APPLICATIONS OF Cu DOPED ZnO NANOPARTICLES

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INTRODUCTION

Cu-doped zinc oxide nanoparticles have been intensively studied because it has considerable potential for applying to wide range of applications, such as optical coatings, light-emitting diodes, laser diodes and catalysts. Recently, the unique properties demonstrated in Cu-doped zinc oxide nanoparticles have gained great interest for developing a wide range of advanced applications including field effect transistors [1, 2], field emission arrays, ultraviolet lasers, light emitting diode [3], sensors, biosensors [4, 5], catalyst [6], energy storage and solar cell [7]. The advanced functional properties of nanostructure materials are closely related to several factors such as high surface mass ratio, selective control surface terminal, different local structure from bulk and magnetic properties. For example, in Cu-doped zinc oxide, its magnetic property and band gap can be controlled by either changing its local structure or oxygen and/or Zn vacancies concentration by Cu^{1+} and/or Cu^{2+} substitution interstitial of ZnO. The doping of metal ions in ZnO nanostructures can lead to effects such as enhancement/decrease in fluorescence and controlling concentration of surface defects. The doping of Cu in ZnO is expected to modify absorption, and other physical or chemical properties of ZnO because of the different structure of the electronic shell and the similar size of Cu and Zn. Cu can enter the ZnO lattice substitutionally as deep acceptors in combination with a neighbouring O vacancy.

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1. **Application in Energy Conservation**

To provide sufficient energy for meeting human requirements is one of the challenges of 21st century and therefore emphasis is given on the development of alternative energy sources in different cost effective ways. Nowadays varieties of nanoparticles (NPs) are used as the new building blocks to construct light energy harvesting assemblies. New initiatives like use of bio-mimetic systems to simulate natural photosynthesis and fabrication of hybrid solar cells by using nanoparticles have been very promising.

Doping TiO_2, ZnO etc. with transition metals like Cu, Co, Ni, Au etc. have created new materials which have potential application in semiconductor devices [8]. The average size of nanoparticle found to be decreased as the doping percentage of copper metal is increased. The band gap values of prepared undoped and copper doped samples are found to decrease from 3.15 to 2.92 eV [9]. Optical absorption measurements indicate red shift in the absorption band edge upon copper doping. Studies shows that Cu doping has significantly and systematically influenced the band gap of ZnO by giving a strong green emission in the visible luminescence region, which is potentially important for photocatalyst and solar cell devices. Using Cu doped ZnO NPs in specially designed electrochemical cell can utilize the heat energy of sun as opposed to traditional light quanta. The new material upon thermal excitation generates voltage of useful magnitude (maximum of ~ 632 mV) and energy conversion efficiency (maximum of 1.36%) with sufficient storage capability (~ 47 hrs). This heat induced voltage generation of Cu-doped ZnO NPs will definitely lead to new possibilities for harvesting thermal energy coming from sun even in cloud covered days or from any other sources, for example, from industrial wasted heat [10].

2. **Applications in Photocatalysis**

For photocatalysis, ZnO has also been considered as a suitable alternative for TiO_2 due to its similar band and lower cost. Moreover, it exhibits better performance in the degradation of organic dye molecule in both acidic and basic media. The intrinsic defects of ZnO are beneficial for setting up catalytic systems, which are expected to degrade the environmental contaminants. It has been widely proved that modifications of oxide semiconductors, including doping of transition metals or rare earths, could enhance their properties. The photocatalytic properties of ZnO were greatly enhanced when modified with the incorporation of dopant ions. The surface defects caused by Cu doping could serve as favourable trap sites of the electrons or holes to reduce their recombination and consequently increase the photocatalytic activities. Furthermore, a bigger surface to volume ratio in

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nanorods results in more surface oxygen vacancies and thus increased surface activity. The Cu-doped ZnO nanorods has found to exhibit good photocatalytic activity for organic pollutants in water and has potential use in wastewater treatment [11].

3. Gas sensing applications

It is well known that many dangerous substances are emitted into the atmosphere, mainly due to industrial activity and the accelerated urbanization in the last decades hence, the use of gas sensors to detect and monitor these substances is essential. Studies on gas sensors based on metal oxide semiconductors specifically chemical sensors, play an important role in the development of sensing devices used for controlling the toxic gases in the environment, that is why in recent years, there has been an increase in the development of sensors with high performance in their response magnitude and selectivity; additionally, a low manufacturing cost. ZnO has been studied in its various structures, such as nanorods used in gas sensors to detect ethanol, with a high reversible and rapid response to reducing ethanol. Nanotubes used to detect nitrogen dioxide, showing excellent detection capacity with a response of 500 ppm at 30 °C. Nanowires were manufactured for interaction with various gas environments, identifying a significant influence on the detection of carbon monoxide, and highly sensitive gas sensors in ethanol detection. Nanoparticles were connected to each other forming ZnO chains for the detection of NO_2, H_2 and CH_4 reflecting a high and reversible response in chemical sensors. Studies showed that Cu doped ZnO nanoparticle powders present a small size that is suitable for manufacturing gas sensors, as the area/ volume ratio is high. The pellets' sensitivity improved markedly with the doping process. Cu doped ZnO pellets has been found to show highest sensitivity towards propane gas absorption [12].

4. Application as Light Emitting Diodes

ZnO as a promising candidate for the development of light-emitting structures and lasers for the blue and ultraviolet. ZnO has high surface to volume ratio at nanometer scale and hence surface defects play an important role in its properties. The effect of Cu doping as a luminescence activator and as a compensator of n-type material is of great importance for semiconductors. The emission spectra of Cu doped ZnO extend from ultraviolet to infrared region depending on the defects in ZnO, excitation conditions, and concentration of Cu. In the past few years, much efforts were made in the field of synthesis of ZnO to devise an approach that is compatible with the current device fabrication technologies, which should be simple, low cost, and should be suitable for mass-scale production. Studies revealed that

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the copper doped ZnO nanoparticles are possess enhanced photoluminescent property along with unique optical and structural properties. Thus, high percentage of green photoluminescent copper (0.3%) doped ZnO nanoparticles are proposed to be useful in the fabrication of white LEDs with broad-band visible phosphors. Currently, light-emitting diodes (LEDs) giving green light emission have been combined with broad-band visible phosphors to make white-light LEDs. Thus, green photoluminescent ZnO:Cu nanophosphors are seen as necessary and condemnatory constituent for white-light LEDs[13].

CONCLUSION

Properties of pure ZnO nanoparticles can be tuned by doping and tailoring the processing parameters associated with synthesis process making it viable for various applications. Doped ZnO nanostructures are multifunctional materials which can exhibit photocatalysis in aqueous medium for detoriation of various exotic dyes released into water bodies by industries with or without illuminating, generating hydrogen which can solve energy as well as environmental issues, sense toxic gases, assist in development of cheap and efficient solar, fuel cells and play an important role in the field of spintronics, medicine, photoluminescence. Copper-doped ZnO nanoparticles are highly beneficial in several applications due to the profound improvement in the physical and chemical properties of the obtained nanoparticles.

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