Characterization of aluminum oxide nanoparticles using egg white as a trap-matrix

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Abstract. In this article, we add egg white (albumen) to the synthesis of aluminum oxide nanoparticles (Al\textsubscript{2}O\textsubscript{3}). Egg white can be used as a trap for the aluminum oxide particle matrix to prevent agglomeration of aluminum oxide particles during the synthesis process. To determine the effect of pH on the characteristics of aluminum oxide crystals formed, variations in pH were carried out starting from 7, 9 to pH 11. The calcination temperature used was 1000°C. We used the results of XRD analysis to determine the crystalline size and crystallinity of aluminum oxide nanoparticles. pH 7 shows the size of the smallest nanoparticles of crystals and the relatively large levels of crystallinity.

1. Introduction

Energy sustainability is one of the most important challenges faced by various countries in the world. On the other hand, issues related to the use of low-carbon energy continue to grow along with the increasing negative impacts of climate change. Because it is located in the tropics, Indonesia has abundant solar energy. Therefore the use of solar energy to meet renewable energy in Indonesia has considerable potential [1].

The use of solar energy can be done through light and heat produced. The heat generated by the sun is used by solar collector systems with output in the form of heat energy [2]. The challenge of using heat collectors lies in the level of efficiency that depends on the amount of solar energy flux and the conversion method applied [3]. Because using water that has sufficiently low conductivity, there will be high energy loss in conventional solar collector systems [2].

The innovation that can be done to improve the efficiency of solar collectors is to develop nanofluid based solar collectors with a direct absorption system [4]. This collector system utilizes nanofluids such as Al\textsubscript{2}O\textsubscript{3}, CuO and graphite to transfer heat because it has a conductivity that is much larger than water [5].

Alumina (Al\textsubscript{2}O\textsubscript{3}) is widely used in the refractory, mechanical, abrasive and insulator industries. Alumina is the best catalyst in oxidation-reduction reactions. In the other hand, alumina have high surface area, good mechanical strength, thermal stability and porous structure [6,7].

The sol-gel method is the best method to synthesize nanoparticle because it has several advantages namely specific surface area, producing ultrafine-sized solid particles, excellent homogenity and
purity and the crystallinity can be controlled. Therefore, sol-gel technology plays an important role in a variety of scientific and technical fields such as the ceramics industry, the nuclear fuel industry and the electronics industry [8,9]. The high porous alumina also can be synthesized through the method [6].

To avoid negative impacts on the environment, in this study an alternative method to synthesize nanoparticles was proposed using chicken egg white (albumen). Principally, the method is a modification of sol-gel method. Chicken egg white is chosen because of its protein and its abundance [10]. Thus, the use of albumen can provide a low-cost synthesis of nanoparticle. By mixing a solution of precursor with egg white polymer, a matrix can disperse the cations [11]. Egg albumin is used as a trap matrix for alumina ion which produce gel precursors and it can be transformed to $\text{Al}_2\text{O}_3$ nanoparticle [12].

2. Methods

$\text{AlCl}_3$ powder is dissolved in distilled water using a magnetic stirrer. After $\text{AlCl}_3$ dissolves then egg white from the commercial eggs is added while continuing to stir until homogeneous. Furthermore, the mixture solution was added with 5 M NaOH solution until it reached a pH variation of 7, 9 and ph 11. The gel obtained was dried at 250°C for 1 hour and calcined for 3 hours with a temperature of 1000°C. The powder that has been obtained is then mashed using mortar and the crystal characteristics are observed using x-ray diffraction (XRD) method. To analyse the crystalline phase we use X’Pert Highscore Plus software with PCPDF-2 database and the size of $\text{Al}_2\text{O}_3$ nanoparticle crystallites ($\tau$) is determined based on the Debye-Scherrer equation,

$$\tau = \frac{K \lambda}{B \cos \theta}$$

where $K$ is the nanoparticle form factor (in this study we assume $K = 0.9$), $\lambda$ is the x-ray wavelength used, $B$ is FWHM, and $\theta$ is the Bragg angle.

3. Results and Discussions

In Figure 1 can be seen the appearance of the gel before the calcination process. The color is milky white. Moreover, the color of powder after calcined at 1000°C changes to bright white. There is a mass reduction in this synthesis as an indication of the decomposition of the hydroxyl group in the $\text{Al(OH)}_3$ compound and transform to $\text{Al}_2\text{O}_3$.

![Figure 1. (a) gel before calcination; (b) after calcination](image)

The pattern of the XRD analysis of $\text{Al}_2\text{O}_3$ nanoparticles based on pH variations is shown in Figure 2. XRD results were analyzed using the X’Pert HighScore Plus software. Based on the comparison between the reference data (PDF 2 – Ref. Code: 00-010-0425), it can be stated that the three pH variations of $\text{Al}_2\text{O}_3$ nanoparticle synthesis have produced $\gamma$-$\text{Al}_2\text{O}_3$ phase with cubic crystal system and $Fd-3m$ space group. The lattice parameter of $\text{Al}_2\text{O}_3$ is $a = b = c = 7.9$ nm while $\alpha = \beta = \gamma = 90^\circ$. The three variations of pH produce peaks with relatively similar orientations. According to the results can be stated that the calcination still leaving the amorphous phase. The phenomenon indicates the calcination temperature does not provide enough thermal energy to satisfy the crystal growth and $\gamma$-
alumina is more stable than $\alpha$-alumina [7]. The three highest peaks of the XRD pattern of the three samples are related to angles ($2\theta$): 37.6°, 60.9°, and 67.02°.

According to the Debye-Scherrer in eq. (1) and the data of XRD pattern we can release information about the average crystallite size in each sample with variations in pH as in the Table 1. Based on the result it can be stated that the smallest size of $\text{Al}_2\text{O}_3$ nanoparticles can be obtained at pH 7 which is 6.18 nm and the greatest size can be obtained at pH 9 which is 35.6 nm.

| pH  | Crystallite size (nm) |
|-----|----------------------|
| 7   | 6.18                 |
| 9   | 35.6                 |
| 11  | 6.54                 |

In Table 4 we present the crystallinity of $\text{Al}_2\text{O}_3$ based on pH variation. pH 7 can reach the highest level of crystallinity of $\text{Al}_2\text{O}_3$ (14.36%) and the lowest crystallinity occurs at pH 9 (12.23%). Thus, according to the results, it can be stated that the optimal pH in the synthesize of $\text{Al}_2\text{O}_3$ nanoparticle occurs at pH 7.

| pH  | Crystallinity (%) |
|-----|-------------------|
| 7   | 14.36             |
| 9   | 12.23             |
| 11  | 13.84             |

4. Conclusions

Based on the results, the egg white can be utilized as a trap matrix of Al2O3 particles and prevent agglomeration in the synthesis of Al2O3 nanoparticles. The smallest crystallite size and the highest crystallinity level was obtained at pH 7. Through the methods, we may develop eco-friendly and low-cost ways to synthesize nanoparticle.
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