An Alternate Solution for Power Consumption Using Self Powered Nanogenerator

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Abstract- In this paper, the fabrication and demonstration of self-powered piezoelectric nanogenerator for converting mechanical energy into electrical energy can be done. The advantage of the piezoelectric nanodevice is that electrical energy can be produced from different types of external stimuli such as including body movement, vibrations, and hydraulic forces or air forces which resulting a wireless self-powered system. The nanogenerator is a five-layer structure: a flexible polymer substrate, ZnO and graphene oxide nanowire textured films of graphene on its top and bottom surfaces. When the nanowires are compressed as a result of movement, the coupling of piezoelectric and semiconducting properties in zinc oxide and graphene oxide creates a strain field across the nanowires as a result of its bending. The successive compression and release resulting the electrons to flow back and forth, producing an electrical current. The principle of nanogenerator shows a new scheme for novel self-powering nanotechnology that harvests electricity from the environment for applications like portable electronics. The feasibility of using ZnO and Graphene oxide nanowire nanogenerators for building self-powered systems with the capability of long distance data transmission in applications such as environmental infrastructures wireless bio- sensing, environmental infrastructure monitoring, sensor networks, national security, and personal electronics.

Keywords: *Nanogenerator, Nanodevice, Nanowires, Piezoelectric, Semiconducting, ZnO, Graphene Oxide*

I. INTRODUCTION

Due to the increasing amount of global warming and energy crises, searching for new renewable and green energy resources is one of the most important challenge to sustainable development of human civilization. The energy required for the operation of nano scale devices is necessary and even priceless. Different proposals have to be developed to solve the energy problems in the world at all scales. Photovoltaic, electromagnetic induction and thermal electricity are the common technologies for energy harvesting. A self-sufficient power source generating its power from the environment and it does not require any maintenance . In order for any system to be self-sufficient, it must utilize its energy from its surrounding environment and store this energy for later use.

There are abundant amount and types of mechanical energy exist in our living environment, such as body movement,light,wind, noises, mechanical vibrations etc. The Nanogenerator converts the given unspecific mechanical energy into electric energy using piezoelectric nano wire arrays. The mechanism of the nano generator depends on the piezoelectric potential created in the nano wires by an external strain results the transient flow of electrons in the external load .One of the main advantage of using nanowires is that they can be triggered by any tiny physical motions, which is ideal for generating random energy in the environment. The various piezoelectric materials used for the nano generator are $BaTiO_3$, PZT, ZnO, CdS and GaN etc. Basically nanowires are used due to their responsiveness and robustness to tiny random mechanical disturbances. ZnO nanowires are preferred for these nano devices since ZnO possess the following properties such as High structural and property controllability, Easy to synthesis and integrate with Si based microelectronics, , Non-toxic , , bio-compatible, High stability and Extremely high elasticity and Environmental friendly.

1.2 Mechanism of Nanogenerator

Piezoelectricity, conversion of mechanical energy to electrical signals, is one of the most adaptable phenomena to collect energy to power small-scale electronic devices from the environment. In addition, the use of a piezoelectric polymer will increase the amount of generated piezoelectric potential. The different configurations of zinc oxide nanowire nanogenerators offer a adaptable, cost-effective, long term stable nanogenerator for promising future application. The main aim is to increase the efficiency and reduce the cost of all the setup and to use the nanogenerator as an alternate solution for renewable energy. The main advantage of the piezoelectric nanodevice is that electrical energy can be generated by a variety of external impulse, including body movement, vibrations, and hydraulic or air forces, resulting in a wireless self-powered system. The nanogenerator was made of a free cantilever beam that consists of a five-layer structure such as a flexible polymer substrate, ZnO and graphene oxide nanowire textured films of graphene on its top and bottom surfaces. When the nanowires are compressed as a result of movement, the coupling of piezoelectric and semiconducting properties in zinc oxide and graphene oxide creates a strain field across the nanowires as a result of its bending. Due to continuous compression and release, the electrons flowed back and forth, producing an electrical current. Zinc oxide (ZnO) is a unique material possessing semiconducting and piezoelectric dual properties. ZnO posses the richest family of nanostructures compared to all materials, both in structures and properties. A variety of ZnO nanostructures, such as nanowires, nanotubes, nanofibers, nanospheres and nano-tetrapods, nano-cabbage, nanocombs, nanowalls and nanoprisms have been successfully grown by different methods including vapour-liquid-solid (VLS) technique, thermal evaporation, low temperature aqueous chemical growth (ACG), electro deposition, etc. The nanostructures have diverse applications in sensors, optoelectronics, and transducers, piezoelectric elements for nano-generators, sunscreens and biomedical science since it is a bio-safe material. ZnO has favourable band energies for forming a heterojunction with many organic and inorganic donor materials.

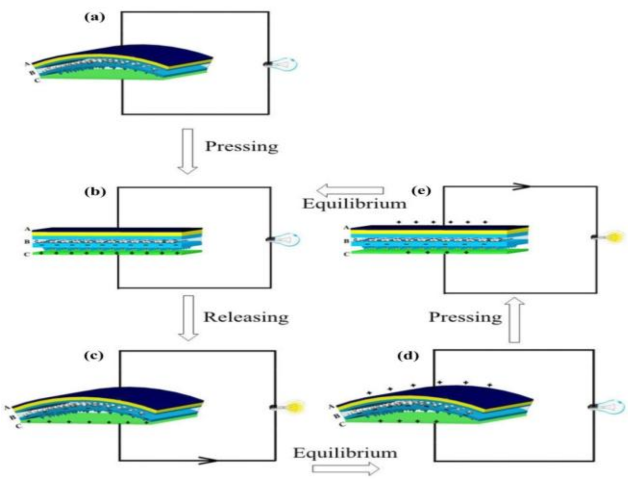

Fig1: Working principle of nanogenerator

The concept of nanogenerator demonstrated a new idea for unique self-powering nanotechnology that harvests electricity from the environment for applications like portable electronics. The feasibility of using ZnO and Graphene oxide nanowire nanogenerators for building self-powered systems with the capability of long distance data transmission in applications such as environmental infrastructures wireless bio- sensing, environmental infrastructure monitoring, sensor networks, personal electronics, and even national security. The working principle was assigned to the coupling between the piezoelectric and semiconducting properties of the ZnO/Graphene NW.

1.3 Materials Used

The materials used in the synthesis of nanogenerator is Zinc Oxide, Graphene, Ply Vinyl Alcohol and Aluminium Substrate

1.3.1 Zinc Oxide

Zinc Oxide is an inorganic compound with formula ZnO. ZnO is a white powder which is soluble in water. Ordinary white powdered ZnO can be produced in the laboratory by electrolysing a solution of sodium bicarbonate with a zinc anode zinc hydroxide of hydrogen are produced. The zinc hydroxide upon heating decomposes to ZnO.

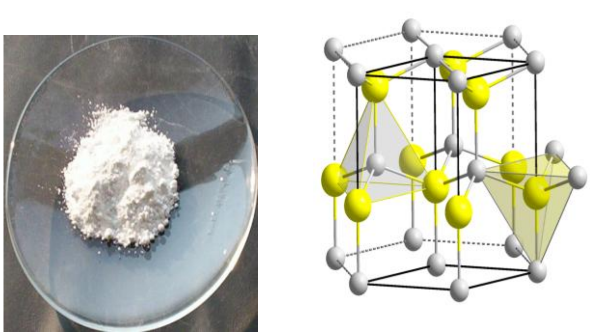

Fig 2:Crystalline and Wurtzite structure of ZnO

1.3.2 Graphene

Graphene is an allotrope of carbon in the form of a atomic scale dimensional, hexagonal lattice in which one atom forms each vertex. It has the basic structural elements of other allotropes such as graphite, charcoal, carbon nanotubes and fullerenes. It can also be considered as an indefinitely large aromatic molecule, the limiting case of the family of flat hydrocarbons.Graphene has many extraordinary properties. It is nearly 200 times stronger than steel by weight, conducts heat and electricity with great efficiency and is almost transparent. The term grapheme was first appeared in 1987 to explain single sheets of graphite as a constituent of graphite intercalation compounds (GICs) where conceptually a GIC is a crystalline salt of the intercalant and graphene.

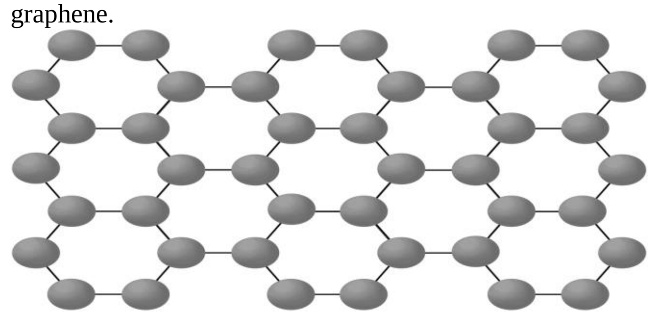

Fig 3: Structure of Graphene

Single layers of graphite were also noticed by transmission electron microscopy within bulk materials. Initially graphitic films can be make atomically using exfoliation techniques similar to the drawing method. Graphene has a theoretical specific surface area (SSA) of 2630 m^2/g. This is much larger than that reported to date for carbon black (typically smaller than 900 m^2/g) or for carbon nanotubes (CNTs), from ≈100 to 1000 m^2/g and is similar to activated carbon. Graphene is a crystalline allotrope of carbon with 2-dimensional properties. Its carbon atoms are densely packed in a regular atomic-scale chicken wire (`G) pattern. Each atom has four bonds, one σ bond with each of its three neighbours and one π-bond that is oriented out of plane. The atoms are about 1.42 Å apart Graphene's hexagonal lattice can be regarded as two interleaving triangular lattices. This perspective view was successfully used to calcinate the band structure for a single graphite layer using a tight-binding approximation.

1.4 Objective of Study

This dissertation focuses on synthesis, surface functionalization and application of graphene and ZnO nanostructures in nano and optoelectronic devices and sensors. ZnO nanostructures contain a large number of defects at room temperature The main objective of this study is to study the synthesis of Zinc Oxide, ZnO typically exhibits one emission peak in the UV region owing to the recombination of free excitons, and one or more peaks in the broad visible spectral range. Nevertheless, there is a possibility of enhancing or minimizing this broad defect emission. Our objective is to control and tune the surface properties according to the application requirements, e.g. white light emitting diodes (WLED)

Graphene Oxide, to know the characterization techniques such as XRD,FTIR,UV,SEM,to study the layer formation in a nanogenerator and to know the applications of a nanogenerator in our day to day life.

The amalgamation of the exceptional properties of graphene with good semiconducting properties of ZnO can pave the way towards the realization of future devices such as transparent, flexible electrical and photonic devices. There has been relatively very less work reported on this combination, previously. We also aim to analyse the growth mechanism of ZnO nanowires on high quality (CVD grown, epitaxial) graphene surface and the junction behaviour. This combination of 1D ZnO and 2D graphene can be very important for realizing the basic goal of 3D assembly at the nanoscales.

II. METHODOLOGY

In this chapter, the details of the experimental techniques used to grow and synthesis reproducible, good quality graphene and ZnO are described. These include wet chemistry routine and sublimation on aluminium by modified Hummer's method for the preparation of graphene, and aqueous chemical growth (ACG), electrochemical deposition (ECD) and vapor-liquid-solid (VLS) for ZnO nanostructures. The main part of nanogenerator is the nanorods which is made up of ZnO/Graphene composite and can be grown vertically in an autoclave. These nanostructures were incorporated in devices with patterns defined by lithography, etching (dry and wet), metallization, passivation etc.

2.1 Initial Characterisation

In first phase various works have o be done. Among this the first one is to take a literature survey about this project and the next one is to prepare graphene for preparing nanorods and then going for the preparation of ZnO-graphene nano composite .It is a difficult task which can take more time .The final step is to characterize all the nanoparticles which is produced. In this project various characterization techniques such as Scanning electron Microscopy, X-Ray Diffraction techniques, Ultra Violet Visible Spectroscopy and Fourier Transform Infra- red Spectroscopy can be done.

2.2 Chemical Background

2.2.1 Properties of ZnO

On the other hand, zinc oxide (ZnO) is a unique material possessing semiconducting and piezoelectric dual properties. A variety of ZnO nanostructures, such as nanowires, nanotubes,nanofibers, nanospheres and nano-tetrapods, nano-cabbage, nanocombs,nanowalls and nanoprisms have been successfully grown by different methods including vapour-liquid-solid (VLS) technique, thermal evaporation, low temperature aqueous chemical growth (ACG), electrodeposition, etc. The nanostructures have diverse applications in optoelectronics, sensors, and transducers, piezoelectric elements for nano-generators, sunscreens and biomedical science since it is a bio-safe material.P-type doping of ZnO is still a problem that is impeding the possibility of a ZnO p-n homojunction devices [12]. ZnO has favourable band energies for forming a heterojunction with many organic and inorganic donor materials.

2.2.2Properties of Graphene

Graphene is a single layer hexagonal packed carbon atoms, has attracted recently in recent year because of its exceptional electronic, mechanical, optical, and thermal properties. Graphene derivatives, such as graphene oxide (GO) and reduced graphene oxide (rGO) sheets, possess surface defects and oxygen functional groups, which make them ideal templates for synthesis of metal and semiconductor nanoparticles (NPs). Graphynes graphene are almost similar, the main difference between is that they have triple bonds between some of their carbon atoms. Graphynes also possess Dirac cones according to principles electronic structure calculations. Mechanical properties of free-standing monolayer graphene membranes have been measured experimentally by Nano indentation in an atomic force microscope. These measurements correspond to a Young's modulus of $E = 1.0 \pm 0.1$ TPa and a third-order elastic stiffness of $D = -2.0 \pm 0.4$ TPa, assuming an effective graphene thickness of 0.335 nm . The shear modulus (G), has been reported to be 280 GPa for CVD grown graphene films. Second and third order elastic stiffness was measured to be 340 Nm–1 and 690 Nm–1, respectively. The fracture strength has been measured to be as 125 GPa which represents the intrinsic strength of a defect free graphene sheet.

2.2.3 Properties of Graphene/ZnO composite

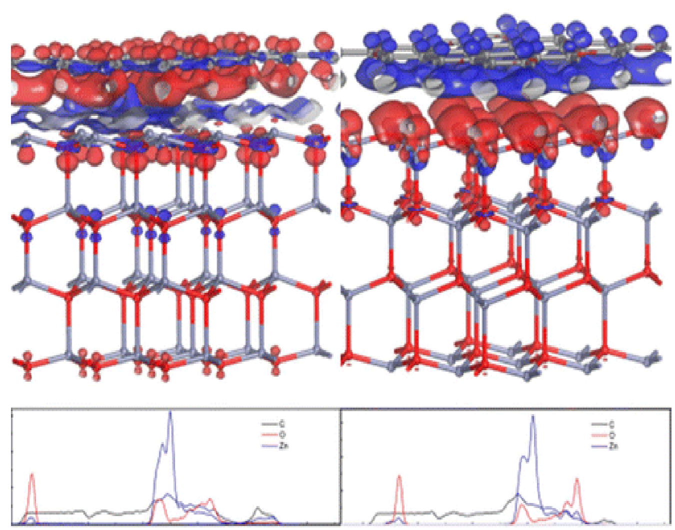

Fig 4: Structure of Graphene/Zno Composite

The structure as well as electronic and optical properties of the ZnO/graphene composites was theoretically studied by density functional theory calculations.

2.3 Synthesis of Nanoparticles

2.3.1 Preparation of ZnO

The zinc oxide can be prepared by adding 1M of zinc acetate with 0.1M of sodium hydroxide and the continuous stirring will results zinc hydroxide and hydrolysing the obtained product will resulting the growing of rod like structure and is heated at 90^{o}C will results Zinc Oxide[1,9].

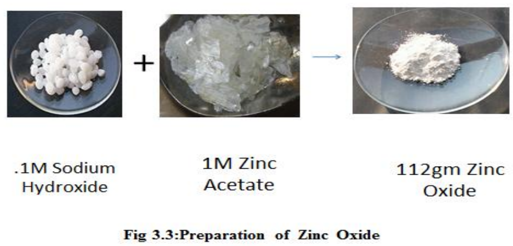

Fig 5:Preparation of Zinc Oxide

2.3.2 Preparation of Graphene

Graphene can be prepared by taking 2g of graphite was sonicated in 200ml water for 30min to obtain expanded Graphene and filtered. 46ml of H_2SO_4 was added to the expanded graphite. 6g of potassium permanganate was crushed and added slowly to the above solution with continuous stirring with the temperature not exceeding 20^oC. The stirring was continued for 2 hours at room temperature and 90ml water was added. Stirring was done for another 1 hour and 280ml of water was added to terminate the reaction. Add 5ml of hydrogen peroxide to the above solution for verifying complete reaction of potassium permanganate. The solution was filtered and washed with diluted hydrochloric acid with a ratio (10:1) to remove metal ions. Then the filtrate was washed several times with water until the pH value of the filtrate reaches to pH7. The resultant filtrate was Graphene oxide. The Graphene oxide was heat refluxed for 2hours with hydrazine hydrate with a ratio 1:2 in the presence of water. The hydrazine hydrate acts as reducing agent and reduces Graphene oxide to Graphene.

Fig 6:Prepared Graphene

2.3.3 Preparation of Graphene/ZnO Composite

1M of zinc acetate was taken in 50 ml water. To that solution 1M of sodium hydroxide was added drop wise with continuous stirring. Meanwhile 0.1 g of prepared graphene was added along with the above solution. The solution was then sonicated for 30mins for uniform dispersion of graphene in the zinc solution. The solution is then kept for hydrothermal treatment using autoclave. The temperature was set to 180ºC for a time period of 6 hrs. After the hydrothermal treatment, the precipitate obtained was filtered and washed with ethanol several times. The filtrate obtained is the required graphene-zinc oxide composite[9].

Fig 7: Prepared graphene/ZnO Composite

III RESULT &DISCUSSION

Graphene and ZnO nanostructures were used to fabricate nano and optoelectronic devices, including field effect transistors (FETs), light emitting diodes (LEDs) and sensors. The junction between graphene and ZnO has also been characterized and reported. In this chapter, the experimental results of the junction analysis and the fabricated devices will be given and discussed. Four types of Characterization can be taken to prove that any impurity is not added in the substrate

3.1 Characterisation Of Nanoparticles Using XRD

The figure represents the X-ray diffraction pattern of ZnO nanopowder. A definite line broadening of the XRD peaks indicates that the prepared material consist of particles in nanoscales range. The XRD peaks shows characteristic diffraction pattern of ZnO alone. The graphene peaks were diminished in the XRD pattern. This may be due to the formation of single layer graphene formation over the ZnO rods which do not produce any peaks. The diffracted peaks at 31.251, 33.903, 35.735, 47.027, 56.081, 62.345, 65.875, 67.438, 68.577, 72.03, and 76.45 were assigned to (1 0 0), (2 0 0), (1 0 1), (1 0 2), (1 1 0), (1 0 3), (2 0 0), (1 1 2), (2 0 1), (0 0 4) and (2 0 2) lattice planes respectively in accordance with JCPDS No. 89-1397. All these data reveal about the structure of ZONP as hexagonal wurtzite structure. Mostly Zinc oxide exhibit wurtzite hexagonal structure since it is a stable one where each Zn^{2+} is packed with four O^{2-} at the corners of a tetrahedron[2,9,11].

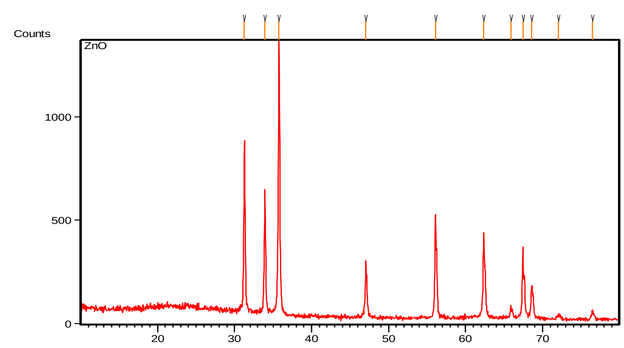

Fig 8:Graphene Zinc Oxide solid state XRD

3.2 Characterization Of Nanoparticles Using UV-Vis Spectroscopy analysis of ZONP

The size of the nanoparticles plays an important role in changing the entire properties of materials. Thus, size evolution of semiconducting nanoparticles becomes very essential to explore the properties of the materials. UV-visible absorption spectroscopy is widely being used technique to examine the optical properties of nanosized particles. The absorption spectrum of ZnO nanopowder is shown in Figure 2 .The reflectance spectrum of ZONP is recorded in the range from 200 nm to 800 nm in solid mode. From the figure, about 98% of the visible light wavelengths from 800 nm to 400 nm were reflected. The low reflectance in the UV region denotes the absorption of photons with higher energy. The lesser reflectance in the UV-region is attributed to the absorption of UV-photons to excite e^- from the valence band to the conduction band[9].

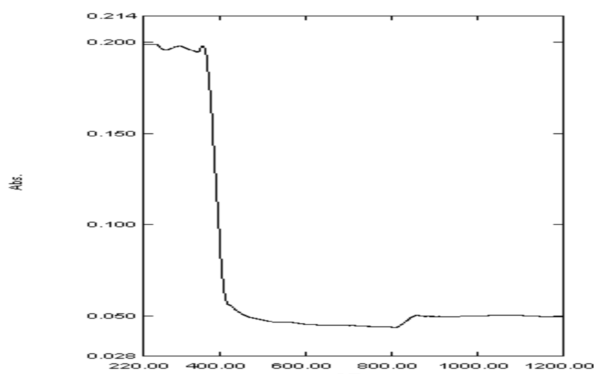

Fig 9 Graphene Zinc Oxide solid State UV

3.3 Characterization of Nanoparticles Using SEM Analysis

The figure represents the SEM pictures of ZnO nanoparticles at different magnifications. These pictures confirm the formation of ZnO nanoparticles. These pictures substantiate the approximate spherical shape to the nanoparticles, and most of the particles exhibit some faceting. From the pictures, it also can be seen that the size of the nanoparticle is less than 10 nm .This analysis can be used to determine the morphology such as shape of the nanoparticles. This can be done at low resolution. From the above the figure, it shows that the nanoparticles have rod like structure[1,2,12].

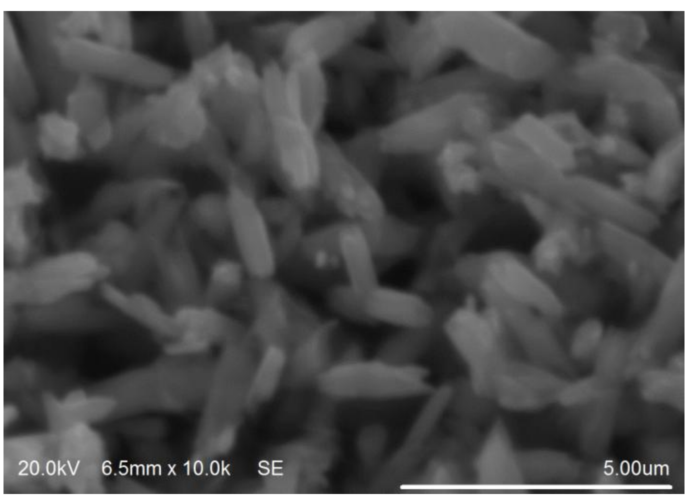

Fig 10:Graphene Zinc Oxide solid State SEM

3.4 Characterisation of Nanoparticles Using FTIR

The structure analysis of wurtzite ZnO was further supported with FT-IR spectroscopy. The FTIR spectrum is recorded in the range of 400 – 4000 cm^{-1}. The characteristic single peak found at 493 cm^{-1} was attributed to the vibrations of Zn and O present in the ZONP. Since the ZONP was obtained by calcinating zinc oxalate at 700ºC for 3hrs, the organic contents and other impurities were totally removed. So the spectrum doesn't have any peak in higher wave number[9,12].

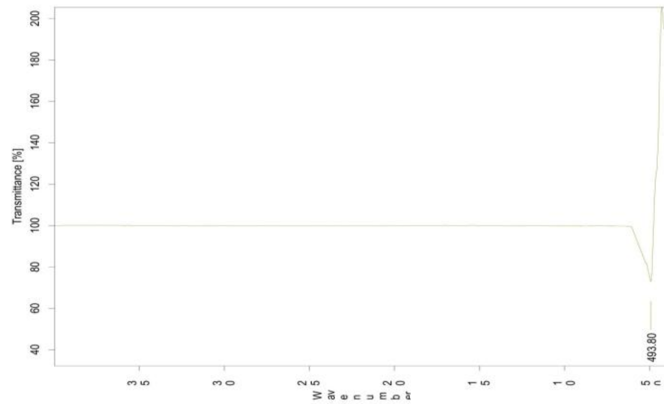

Fig 11: Graphene Zinc Oxide solid state FTIR

CONCLUSION

In this phase the synthesis of all the nanoparticles which can be required for the making of nanogenerator can be done .The graphene can be prepared from graphene oxide using modified hummer's method. ZnO/Graphene composite is prepared for using it as nanorods. The characterization methods such as UV vis Spectroscopy ray Diffraction (XRD),Scanning Electron Microscopy(SEM),Fourier Transform Infra-Red (FTIR)analysis can be performed. This analysis shows that the prepared materials are graphene –zinc oxide solid state nanorods. The SEM proves that the prepared composite is rodlike structure with a diameter of 1nm . XRD peaks indicates that the prepared material consist of particles in nanoscales range. The size of the nanoparticles can be determined by using UV-VIS spectroscopy. The structure of the prepared composite was supported by FTIR spectroscopy.

Reference

[1]. E. S. Nour, Azam Khan, Omer Nur and Magnus Willander"A Flexible Sandwich Nanogenerator for Harvesting Piezoelectric Potential from Single Crystalline Zinc Oxide Nanowires" Nanomater Nanotechnol, 2014.

[2]. Leila Shahriary, Anjali A. Athawale. "Graphene Oxide Synthesized By Using Modified Hummers Approach" January 2014

[3]. Xia Ni, Fei Wang, Anan Lin, Qi Xu1, Zhi Yang, And Yong Qin." Flexible Nanogenerator Based OnSingle Batio3 Nanowire" Science Of Advanced Materials 2013

[4]. K.T. Dissanayake1, W. Rohini De Silva1, A. Kumarasinghe2 , K.M. Nalin De Silva." Synthesis Of Graphene And Graphene Oxide Based Nanocomposites And Their Characterization", 2014.

[5].Te-Chienhou, Yayang, Zong-Honglin, Yongding, Chan Park, Kenc.Pradel, Lih- Juannchen, Zhonglin Wang. “Nanogenerator Based On Zinc Blende Cdte Micro/Nanowires”. Nano Lett. 2012.

[6]. Xi Chen Et Al.”1.6V Nanogenerator For Mechanical Energy Harvesting Using PZT Nanofibers “.Nano Lett 2010.

[7].Kwi-Il Park, Sheng Xu,Ying Liu, Geon-Tae Hwang,Suk-Joong L. Kang,Zhong Lin Wang, And Keon Jae Lee.” Piezoelectric $BaTiO_3$ Thin Film Nanogenerator On Plastic Substrates”. Nano Lett. 2010.

[8].Husnu Emrah et al.” Rapid Synthesis Of Aligned Zinc Oxide Nanowires”. 2008 IOP Publishing 0957-4484/08.

[9].Kamran Ul Hasan.” Graphene And Zno Nanostructures For Nano- Optoelectronic & Biosensing Applications”. Meas. Sci. Technol. 2006.

[10].Brijesh Kumaret al“Controlled Growth Of Zno Nanowire, Nanowall, And Hybrid Nanostructures On Graphene For Piezoelectric Nanogenerators”. Adv. Energy Mater. 2013.

[11].Mohammad Reza Khanlary et al.” Synthesis And Characterization Of Zno Nanowires By Thermal Oxidation Of Zn Thin Films At Various Temperatures”. Molecules 2012.

[12]. Paulchamy B, Arthi G And Lignesh BD,” A Simple Approach To Stepwise Synthesis Of Graphene Oxide Nanomaterial”. Nanotechnol 2015.