Optik 127 (2016) 4281–4286

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Synthesis, characterization and antibacterial efficiency of ZnO nanoparticles using rice as soft bio-template

C. Amutha[a], S. Thanikaikarasan[b], V. Ramadas[c], S. Asath Bahadur[d], B. Natarajan[a,*], R. Kalyani[e]

[a] Post Graduate and Research Department of Physics, Raja Dorai Singam Government Arts College, Sivagangai 630561, Tamil Nadu, India
[b] Centre for Scientific and Applied Research, School of Basic Engineering and Sciences, PSN College of Engineering and Technology, Tirunelveli 627152, Tamil Nadu, India
[c] Post Graduate and Research Department of Zoology, Raja Dorai Singam Government Arts College, Sivagangai 630561, Tamil Nadu, India
[d] Department of Physics and International Research Centre, Kalasalingam University, Krishnan koil 626126, Tamil Nadu, India
[e] Nanofunctional Materials Lab, Department of Nanoscience & Technology, Alagappa University, Karaikudi, 630003, Tamil Nadu, India

A R T I C L E I N F O

Article history:
Received 4 December 2015
Accepted 15 January 2016

Keywords:
Rice
Bio-template
Sol–gel technique
Structural analysis
Photoluminescence Spectroscopy

A B S T R A C T

Rice as a renewable, abundant bio-resource with unique characteristics can be used as a bio-template to synthesize various functional nanomaterials. Rice-doped Zinc Oxide nanoparticles have been successfully synthesized using co-precipitation method. X-ray diffraction analysis showed that the prepared material possess polycrystalline in nature with hexagonal structure with (1 0 1) orientation for undoped material and (0 0 2) orientation for Rice-doped Zinc Oxide nanoparticles. Optical absorption analysis have indicated the red shift change in band gap value in the range between 3.6 and 3.9 to 3.75 eV is observed for undoped and rice-doped Zinc Oxide nanoparticles, respectively. The FTIR spectra have confirmed the presence of ZnO band at ~850–900 cm^{-1}. Photoluminscence spectroscopy depicted of blue shift in the wavelength in the range between 440 and 370 nm for Rice-doped Zinc Oxide nanoparticles. The antibacterial efficiency of ZnO NPs- doped with rice was tested against the growth of bacterial species using a disc diffusion method. The rice-doped ZnO sample exhibited strong antibacterial activity against the *Escherichia coli*, *Pseudomonas aeroginosa* and *Klebsiella pneumonia.*

1. Introduction

A technique that employs natural materials as biotemplates to synthesize micro- and nano-scaled materials with morphologies and structures resemble to those of the biotemplate is called as biomorphic mineralization [1]. These kinds of works keep on growing and contributing to a new interdisciplinary area, especially with the synthesis, self-assembly and processing of the organized inorganic materials [2]. The advantages of application of biotemplates are relatively cheap, economical, environmentally benign and renewable [3]. A series of natural biotemplates that were utilized in the fabrication of functional materials includes DNA, proteins, viruses, bacteria, diatoms, pollen grains, cell membrane, wood and cellulose fibers.

Application of metal oxides materials have extensively arisen throughout human civilization and the uses of nano-sized particles are even more significant. Among them, ZnO nanoparticles are always in the center of attention due to their fascinating properties and extensive application. Bio-inspired synthesis of ZnO nanoparticles have been achieved using environmentally and ecofriendly accepted systems. Several studies have been investigated using natural materials for ZnO nanoparticles synthesis such as DNA [4], silk [5], albumen [6], orange juice [7], pea starch [8], peptide structures [9] and etc. Agricultural materials particularly those containing cellulose have indicated potential metal bio-sorption capacity. The basic component of the agricultural materials includes hemicellulose, lignin, extractives, lipids, proteins, etc.

Rice is an agricultural bio-resource which can be used as nonmetalic bio-precursor to synthesize functional materials. The main component of rice is starch which is one of the most fascinating bio resources that can be used for nanotechnological application. The carbohydrate polymeric chains build up from glucose units and parted in linear amylase and branched amylopectin. These peculiarities are representing the key structural elements for the synthesis of new functional nanomaterials. Starch-based oxides with biocompatible and non-toxic features grant a new class of functional nanomaterials with potential application in various industries.

* Corresponding author. Tel.: +91 098941 86345.
E-mail address: b_natraj_b@rediffmail.com (B. Natarajan).

http://dx.doi.org/10.1016/j.ijleo.2016.01.124
0030-4026/

Therefore, using rice as a soft biotemplate appears to be a promising way to synthesize zinc oxide nanoparticles. Hence in the present study, rice was chosen as a soft template material due to its high porous structure, special components and relatively low cost. Workers have reports about to the use of rice husk and starch for the synthesis of various functional materials due to their high porous structure.

Nanometer size multifunctional materials are gearing the biological fields in various ways. One of the promising nontoxic and biocompatible semiconductor material is Zinc Oxide (ZnO), which has received extensive application due to its exceptional electrical and optical characteristics in fabricating nano-scaled electronic and optoelectronic devices. ZnO is a kind of wide band gap (3.37 eV) semiconductor with large exciton binding energy (60 meV) [10]. ZnO possesses higher quantum efficiency and higher exciton energy when compared with other side band gap semiconductor. Besides, ZnO is a bio friendly oxide semiconductor and an inexpensive luminescent material.

Owing to the properties stated above, it is expected to have a wide range of applications in room temperature ultraviolet (UV) lasing [11], biosensors [12], bio imaging [13], drug delivery and piezoelectric transducers. ZnO nanosystem may be of important relevance in the context of nanomedicine, where targeted treatment of biological systems at molecular level is a necessity. Recently, there are several physical or chemical synthetic methods of preparing ZnO, such as thermal evaporation [14], pulsed laser deposition (PLD) [15], ion implantation, reactive electron beam evaporation, thermal decomposition [16] and sol–gel technique [17]. To obtain ZnO nanoparticle, we choose sol–gel method because of its simplicity, which offers a possibility of large-area yield at low cost.

Antimicrobial agents are natural or synthetic compounds that inhibit microbial growth. Various classes of antimicrobial agents are used in the textile industry, most of which are biocides. The use of inorganic nanoparticles has advanced rapidly due to the amount of work done toward the synthesis and modification of particles for biomedical applications. Many heavy metals and metal oxides either in their free state, or in compounds at very low concentrations, are toxic to microbes [18]. These inorganic materials kill bacteria through various mechanisms, such as by binding to intracellular proteins and inactivating them, generation of reactive oxygen species and via direct damage to cell walls [19]. Zinc oxide (ZnO), copper oxide (CuO), magnesium oxide (MgO), titanium dioxide (TiO2) and silver (Ag) are some of the most commonly used inorganic materials in the fabrication of antimicrobial coatings.

In the present investigation, the ZnO nanoparticles were synthesized through by co-precipitation method using zinc acetate-sodium hydroxide and uncooked rice flour at various ratios as precursors at 100 °C for 1 h. Prepared samples are subjected to X-ray diffraction, Scanning electron microscopy, and Energy dispersive analysis by X-rays, UV–vis NIR spectroscopy and photoluminescence spectroscopic techniques for the determination of structural, morphological, compositional and optical properties, respectively. Further the ability of the antibacterial agent to inhibit bacterial growth was tested using a disc diffusion method.

2. Experimental procedure

2.1. Chemicals used

Zinc acetate dihydrate Zn $(CH_3COO)_2$. $2H_2O$, Sodium Hydroxide (NaOH), liquid ammonia were purchased from Sigma Aldrich. The raw rice was purchased from a local market and then ground into powder form in a milling machine, (Fritsch Pulverisette 6 type planetary monomill, Germany).

2.2. Synthesis of rice-doped ZnO nanoparticles

In a typical procedure, 1 g of zinc acetate $(Zn(Ac)_2.2H2O)$ and 0.8 g sodium hydroxide (NaOH) were dissolved in 25 mL distilled water under constant stirring (Zn^{2+}: OH- = 1: 4).a PH of 13. After 1 h stirring, different concentrations of rice powder 0, 0.5, 1, 1.5, 3 and 6 g were introduced into the solution (the ratio of zinc acetate to rice powder was chosen at i.e. 1:0, 1:0.5, 1:1, 1:1.5, 1:3, and 1:6 w/w%) and stirring was continued until the rice powder was completely dissolved. The solutions with lower concentrations of rice powder were easily dissolved and the color of solution remained white. At higher concentrations of rice powder, yellow colored solutions were obtained after longer time of stirring and the solution was transferred into a Teflon-lined stainless steel autoclave; the resulting white precipitate was stirred vigorsly at an ambient temperature for a duration of 1 h. The precipitate was washed thoroghly with deionized water followed by ethanol to remove the impurities present in it and which leads to the production of white powder. The resulting white powder was dried in hot air oven at a temperature of 100 °C for 1 h duration.

2.3. Method of antimicrobial activity

Disc diffusion method was used to determine the inhibition zones in the growth of bacterial species, sterile molten Mueller Hilton agar (Himedia) cooled at 45 °C was used with discs containing ZnO nanoparticles. Then plates were incubated at 37 °C for 24 h with different concentration of ZnO nanoparticles, the zone of inhibition was measured using a zone reader.

2.4. Characterization

X-ray diffraction pattern of the prepared samples was recorded using a Brucker D8 X-ray diffractometer with Cu kα radiation with wavelength (λ = 1.5418 Å). Surface morphology and composition of the prepared powder samples were recorded using an Energy dispersive analysis by X-rays set up attached with Scanning Electron Microscope (INPECT-F Model, 30kV). Optical absorption and transmittance measurements were taken out using an UV–vis–NIR spectrophotometer (Shimadzu UV–vis 1800). A Photoluminescence spectroscopic measurement of the prepared powder samples was taken out using a Perkin Elmer LS55 Spectroflurometer. Whereas, FTIR measurements were performed over the range from 400 to 4000 cm^{-1} using Shimadzu 8400S. The antibacterial efficiency of ZnO NPs was tested against bacterial growth using disc diffusion method.

3. Results and discussion

3.1. Structural analysis

X-ray diffraction pattern recorded for both undoped and uncooked rice powder doped with ZnO nanoparticles (Fig. 1a–e). It was observed that, the prepared samples were polycrystalline in nature with hexagonal structure and lattice constants (a = 3.0753 Å; c = 5.3273 Å). The diffraction peaks of hexagonal ZnO are found at 2θ values of angles such as, 31.82, 35°.36.32°, 47.6°, 56.7°, 62.9°, 66.4°, 68° and 69.14° corresponding to the lattice planes of (0 0 2), (1 0 0), (1 0 1), (1 0 2), (1 1 0), (1 0 3), (2 0 0), (1 1 2) and (2 0 1), respectively. The 'd' values observed in the present study were found to be in close agreement with JCPDS ICDD file for hexagonal ZnO (JCPDS card No.36–1451) [20].

In the case of undoped ZnO that the intensity of (1 0 1) plane was found to higher than all other peaks in the diffractogram which indicated that the crystallites are preferentially oriented along (1 0 1) plane (Fig. 1a). Whereas, doped ZnO, the intensity of