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Preparation and characterization of Ce doped ZnO nanomaterial for photocatalytic and biological applications

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ABSTRACT

Cerium doped zinc oxide (CZO) nanomaterials have been synthesized by the sol–gel combustion method. The effect of Ce doping (up to 5 mol%) on the structural, morphological, optical and photoluminescence properties has been investigated and the applications of CZO in photocatalytic and antibacterial studies were also assessed. X-ray diffraction analysis revealed that the CZO nanomaterials have the hexagonal wurtzite structure. The maximum crystallite size of 84 nm was obtained for the 1 mol% Ce doped nanomaterial. The morphology of the CZO powder was gradually affected by the Ce doping concentration. Element mapping using energy dispersive X-ray spectroscopy showed the uniform distribution of Ce atoms in the ZnO, but higher resolution nano-scanning Auger microscopy measurements revealed enhanced Ce concentration in nanoparticles occurring in the doped material. The absorption spectra were calculated from reflection measurements using the Kubelka-Munk function and showed strong absorbance below 410 nm. The optical bandgap slightly varied around 3.20 eV for the different Ce doping concentrations. Photoluminescence consisted of a broad emission band centered at 635 nm having a clear blue shift as the Ce concentration increased. A photocatalytic study was done by means of methylene blue as a dye in UV light. The doped oxide is also an antibacterial/antifungal agent and its efficiency has been measured against bacteria (*Staphylococcus aureus* and *Escherichia coli*) and yeasts (*Eremothecium ashbyii* and *Nadsonia fulvescens*).

1. Introduction

Semiconductor nanomaterials offer great possibilities in various fields of science and technology [1]. Semiconductor nanocrystals or nanoparticles may have superior optical and antibacterial properties than bulk crystals due to quantum confinement effects and the large surface to volume ratio. Metal oxides such as TiO_2, ZnO, SnO_2 and CeO_2 have great importance in the fields of environmental remediation [2,3], clean energy production [3], biological uses and nano electronic devices [4–7], photovoltaics and solar cell applications [7], sensors [8] and photocatalytic applications [9]. Among these, ZnO has great importance due to its excellent physical and chemical properties. ZnO is a wide band gap (E_g = 3.37 eV) semiconductor with a large free excitation binding energy (60 meV) [10]. Although TiO_2 is universally considered as the most photo active catalyst, ZnO has the potential to replace TiO_2 with a similar bandgap, good performance in degradation of organic contaminates and low cost [11].

The photocatalytic activity of semiconductor oxides may be improved by doping of transition metal or rare earth metal ions. In some literature the incorporation of rare earth ions increased the photo current response and the separation of electron hole pairs under UV illumination [12]. La doped ZnO nanoparticles [13], Sm doped ZnO nanorods [14], Ce doped ZnO nanorods [15] and Nd doped ZnO nanoneedles [16] are different rare earth doped catalysts that have been successfully fabricated and appeared to be very efficient for the photodegradation of organic pollutants.

ZnO also shows a potential application in the field of antibacterial and antifungal studies. Its particles are effective to inhibit the bacteria growth zone [17]. It also has shown activity against spores that are high-temperature and high-pressure resistant [18]. Thongsuriwong et al. [19] investigated the antibacterial properties of Ag doped ZnO thin films with various loadings of Ag in the range of 0–10 mol% prepared by the sol–gel dip-coating method. Co doping of ZnO and exposure to sunlight were reported to enhance the antibacterial activity against water borne bacteria [20]. Guo et al. [21] synthesized Ta doped ZnO nanoparticles by a modified Pechini-type method. The

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