

Nanoelectronics Engineering Development, Performance and Applications based on ZnO Metal Nanoparticles

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ABSTRACT: Nanoelectronics Engineering in which the manipulation of nanoscale materials at nanometer scale leading to the manufactured of nanodevice components having reliable performance. A nanometer scale is one billionth of a meter, or 10^{-9} m. nanomaterials exhibit and remark specific properties. Nanoscale materials are typically defined as particles which are very small sizes and they are available in different shapes like crystals, rods, or spheres that are very small scale between 1 and 100 nm in size at least in one dimension. In the recent years there are several reasons for the Electronics Engineering and Technology to have great interest toward Nanotechnology and especially for Nanoelectronics devices. The motivation is because nanoscale materials typically have different unique electronics properties, optical, and mechanical properties compared to their bulk counterpart material and molecular complements. Present study for application in Nanoelectronics Engineering have been based on basic three parts of the nanoparticles material that is preparation of ZnO nanomaterials from green synthesis method, characterization of the ZnO Nanomaterial and search the applicability in the Nanoelectronics for gas sensing applications which is more reliable, ecofriendly & cheap.

KEYWORDS: Nanoelectronics Engineering, Development of the Nanomaterials, ZnO Metal Oxide, Electronics Nanosensors.

I. INTRODUCTION

Nanoelectronics Engineering in which the manipulation of nanoscale materials at nanometer scale leading to the manufactured of nanocomponents having reliable performance. A nanometer scale is one billionth of a meter, or 10^{-9} m. nanomaterials exhibit and remark specific properties. E.g. crystals in the nanometer scale material have a very low melting point and the lattice constants are reduced. Crystal structures of the Nanoparticles materials have stable at elevated temperatures and at much lower temperatures in nanometer scale sizes. Nanoscale materials are typically defined as particles which are very small sizes and they are available in different shapes like crystals, rods, or spheres that are very small scale between 1 and 100 nm in size at least in one dimension. In the recent years there are several reasons for the engineering to have great interest toward Nanotechnology and especially for Nanoelectronics. The motivation is because nanoscale materials typically have different unique electronics properties, optical, and mechanical properties compared to their bulk counterpart material and molecular complements.

This review paper shows the History of the Nanoparticles Material like ZnO for the development in the field of Nanoelectronics Engineering. The properties of nonmaterial which attracts a very much interest in the synthesis of metal oxide nanomaterials in these days. The Metal oxide nanoparticles are exhibit metallic, semiconducting or insulating properties behavior due to the difference the scale of material electronic structure. The metal have very small

band gap available between the conduction and valance band .The semiconducting oxide such as ZnO have wide band gap and there for it is used for the various fields of Nanoelectronics applications such as sensors .

Nanoelectronics Engineering is the technological innovations in this modern century. Research and development in the nanotechnology field is increasing rapidly throughout all over the world. A major challenge of this field is the development of new nanomaterials in the nano scale [1]. The nanoscale material particles have the small dimensions is about less than 100 nm and it is also called quantum dots .These are usually particulate materials with at least one dimension of less than 100 nanometers (nm). Metal nanomaterials particles have been of great interest due to their distinctive features such as catalytic properties, optical properties, magnetic properties and electrical properties [2]. Nanoscale materials particles are completely improved properties with large particles and bulky nanoscale materials which has specific distribution properties and morphology properties [3]. The phenomenon of different materials shows electronics properties in nanoscale size is referred to as the quantum size [4]. The wide variety of the nanoscale particles of metal oxide material have many electronics and chemical properties which makes the very useful materials for basic research oriented and engineering applications. Metal Oxides Nanoparticl have a various range of electrical and electronics properties from wide band-gap insulators to semiconductor, metallic and small band gap superconductor. Metal oxides nanoscale material plays very important role in a various applications of microelectronics devices [5]. The metal oxide nanoparticles are used for the various sensors [6]. The metal oxide nano scale materials are used in the optoelectronics devices [7].

II. LITERATURE REVIEW

1. **Richard Feynman:** On December 29th, 1959 at Caltech Dr. Feynman addressed the American physical society with “There’s plenty of room at the bottom “, his classic talk about the future of design and engineering at the molecular scale [8].
2. **Kim Eric Drexler:** During the mid 1970s, Kim Eric Drexler starts to develop the idea of molecular nanotechnology (MNT).In 1979, he encountered Richard Feynman's provocative 1959 talk “There's Plenty of Room at the Bottom.” [9]. In 1980s MIT student Kim Eric Drexler writes the first paper on the subject “Advanced Nanotechnology.”[10].
3. **Aviran and Seiden:** In the year 1974 the first Electronics molecular device was patented by A Aviram and P Seiden of IBM [11].
4. **Gerd Binnig and Dr. Heinrich Rohrer:** Gerd Binnig is a German scientist, won the Nobel Prize in the year 1986 for the invention of the “Scanning Tunneling Microscope [12], [13]. Dr. Heinrich Rohrer is the co-inventor of the scanning tunneling microscope. He worked in IBM for 34 years. Dr. John E. Kelly III, IBM senior vice president and director of Research said about the research of the Dr. Rohrer that ““The invention of the scanning tunneling microscope was a seminal moment in the history of science and information technology, This invention gave scientists the ability to image, measure and manipulate atoms for the first time, and opened new avenues for information technology that we are still pursuing today.”[14],[15]. In the year 1986 the “ AFM” was invented by Binning , Quate and Gerber. The AFM has three major abilities: force measurement, imaging, and manipulation. [16].
5. **Sumio Iijima:** In the year 1991 the discovery of the carbon nanotubes. [17].
6. **Collier & Wong :** In 1999 , A team of UCLA and HP developed several devices to produce AND and OR logic gates.[18] .
7. **U Hakanson & V Zwiller:** In 2003 The nanoelectronics Devices with one dimensional heterostructure are made from the Nanowires using semiconductor materials. [19].
8. **Choi and Kundaria:** In 2003 develops the single-walled carbon nanotubes, the carbon nanotube device is used to detect gas molecules .[20].
9. **Suny Albany College:** In 2004 the world’s first college of Nanoelectronics and Nanotechnology is established at Suny Albany, USA.[21].
10. **H. Romero and K. Bolton:** The carbon nanotubes are hits to the atom then the nanomaterials have the change in the electrical resistivity. Using the resistivity property the gas sensors are developed. [22].

International Journal of Innovative Research in Science, Engineering and Technology*An ISO 3297: 2007 Certified Organization**Volume 6, Special Issue 1, January 2017***International Conference on Recent Trends in Engineering and Science (ICRTES 2017)****20th-21st January 2017****Organized by****Research Development Cell, Government College of Engineering, Jalagon (M. S), India****III. NANOELECTRONICS AND NANOMATERIAL**

The chemical synthesis and green synthesis have been useful for the synthesis of metal oxide Nanoparticles. The chemical synthesis method requires care because of the toxicity chemicals are used in the synthesis. Chemicals used in the synthesis are costly, harmful to human health and the environment. Green synthesis of the metal oxide is eco friendly, no toxicity to the human health and the environment. The green synthesis method is simple, cheap,. In the green synthesis method generally green plants extracts are used in this research aloe Vera plant is used and which is more stable, antibacterial agents for the medical applications, larger surface area with smaller size, etc. Present study for application in Nanoelectronics have been based on basic three parts of the nanoparticles material that is preparation of ZnO Nanomaterial from green synthesis method, characterisation of the ZnO Nanomaterial and search the applicability in the Nanoelectronics for gas sensing applications which is more reliable, ecofriendly & cheap.

Green plants are the chief and cheap source so it is available easily for the medicinal purpose. In India Ayurveda is the most important field. Now days in the various fields the green plants are used for the various fields of Nanoelectronics. The applicability of the Nanoparticles using green plants increases day by day in the research and development area of Nanoelectronics. Nanobiotechnology used in Nanoelectronics is presently one of the most important disciplines of research in the material engineering whereby green plants are used to find an attractive use in the synthesis of Nanoparticles. The size of the Nanomaterial particles are very small is in nano scale.[23]. Nanomaterials are using from metals like Zinc, Copper, gold, silver and platinum are well recognized to have different applications in Nanoelectronics, magnetic fields, optoelectronics and for information storage use.[24],[25]. Nanoelectronics is the growing field with different applications in technology for the purpose with the new nanoscale material.[26]. Nanoelectronics is the branch of Nanotechnology study and manufacture of various component applications, devices used in the electronics using the nanoscale level of the material.[27]. The metal oxide i.e. the zinc oxide is interesting because of its properties such as nanoparticles material more stable, high catalytic activity, luminous transmitting properties, effective antibacterial properties, intensive Infrared properties etc.[28],[29]. The metal nanomaterials are smaller near about it is tens of nanometers, using the small scale nanomaterials the Metal nanorods and nanowires are manufactured and it is the used for different components in Nanoelectronics.[30]. The metal oxide nanomaterials are also used for biological applications like gas sensing purpose. [31].

IV. NANOELECTRONICS APPLICATIONS FOR THE GAS SENSOR

The nanosensor can be referred as the device that uses the chemical species or the component that generates a signal in presence of an nanoparticles. The flow of the nanosensor design is “Nanoscale Material –Sensor-Transducer-Detector-feedback to Sensor”. The different properties of nanomaterials that are the nanomaterials have the high surface to volume ratio , optical properties , physical properties, electrical and chemical properties.

Gas sensing devices demand increases rapidly with the increasing growing demand of different applications. There are different metal oxide and semiconductor gas sensors , have their demand growing in current and projected applications for industrial, environmental, for human safety in mines, in different research labs, in offices, in hospitals, in homes, etc. The surface conductivity of ZnO is good therefore a great deal of attention has been given to this material for gas sensors applications. Zinc oxide is sensitive to many gases such as CO, hydrogen, water vapor and hydrocarbons.[32].The metal oxides semiconductor nanoparticles have been great attention for the research today in the field of nanotechnology both from a basic fundamental and commercial industrial point of view. Their electrical properties are suitable for active sensing nanomaterials in resistive sensors, with good and enhanced performance with respect to bulk materials used in the process.[33]. Various shapes of the nanomaterials can exhibit various different physical properties therefore the performance is highly desirable to have pure nanomaterials with controlled morphological properties. However, the controlling morphology of the materials is not a simple process for controlling their size of the nanoparticles, yet. Therefore for the fact, there is more interest in developing the different novel methods for the preparation of metal oxide nanoscale material nanoparticles is possessing particular morphological properties and shape of the nanomaterials, for the nanoelectronics applications in gas detection sensing .[34].

A gas sensor is a electronic device that sense the presence of gas, often it is used for the part of a safety system. The electronics gas sensor device is used to detect a leakage of the gas and it will interface with a control system so a process of the system can be automatically stop. When the process shut down then gas sensor can sound an alarm or

buzzer, it shows in the operator area the leakage of the particular gas takes place and it helps to solve the problem of the leakage of the gas. Thus the gas sensors devices are very useful for the human being and for the environment because there are so many gases available in the environment which is useful for the human or harmful for the human life, organic life and also for the animal's life. Gas sensors can be used to detect combustible gases, flammable gases and toxic gases, and oxygen depletion gases. The gas sensors are used in many industries and can be found in different locations, used in oil rigs, used to monitoring and manufacturing processes and also may be used used in firefighting. Gas leakage sense is the process of identifying the hazard gases and the sensors are used for the different fields like industrial plants, refineries, waste-water treatment facilities, vehicles, and also in the homes. In the sensor one parameter converted into other like electrical therefore in another meaningful way sensor is also called transducer [35]. From the all nano metal oxides, tin (IV) oxide has various applications in the field of gas sensing [36].

The Electronics nonosensors have the very important role in monitoring the environmental, in the chemical industries for monitor chemical process, in the medical field for health monitoring and for safety purposes.[37]. The metal oxide semiconductor have widely used in many applications because of the nanoparticles properties of material ,low cost in the manufacturing , high sensitive material, fast response of nanomaterials, high speed with high compatibility of material with silicon based nanoelectronics, The metal oxide semiconductor have the many nanoelectronics properties to use in the many applications in electronics.[38]. Using various metal oxides semiconductor oxides, such as tin oxide, indium oxide ,zinc oxide have been used to manufactured the gas sensors.[39],[40]. The single dimension metal oxide have high surface area, have good stable thermal properties and chemically stable nanomaterials have great interest now a days in nanoelectronics applications. [41],[42].

V. GAS SENSING PROPERTIES FOR ZINC OXIDE NANOMATERIAL

Zinc oxide (ZnO) is an important metal oxide and has a wide band gap 3.37eV. The zinc oxide have a binding energy is 60 meV. The zinc metal oxide have many useful properties because of large band gap and binding energy [43],[44],[45].The zinc metal oxide have many applications in the Gas sensors for Nanoelectronics, have the solar applications. The zinc metal oxide has been used for photo-catalysis, used for transducers and so many electronics component and used in Nanoelectronics devices. [46].The ZnO nanomaterials particles has been widely used for many applications in the electronics field because of their physical and electronics properties like very stronger piezoelectric properties ,wide band gap and it is near about 3.36 eV at room temperature.[47] , good sensitivity about the different gases, cheap nanoparticles material, have easily gas monitoring material capability Metal oxide semiconductor gas sensors have attracted a lot of attention due to their cheap and easy-to-use gas monitoring capabilities.[48]. ZnO nanoparticles have the nanorods type of materials and the type of chemo resistor sensor in the air it detect the various gases like NO₂, NO, N₂O with the detection limit 10ppm under the temperature 125⁰C for the response time 30 second .[49] .The ZnO nanomaterials have been used for the detection of H₂S gas with the help of thin film at room temperature to detect the hazard gas with high sensitivity and selectivity of the nanomaterials used in the design of the gas sensing material [50].

TABLE I: Gas Sensors based on ZnO Metal Oxide Nanoparticles

ZnO Material	Medium/ Temperature	Sensor Target Gas	Response Time of sensor	Detection Threshold	Ref.
ZnO Nanorods	Air/125 Degree C.	NO ₂	30 Sec.	10 ppm	[51]
ZnO Nanorods	Air/125° C	NO	30 Sec.	10 ppm	[51]

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ZnO Nanorods	Air/125 °C	N ₂ O	30 Sec.	10 ppm	[51]
ZnO Nanorods	Air/350 °C	Et-OH	N/A	1 ppm	[52]
ZnO Nanowire	Air	NO ₂	N/A	1 ppm	[52]
ZnO Multi-nanowires	Air/300 °C	Et-OH	N/A	1 ppm	[52]
ZnO Nanowire Paste	Air/ 500 °C	LPG	N/A	500 ppm	[53]

The table I shows the different Nanomaterials of the ZnO with different materials like nanorods , nanowires , nanowires, Multi-nanowires , Nanowire paste. The medium in which the metal oxide have detected the different target gas in particular temperature . The metal oxide used for the sensing of gas have different time response and the detection limit in ppm for the gas .Zinc oxide nanomaterials has multifunctional properties like high electrochemical, radiation absorption ,electrical, physical and high chemical stability , high photo stability, etc properties.[54],[55]. ZnO has many applications in nanoelectronics such as sensors, transducers, varistors, phosphors, and transparent conducting films due to their wideband gap and have a large binding energy about 60meV. The main advantages of ZnO as a light emitter are its large exciton binding energy (60 meV), and nanoelectronics material have the large surface area so it is developed in bulk and used in many nanoelectronics field. The nanomaterials of zinc oxide have been great interest because of physical and electronics and chemical sensing properties of different gases such as LPG,CO,H₂,NH₃,H₂S.

The ZnO Nanomaterial have been used widely for detection of different gases so it is very important to use in the Electronics Nanosensors. The Electronics Engineering has more applications in the gas sensing in the Nanoelectronics because of the very small size in nano scale. The study of the electronics properties of the ZnO nanomaterial is important using the electronics parameter conductance, Mobility of electronics, Transconductance , Thershold voltage ,n-type material,p-type material, doping concept,carrier concentration ,etc.and also nanomaterial partical is based field effect transistor to improve the sensitivity and selectivity of the sensors.The nanomaterial ZnO n-type semiconductor have the mobility 1175 cm²/vs and the transconductance 0.06 e micro second.

The various growth modifier methods , Synthesis Methods like Vapor phase synthesis [56],Solution Phase synthesis [57], these methods are very useful for the synthesis of Nanoelectronics Material to reduce size and cost-efficient way to produce nanomaterials in the large scale and the diameter of the nanopartical size 10nm.

TABLE II
ZnO Electronics Properties

ZnO Material	Mobility of the nanomaterial (cm ² /V*s)	Transconductance of the ZnO material (eMicroSecond)	Synthesis Method
ZnO:P (p-type)	1.7	0.1	Thermal CVD
ZnO (n-type)	1175	0.06	Thermal CVD
ZnO: Ga (n-type)	10.2	N/A	Thermal CVD

VI. THE PROGRESS OF RESEARCH WORK

Zinc oxide (ZnO) nanoparticles synthesized by using green synthesis route using aloe vera plant extract and zinc nitrate. The Zinc Hydroxide collected was further calcinated at 400 °C for two hours to get ZnO nanoparticles.

VII. SUMMARY AND PROPOSED PLAN OF RESEARCH

This review is a report of the current gas sensing application properties used for nanoelectronics field of the ZnO Nanomaterials by using different synthesis methods.

The proposed research aims to study synthesis of Zinc oxide (ZnO) nanoparticles by plant mediated synthesis routes and to investigate their gas sensing properties. In this work, the Zinc oxide (ZnO) nanoparticles will be synthesized by using different plants as crystal growth modifiers. The resulting Zinc oxide (ZnO) nanoparticles will be characterized using X-ray diffraction (XRD), Ultraviolet visible absorption spectroscopy, Fourier transform infrared (FTIR) spectroscopy, field emission scanning electron microscopy (FESEM), transmission electron microscopy (TEM). The LPG, NH₃, H₂, NO₂, H₂S, CO and ethanol vapor sensing properties of the Zinc oxide (ZnO) nanoparticles at different operating temperatures and gas concentrations will be investigated. The gas sensing characteristics such as sensitivity, selectivity stability, response time and repeatability will be evaluated. The various parameters of the synthesis method will be optimized to synthesize Zinc oxide (ZnO) nanoparticles having excellent gas sensing properties.

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