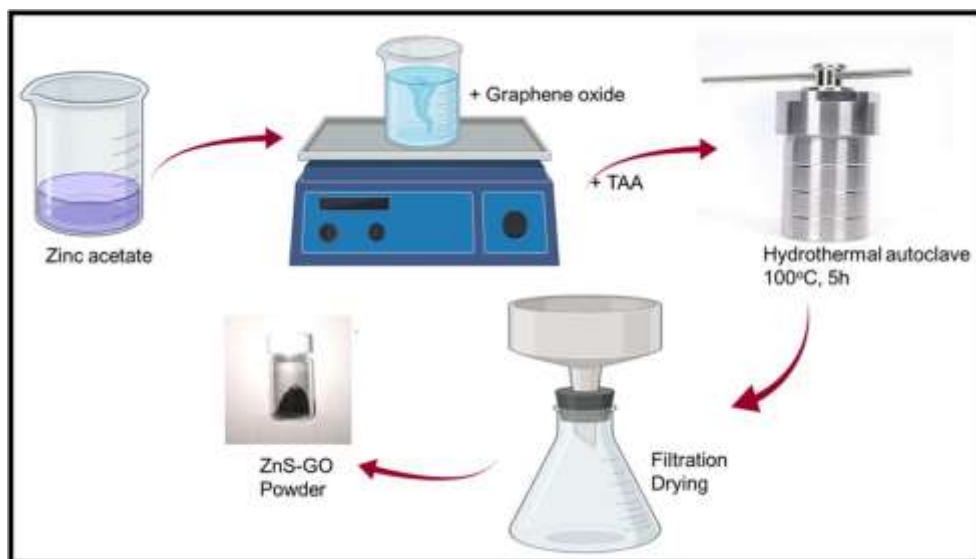


Figure 08: Schematic of the graphene/ZnO NS synthesis procedure

3.2 Testing

3.2.1 Preparation of Thin Films

3.2.2 FTO Glass Substrates

FTO (Fluorine-doped Tin Oxide) glass is a transparent conductive metal oxide that can be used in a fabrication of a transparent electrodes for thin film photovoltaics, such as; organic photovoltaics, amorphous silicon, cadmium telluride, dye-sensitized solar cells, and hybrid perovskites. There are several properties of FTO glass that make it suitable for the fabrication of a wide range of optoelectronic devices; these include low surface resistivity, high optical transmittance, scratch and abrasion resistant, thermally stable up to high temperatures and inert to a wide range of chemicals.

Drop Casting Method

I have prepared five catalysts (ZnO, graphene, graphene/ZnO nano prisms, graphene/ZnO nano rice, graphene/ZnO hollow prisms). Then I took each catalyst (25mg) to prepare for paste that is varied with 0.5ml of dimethyl formamide holding 25μL of 5wt% Nafion to help in adhesion under sonication to make a slurry. The slurry was then dip-coated onto FTO glass substrate and tap molding procedure engaged to confirm the make breadth. After the air aeration, the films were hardened at 350°C for 30 minutes. (Eslamian & Soltani-Kordshuli, 2018).

4. RESULTS AND DISCUSSION

4.1 Structural analysis

Results from X-ray powder diffractometry, a non-destructive method for determining crystal structure, composition, and other physical characteristics of produced materials, demonstrate that all ZnO nanostructures have a hexagonal wurtzite structure. ZnO films (on a glass substrate) and perovskite films (on a ZnO/FTO-coated glass surface) both have distinct Xrd analysis, as seen in Fig. Graphene's diffraction pattern, which has a distinct characteristic peaks, is seen in Fig. 10. Fig. b shows diffraction peaks at 2θ equal to the reflection from the plane (002), (100), (002), (101), (102), (110), (103), (112), (201) respectively. Except the peaks of ZnO nanostructures no other peaks are observed which indicate that no impurity is present in the final product of hydrothermal synthesis. It can be shown in Fig. c that, despite the existence of graphene in Nanomaterials, there is no dispersion peak associated with graphite. So, the X-ray diffraction analysis of the G/ZnO NS is quite similar to the ZnO design.

When comparing the pure ZnO film to the G/ZnO NS film, I found that the diffraction peak at (101) was much stronger in the G/ZnO NS film, suggesting that this material is involved in electron transport. Which points to graphene's function in the enhanced crystallization and faster development of polycrystalline thin films. (Chandrasekhar & Komarala, 2017).

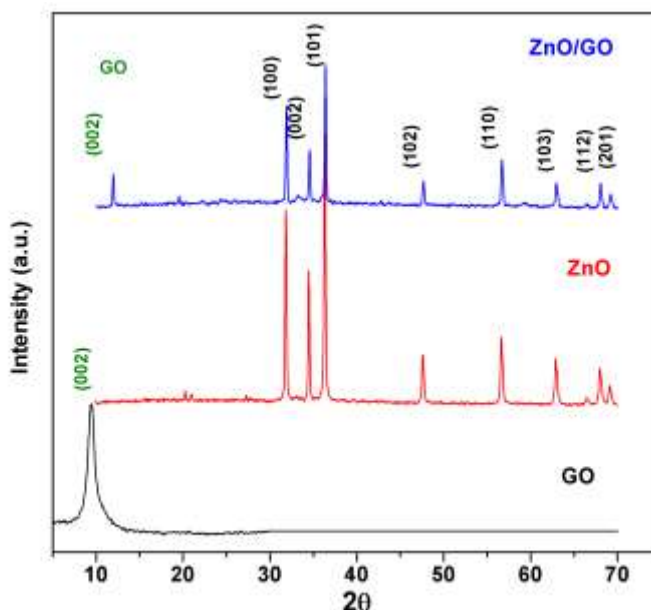


Figure 9: XRD Pattern of graphene, ZnO and G/ZnO Nanostructures

4.2 Morphology and Elemental Analysis

Studied by means was used to study the nanoparticles of ZnO. Images from a scanning electron microscope (SEM) of each of the nanostructures depicted in the Figures. ZnO is composed of a variety of nanomaterial's, comprising hexagonal nano refraction, hollow prisms, and rice-like morphology. Broken prism ends and exploded prisms in fig. (b) suggest that the prisms' cores are hollow because of the existence of O-2 polar facets. Besides, nano rice tends to aggregate and build in an unorganized form.

The SEM images of G/ZnO are shown in fig (d), (e) and (f). The samples were prepared with different concentration as 0.5wt% , 1.0 wt% and 2wt% G/ZnO NS. The fig (f) shows that the surface morphologies of G/ZnO NS with 0.5wt% is much different than other G/ZnO NS because of the tiny addition of graphene, whereas there is a small difference between fig (d) and (e). In fig (e) in case of 1wt% of G/ZnO NS the grains are close to each other with some pin holes.

In case of 2.0wt% of G/ZnO NS the surface morphology of fig (d) is much better than other NS because of high surface area.

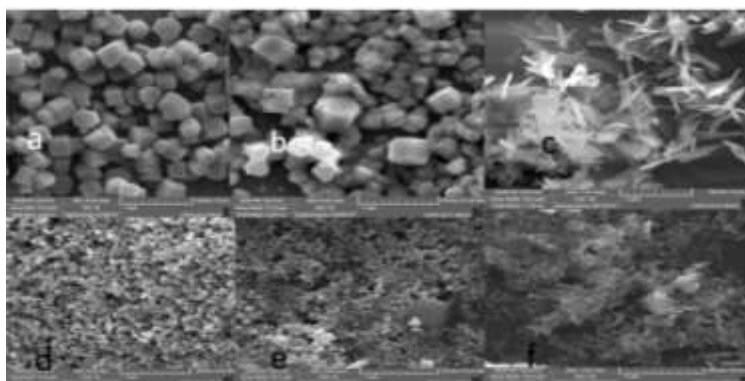


Figure 10: The SEM images of ZnO nano structures as (a) Nano prisms (b) Hollow prisms (c) Nano rice; incorporation of G/ZnO NS (0.5wt%, 1wt%, 0.2wt%).

4.3 Optical properties

In the following graph the transmittance of ZnO is on the peak level then the other nano composites but the absorption is low then the other composites. The absorption of 2.0wt % is high because the graphene primarily. The presence of pi-electron on graphene's surface establishes Van der Waal forces due to which the composite can absorb a wide array of chemical compounds. Other factors which are contributing in maximum adsorption by ZnO-GO 2.0 wt% are enhanced surface area, availability of more active sites and chemical stability of the composite.

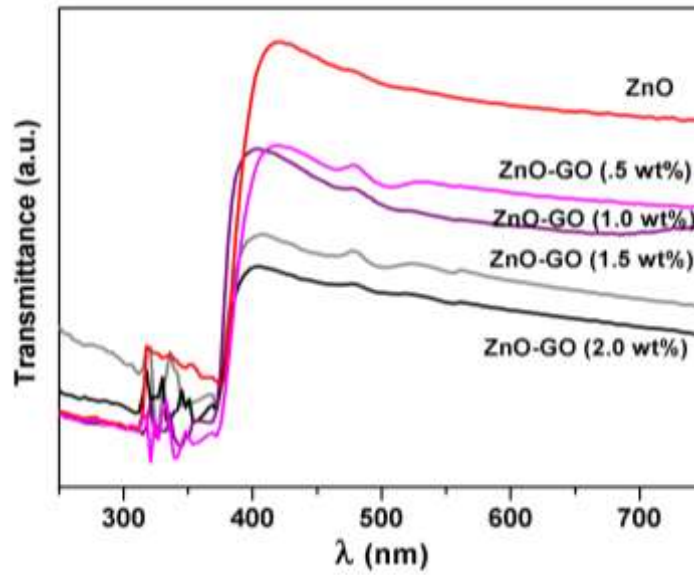


Figure 11: UV-Vis spectroscopy of as synthesized ZnO nanocomposites and G/ZnO NC with different concentrations as 0.5%,1.0wt%,1.5wt% and 2wt%.

The band gap of as synthesized materials was calculated by using a model Kubelka Munk function e . The UV vis absorbance data is utilized to calculate the equation as below:

$$\alpha h\nu = A (h\nu - E_g)^n$$

where $h\nu$ is the energy of photon

α is absorption coefficient

E_g is the band gap material and n have $\frac{1}{2}$ and 2 for indirect and direct band gap semiconductor materials respectively. Band gap for grown nanostructures was calculated using the Tauc plots as shown in fig. The optical band gap of the pure ZnO was 3.3eV reducing to 3.1eV for the graphene/ZnO nanocomposites as shown in fig. This decrease in bandgap is due to the concentration of graphene. It was also analysed that with increasing the concentration of GO content the band gap narrowing also increased that is indicating the interaction between ZnO and GO increased. (Saleem et al., 2018).

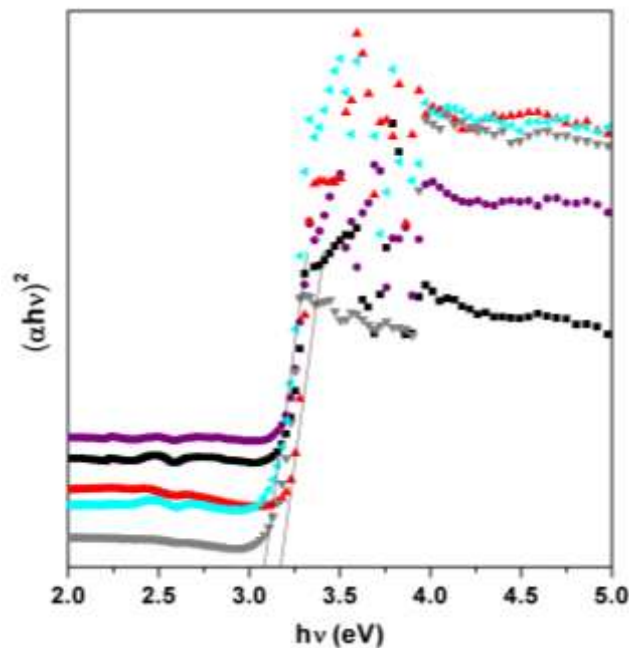


Figure 12: Band gap analysis of ZnO NS and G/ZnO nanostructures

5.4 IV-Testing

To study the electrical properties of the GO/ZnO nanocomposite (.5wt%,1.0wt %,1.5wt% and 2%wt) thin films we analyzed the current-voltage (IV) characteristics. From this graph it is observed that for the pure ZnO nanocomposites thin films the current increased linearly with increased in voltage that represent the ohmic contact between ZnO nanoparticle layer and ITO substrate. We also analyzed that current flowing through the GO-ZnO nanocomposites films was lower than that the pure ZnO nanoparticle film, when we increased the concentration of GO in the nanocomposites then it decreased further. The current was decreased because of the presence of functional group sheets. Some functional groups are present in highly oxygenated GO disrupt the sp^2 hybridization of the carbon atoms, making the material insulating. However, post annealing of the performed GO-ZnO 2%wt film at 400°C was also demonstrated to result in rGO thin film with improved conductivity that is shown graph. During thermal annealing, oxygenated functional groups in GO can be removed via detachment of functional groups from the carbon basal plane, decreasing the sheet resistance of the film. Annealing of the sample at high temperature improved the sp^2 carbon network in the GO sheets, thereby increasing the conductivity of the sample.

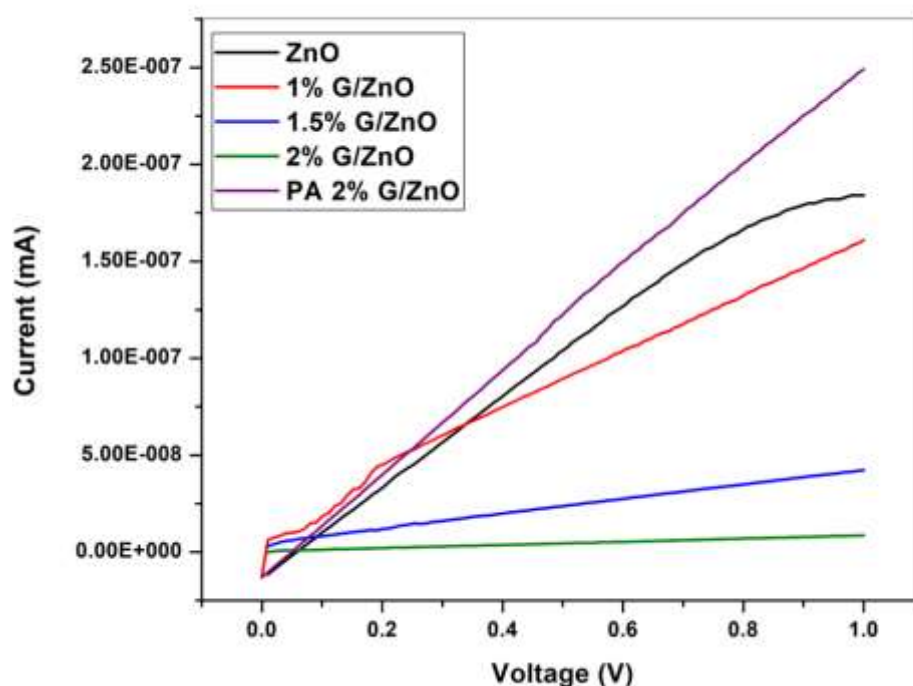


Figure 13: IV-Characteristics of Graphene/ZnO nanocomposites

CONCLUSION

Graphene was successfully prepared by Hammer's method and ZnO nanostructures were prepared by changing solvent conditions. The Incorporation of Graphene/ZnO nanostructures was synthesis by changing different concentration like 0.5% to 2.0% wt and deposited onto FTO substrate by employing drop casting technique-Ray diffraction analysis of the G/ZnO nanostructures is quite similar to the ZnO design. When comparing the pure ZnO film to the G/ZnO NS film, I found that the diffraction peak at (101) was much stronger in the G/ZnO NS film, suggesting that this material is involved in electron transport. In case of 2.0wt% of G/ZnO NS the surface morphology of nano prisim is much better than other NS because of high surface area. From UV it is observed that the transmittance of ZnO is on the peak level then the other nano composites but the absorption is low then the other composites. The absorption of 2.0wt % is high because the graphene primarily. These results suggest that thermally post annealed GO-ZnO nano composites could be used to improve the conductivity of electron transport layer in perovskite solar Cells.

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