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Synthesising of metal oxide (ZnO)Nanostructuresfor Optoelectronic Devices,A review

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ABSTRACT
In recent years, Nanomaterials has been revolutionized because of its alluring properties in comparison to the bulk phase of similar materials. These properties are physical, chemical, catalytic and optical. Among these nanomaterials, the metal oxide nanostructures have become the most interesting concept for the development of different optical, biochemical and biomedical nanodevices. The advantageous features of nanotechnology is the demonstration of highly sensitive sensor devices and optoelectronics with a wide band gap.

ZnO, CuO and NiO are attractive materials Among all metal oxide nanostructureson behalf of their unique properties; their high surface area to volume ratio, their energy band gap of 3.37 eV, 1.2 eV and 3.7 eV, respectively, biocompatibility, high electron mobility, fast electron transfer rate and they are environmental-friendly in many applications.A full potential of this technology can be exploited for the advantage of mankind.

I. INTRODUCTION:

In Recent study, Nanomaterials are widely used for sensing and optoelectronic devices. According to their size, shape, and material properties, they can be classified into various types.Nanoparticles exist in the natural world and also created as a result of human actions.

Nanotechnology based devices have many advantageous features but there are concerns about their effect on both human health and environment [1].It deals with the materials whose structures exhibit significantly novel and improved physical, chemical, and biological properties and functionality due to their nano scaled size.
Nanotechnology can be termed as the synthesis, characterization, exploration and application of nanosized (1-100nm) materials for the development of science.Nanomaterials are cornerstones in nanotechnology.

Fig. 1. Nanomaterial (For example: Carbon nanotube)

The nanotechnology fields have been greatly improved by the fabrication of nanodevices and their unique properties of nanomaterials, such as:
For optoelectronic nanodevices, due to electron transfer from one state to another state optical emission and absorption increased [3].

1. Metal oxide Nanostructures

For practical and theoretical importance in biological, environmental science and analytical chemistry applications, the nanostructures of metal oxide semiconductors have alluring nature and important for nanosensors research [2].

Metal oxide NSs (ZnO, CuO and NiO) have a high surface area to volume ratio, low toxicity, are environment-friendly, have chemical stability and biocompatibility and were grown using the low temperature growth method. So, metal oxide nano structures (NSs) also show fast electron transfer properties required to improve nanomaterials performance when used as a biomimetic membrane that will detect for example: proteins and retain their activity [3,4].

Semiconductor Q-particles also show quantum confinement effects which may lead to special properties, like the luminescence in silicon powders and silicon germanium quantum dots as infrared optoelectronic devices. Nanostructured semiconductors are used as window layers in solar cells [6].

ZnO were synthesis by the hydrothermal growth method using a composite seed layer of ZnO nanoparticles and chitosan-polymer in paper I. This research work showed that different concentrations of ZnO nanoparticles in composite seed layer controlled the size, density, alignment and optical properties of ZnO NSs [5].

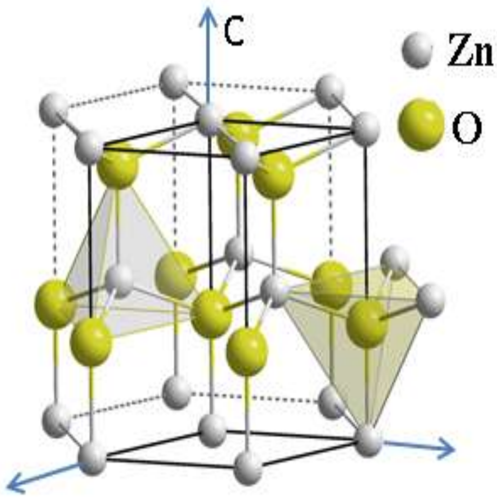

Figure 2. The hexagonal wurtzite structure of the ZnO semiconductor.

CuO nanoflowers have been prepared by different urea concentrations assisted growth solution in the hydrothermal method. This work showed that the obtained CuO NSs are highly dense, uniform and compromise pure CuO crystal phase. Moreover, Cd^{2+} ions have been detected with the obtained CuO nanoflowers [6,7]

Fig.3 CuO nanoflower

Nickel oxide (NiO) is a p-type semiconductor with a wide energy band gap of 3.6 eV to 4 eV and interesting properties such as magnetic, optical, catalytic and electrochemical [10,11].

NiO NSs have been used in the fabrication of nanodevices such as electrochemical energy storage devices, gas sensors, dye-sensitized solar cells, and as an optical active counter-electrode tool [8]. There are many methods for the synthesis of NiO NSs, but most of these have disadvantages except the hydrothermal method which is low cost, user friendly, easily controllable and environment-friendly [9].

2. Synthesis of ZnO NSs:

It can be synthesizedby various techniques such as chemical vapor method, spray pyrolysis, laser synthesis techniques and vapor condensation method. It deals with the reaction of one type of solution containing zinc particle like acetate, nitrate, chloride etc. Many solution-based techniques such as precipitation, solvothermal, hydrothermal, sol-gel, sono-chemical etc. Here some methods are discussed:

2.1 Methods for the preparation of ZnO NSs:

Sol-gel method: Here two types of compounds ‘sol’ and ‘gel’ involves. Here the solution act as a precursor for an integrated network of either discrete particles or network of polymers. Zinc alkoxides or zinc chlorides are two typical precursors which undergoes various forms of hydrolysis and poly-condensation reactions. ZnO monoliths were synthesized by sol-gel route using alcoholic zinc nitrate solution with propylene oxide as the gelatine initiator. A sol gel process involves formation of sols in a liquid and then connecting the sol particles to form a network. By drying the

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liquid, it is possible to obtain powders and thin films.It is also possible to synthesize nanoparticles like nanorods, nanotubes etc. by sol-gel technique [19].

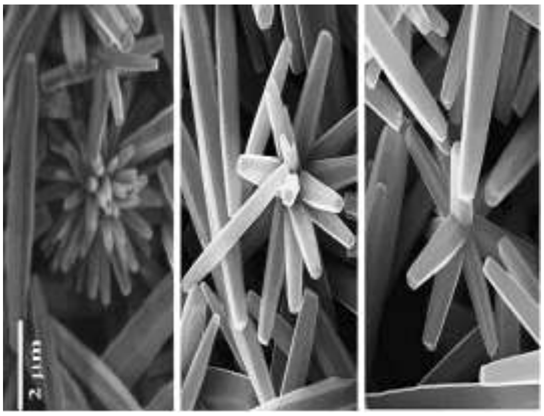

Fig. 4 SEM images of Sol-gel derived zinc oxide

Solvothermal method: There are numbers of reports of zinc oxide nanostructures with solvothermal route employing different zinc precursors, different organic solvents and reaction temperatures [20, 22]. Zinc oxide nanorods of 80-800 nm diameter are synthesized by Varghese et al [21] with the reaction between zinc acetate (300 mg), absolute alcohol (4 ml) and ethylenediamine (6 ml) in 20 ml of stainless steel autocalve under solvothermal conditions (300 °C for 20 h). Precipitate was filtered and washed with ethanol and distilled water. Addition of Triton X-100 into the reaction mixture produces zinc oxide nanorods of uniform 300 nm diameter, while addition of NH3 produces N doped zinc oxide nanorods [23-25].

Combustion Synthesis: Combustion or burning is the sequence of exothermic chemical reactions between a fuel and an oxidant accompanied by the production of heat and conversion of chemical species. Most fuels of interest are organic compounds (especially hydrocarbon) in the gas, liquid or solid phase. Three types of combustion synthesis of nanomaterials:

(a) Solid phase combustion (b) Solution combustion synthesis and (c) Gas phase combustion synthesis. Solution phase combustion. Which is widely used Jayalaxmi et al [26] have synthesized ZnO Nano powder using solution combustion synthesis and employed 10g of zinc nitrate and 3.6 g of dextrose solution into 25 ml of water. Glass vessel containing aqueous solution was placed on the hotplate for 15min. to form a gel and placed into muffle furnace at 400°C for 5 min. The formed powder was highly amorphous in nature.

Zinc oxide nanostructures are synthesized by Alvarado-Ibarra et al. [27]For solid combustion the mixture was heated until all the water evaporated before placing it in the muffle furnace, while for solution phase synthesis aqueous mixture was placed in the furnace operating at 800 °C. SEM images of the zinc oxide nanostructures obtained by direct calcination of zinc nitrate, solid combustion and solution phase combustion methods are illustrated [**Figure 5].**

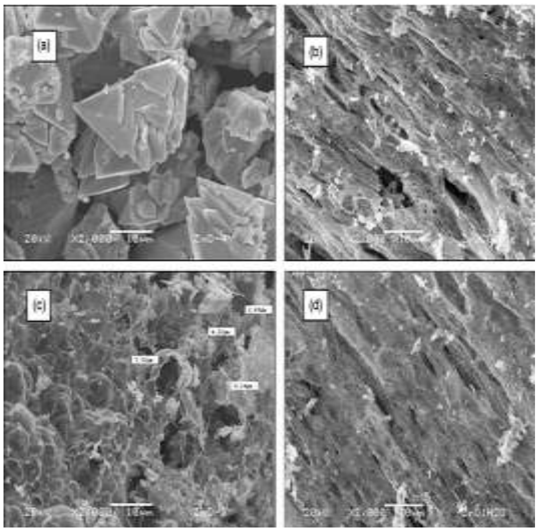

Fig.5 SEM images of zinc oxide nanostructures

Sono-chemical method: Sonochemical method is another solution-based method for zinc oxide nanostructured material. In the synthesis procedure aqueous solution of zinc precursor such as zinc nitrate hexahydrate, zinc acetate, zinc chloride etc. and hydroxide anion precursor such ashexmethylenetetramine (HMT) is taken as starting materials [29]. The solution is being placed in ultasonochemical apparatus for different time. Concentration of zinc precursor, hydroxide anion precursor, surfactant nature and concentration, power of ultrasonic wave and time of ultrasonic treatments are key parameters available to control size, shape and morphology of zinc oxide nanostructures. Jung et al. [28] have synthesized zinc oxide nanorods, nanoflowers, nanocups, nanodiscs and various nanoarchitectures employing sonochemical approach employing 0.02 M, 50 ml solution of zinc nitrate hexahydrate with equi-molar and equal volume of HMT.

3. Application of ZnO

Due to its numerous potential applications in photonics, electronics, optoelectronics, sensors,

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harvesting device fabrication and energy storing etc [17]. Gas sensors based on ZnO had already been developed for detection and control of gases such as CO, H_2, H_2S, NH_3, etc. Al-doped ZnO increases its conductivity without 11 impairing the optical transmission, which is regarded as a potential alternative candidate for ITO materials [16,18]. The stabilization of these nanoparticles was achieved by the presence of soluble starch in the reaction medium. The average size of the ZnO nanoparticles was estimated to be 38 ± 3 nm using a TEM [14,13].

Instead of technological and biological applications it has also tremendous industrial applications [21,22].zinc oxide nanostructures are three times more efficient compared to any other solid-state detector. There is large number of cheap and simple available physical and chemical, solution and vapor phase routes for the synthesis of wide morphology of zinc oxide nanostructures with great optoelectronic, electronic, spintronic and optical properties, which makes it more popular amongst the researchers.

ZnO is one of the best semiconductors materials with advanced technological applications in the fabrication of semiconductor laser diodes, light emitting diodes, transistors/FETs, Lithium ion and fuel cells for energy storage, sensors (Physical, biological as well as chemical), hydrogen generation and its storage, environmental pollution monitoring and biological/medical applications.

ZnO transparent thin film transistors are very recent development in this area.

zinc oxide is wide band gap semiconductor, absorbs UV light, high exciton binding energy and higher carrier mobility therefore it is widely used for the fabrication of zinc oxide-based UV detector [11-15]. According to Maxtronics Inc., which is fabricating zinc oxide based optoelectronic devices.

Hybrid solar cells have ability to provide cheap, flexible and thinner photovoltaic devices in sufficiently large scale. Most of the polymers have high absorption coefficient (105 cm^{-1}), short exciton length due to the less than 10 nm diffusion length and very low hole mobility (10^{-1}-10^{-7} $cm^2V^{-1}s^{-1}$) as compared to silicon (500 $cm^2V^{-1}s^{-1}$) therefore several parameters have to be optimized to get good conversion efficiency. For the cheapest and easiest fabrication of excitonic solar cells, HSCs are not as more advanced as DSCs due to their low conversion efficiencies. Zinc oxide of single crystalline NRs/NWs array are used in the HSCs to speed electron conduction and improving its conversion efficiency [19-26].

4. Future Prospects

Semiconductor and microchip industries are continuously seeking alternative materials due to the high cost of the silicon wafers, and requirement of highly standard quality of clean rooms for their processing.

Metal oxide nanostructures may comply with their need and create a new roadmap of the future semiconductor industry.

It is expected that metal oxide nanostructures will be a reliable partner of mankind and society in the near future because of their continuously increasing biological, medical, and cheap device fabrication applications.

II. CONCLUSION

Well-aligned ZnO NRs were prepared by the hydrothermal growth method using a composite seed layer of ZnO nanoparticles and chitosan-polymer in paper I. This research work showed that different concentrations of ZnO nanoparticles in composite seed layer controlled the size, density, alignment and optical properties of ZnO NRs. In paper II, a comparative study of ZnO NRs and thin films have been carried out by investigating chemical and biosensing

Applications and characterization of the nanoparticles was carried out using UV-Vis spectroscopy, Dynamic Light Scattering (DLS) particle size analysis, Scanning Electron Microscopy (SEM), X-Ray Diffraction (XRD) analysis. From Dynamic Light Scattering (DLS) particle size and SEM image analysis, the average particle size was found to be 90 nm and 50 nm, respectively for ZnO and Ag and here Antibacterial potential of both ZnO and Ag nanoparticles as a function of nanoparticles concentration was tested against four different bacteria just like the Escherichia coli, Pseudomonas aeruginosa, Bacillus subtilis, and Streptococcus pneumonia.

The test was performed by both Disc diffusion assay and colony forming unit (CFU) estimation method. From the study, both types of nanoparticles were observed to have strong antimicrobial potential. When the result was compared with the effect by antibiotics like Vencomycin, Tobramycin and Erythromycin, nanoparticles were found more potent than antibiotics.

The result showed that both fabricated sensor devices of ZnO NRs and thin films worked very well, but the sensor device based on ZnO NRs has shown better performance in terms of higher sensitivity and lower detection limit.

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