

ZnO Nanoparticles Synthesis and Characterization by Hydrothermal Process for Biological Applications

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This research is interested in the development of zinc oxide (ZnO) nanoparticle synthesis by hydrothermal precipitation solutions for biological applications. The synthesis of ZnO nanoparticles study from zinc nitrate ($Zn(NO_3)_2$) precursor under the three precipitator solutions consists of potassium hydroxide (KOH), sodium hydroxide (NaOH), and ammonium hydroxide (NH_4OH), respectively. The synthesis of ZnO nanoparticles is investigated using the following techniques: X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FT-IR), and Raman spectroscopy techniques. The structure and size of the ZnO nanoparticles are analyzed by using a field emission scanning electron microscope (FE-SEM), and finally, the antibacterial efficacy of the ZnO nanoparticles is studied. The hydrothermal synthesis condition realizes that the smallest ZnO nanoparticles come from the zinc nitrate ($Zn(NO_3)_2$) precursor reacted with sodium hydroxide (NaOH) precipitator at 120 °C for 4 h.

1. Introduction

The well-known nanoparticles are ZnO metal oxide semiconductor materials because they have large excitation binding energy (60 meV) and direct wide bandgap (3.37 eV).^[1] Many applications of ZnO, e.g., catalysts,^[2] solar cells,^[3] gas sensors,^[4] light emitting diodes,^[5] rubber additive,^[6] and pigments.^[7] Due to the advantage of ZnO nanoparticles with good UV absorbance, it is widely used in the cosmetics and sunscreen industries.^[8] In addition, its unique physical properties are characterized by its photocatalytic and photo-oxidizing ability, chemical resistance, and inhibition of the growth of fungi and microorganisms and bacteria effectively. ZnO is acceptable for its benefit in biological applications as an antibacterial material.^[9] Due to the ability of zinc oxide

nanoparticles to inhibit bacteria due to the photocatalytic reaction, the electron holes of the zinc oxide nanoparticles will react with water. It can break down water into free radicals in the form of hydroxyl radicals ($\cdot OH$) and hydrogen ions (hydrogen ion; H^+). Conduction band (CB) electrons react with oxygen in the air to form superoxide radical anion ($\cdot O_2^-$). The free radicals of the superoxide ions continuously react with the hydrogen ions until they form hydrogen peroxide (H_2O_2). Hydrogen peroxide free radicals of superoxide ions and hydroxyl free radicals are reactive oxygen species (ROS) that affect cell wall damage by permeating bacterial cell membranes thus causing the deterioration of bacterial cells.^[10] There are also other physical and chemical factors that affect bacteria inhibition of zinc oxide nanoparticles

such as the UV illumination effect, the impact of ZnO morphology, the surface modification by thermal annealing, the influence of ZnO particle size and concentration, and the surface defect.^[11–14] Synthesis of ZnO nanoparticles for inhibition of bacteria that are the main cause of disease. Synthesized ZnO nano-materials to a specific size and morphological shape suitable for inhibiting bacteria must important consider the synthesis process.

There are several methods for creating ZnO nanostructures such as sol-gel,^[15,16] combustion,^[17,18] co-precipitation,^[19] and hydrothermal process.^[20] Most commonly used is hydrothermal process, which is interesting and popular recently because of its cost-effectiveness. It is easy to implement and an environmentally friendly approach that can be controlled and replicated. Hydrothermal technique is a chemical synthesis process that is a bottom-up process under the influence of zinc precursor and the type of precipitant agents that affect the ZnO nanoparticles. Hydrothermal techniques use high temperatures and pressures in the reaction. The temperature is usually close to the boiling point and the critical temperature of water (374 °C), and the pressure used is in the range of ≈ 20 MPa, therefore it must be prepared in an autoclave. From the literature review, it was found that the use of precursor as zinc nitrate reacts with base sodium hydroxide showed a trend of zinc oxide size tending to increase when the reaction temperature is increased.^[21] A study of differential morphological preparation of zinc oxide nanoparticles through pH control reveals that at pH 8, 9, and 10, the synthesized zinc oxide nanoparticles exhibited nanorod, nanowire, and nanosheet morphology, and at pH 11, 12, and 13, the synthesized zinc oxide nanoparticles exhibited spherical morphology. It was found that zinc oxide nanoparticles with rod morphology will be able to suppress bacteria better than spherical.^[22]

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