Synthesis of Alpha-Gamma Aluminum Oxide Nanocomposite via Electrochemical Method for Antibacterial Activity

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Abstract

This work was devoted to synthesizing α-γ Al₂O₃ nanocomposite by the electrolysis method. A plate of aluminum was used as the anode, while the graphite rod was used as the counter electrode (cathode). The structure and morphology were investigated and characterized by X-ray diffraction (XRD) and transmission electron microscopy (TEM). The results indicated the average size of α-γ Al₂O₃ nanocomposite was smaller than 10 nm. The value of inhibition zone indicated the nanocomposite’s effect on different bacteria. The results demonstrated the newly synthesized nanocomposite as promising antimicrobial agents against bacteria.

Keywords: α-γ Al₂O₃ nanocomposite, TEM, Electrochemical method, Antibacterial activity

Introduction

Nanotechnology is developing as quickly with its application in science for the engineering of new materials at the nanoscale [1-7]. The possess of Nanoparticles are different chemical properties when compared to bulk kinds of similar chemical composition [8-11]. Nanotechnology has extensive interests, especially in the medical, industrial, and environmental fields [12-15]. Metal oxide nanoparticles have exhibited better stability, low poisonousness, high immovability, and selectivity associated with organic compounds [16-18]. Moreover, the particle size of such is responsible for the changes in their basic physical and chemical properties. These particles exhibit remarkable applications in catalysis, drug delivery, water treatment, sensor devices, semiconductor materials, and solid oxide fuels [19, 20]. Aluminum oxide nanoparticles have significant industrial applications [21], and they has many usages like abrasive material, as an absorbent in heterogeneous catalysis and metal-matrix composites as a biomaterial and reinforcements [22, 23]. A wide range of applications of Al₂O₃ was employed, such as sensors, electronics devices, antimicrobial, catalyist, and so on [24, 25]. Here it is many forms of crystallographic phases, on which γ and α forms were used for application because of its different features. The high surface area of γ-Al₂O₃ lead to it useful for catalyst related application [26, 27], whereas
the polycrystalline α-Al₂O₃ is widely used for glass-ceramic application [28, 29]. It is outstanding from information in writing that for acquiring items of thick nanocrystalline Al₂O₃, both phases change from γ to α phase must be prevented or nanocrystalline α-Al₂O₃ powders must be utilized [30-32]. Aluminum oxide nanoparticles can be the preparation by several methods containing electrolysis, hydrothermal, sol-gel, spray pyrolysis, plasma sputtering, laser ablation, and pulse laser deposition [33-37]. The purpose of this work is to synthesis a novel nanocomposite of two phases of aluminum oxide (alpha and gamma) by electrolysis method, which is considered a new with a nanocomposite because whole methods were prepared one phase structure. There is not considered an important research effort on the antibacterial of α-γ Al₂O₃ nanocomposite. Thus the result can be considered high, and the work can be a good attempt to syntheses α-γ Al₂O₃ nanocomposite by electrochemical method and employ in such an important application.

**Experimental**

**Chemicals and reagents**

No further purification, both chemicals were of analytical reagent grades and used as obtained.

**Synthesis of α-γ Al₂O₃ nanocomposite**

α-γ Al₂O₃ nanocomposite have been synthesized by the electrolysis method, Fig. 1, using 150 ml of 0.08 M KOH at 25 °C as the electrolyte. A rectangular aluminum plate (50 mm×25 mm×1 mm) used as the anode. Graphite rod (7×70 mm) used as the counter electrode cathode. Before mounting the substrates in the cell, they are cleaned sonically using organic cleaner and aqueous solvents (ethanol, acetone, chloroform, de-ionized water) Sequentially, and each cleaning step duration is 5 minutes. The applied d.c. voltage between the electrodes is 15 V under a current density of 9.22×10⁻³ mA/cm² for 8 h. A brown precipitate has obtained, and the product has been washed with de-ionized water and dried overnight to subsequent analysis.

**Antibacterial assay**

The α-γ Al₂O₃ nanocomposite synthesized using the electrolysis method. The nanocomposite was tested for antibacterial activity by agar disc diffusion method against bacillus anthrax, then incubated at 37 °C for 24 h. Finally, the inhibition zone of bacteria was measured at different levels.

**Results and Discussion**

Fig. 2 shows X-ray diffraction patterns of α-γ Al₂O₃ nanocomposite powders. It observes six crystalline peaks of γ-Al₂O₃, which have miller indices (220) (311) (222) (400) (511) and (440) [38], and five crystalline peaks of α-Al₂O₃, also have miller indices (012) (311) (024) (122) and (128) [39]. The crystalline size of α-γ Al₂O₃ nanocomposite has been calculated by using Scherer’s formula (D = 0.9λ/B cosθ) [40]. The mean crystallite size of nanoparticles was 9.1 nm, while the (222) reflection peak indicated the formation of γ-Al₂O₃.

The morphology of α-γ Al₂O₃ nanocomposite powders has been characterized by transmission electron microscopy (TEM) in Fig. 3. The size of the nanocomposite is apparent with a size of less than 10 nm. The agglomeration of more nodular individual particles has existed in the structure of nanocomposite. Most of the particles have rough surface morphology.

Fig. 4 shows the inhibition zone, which indicates the nanocomposite of α-γ Al₂O₃ shows the strong
effect against gram-negative bacteria type bacillus anthrax. Hence, the results demonstrate that the α-γ Al₂O₃ nanocomposite promising antimicrobial agents against bacteria. The activity of nanoparticles against bacteria has been reported by several studies that were obtained the mechanism of the bactericidal effect of nanoparticles is not understood wholly. It may be the nanoparticle attack to surface membrane. Many changes took place in its membrane morphology and disturb its power function, such as permeability, produced an essential increase in its permeability, affecting suitable transport through the membrane of plasma, resulting in cell death. It can be that the penetration of nanoparticle inside bacteria causing damage via interaction with Sulphur and phosphorous having compounds such as DNA. It can vanish its replication ability, and cellular proteins convert an inactive after the treatment of nanoparticle. In this project, the strong activity of Al₂O₃ due to the small size of the nanoparticles provides good penetration of the nanoparticles inside the cell then caused many changes later cell death [1, 14, 16, 41].

Conclusions

α-γ Al₂O₃ nanocomposite was synthesized by electrolysis method, which was a simple and efficient method for preparing α-γ Al₂O₃ nanocomposite. The prepared nanocomposite was characterized using X-ray diffraction analysis, field emission scanning electron microscopy, and transmission electron microscopy, which displayed that the as-prepared sample had the size of α-γ Al₂O₃ nanocomposite less than 10 nm. In addition, α-γ Al₂O₃ nanocomposite showed a strong activity against bacteria, and this activity was influenced by the size of nanoparticles due to which they could easily reach the nuclear content of bacteria. The nanoparticles presented large and impressive surface area; thus, the contact with bacteria was
the greatest, which could be the reason behind the strong activity against bacteria, and that smaller particles made large inhibition zones.

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