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Morphology And Distribution of Platinum Nanoparticles In Deionized Water Synthesized Using The Pulsed Laser Ablation

Wahyuddin, Eko Hidayanto, and Ali Khumaeni*

Department of Physics, Faculty of Science and Mathematics, Diponegoro University, Jl. Prof. Soedharto, S.H., Tembalang, Semarang 50275, Indonesia

*Corresponding email: khumaeni@fisika.fsm.undip.ac.id

Abstract– In this study, platinum nanoparticles were successfully synthesized using the pulsed laser ablation method with the assistance of an Nd:YAG laser at a wavelength of 1064 nm. The synthesis process was marked by a color change in deionized water from clear to dark brown, indicating the formation of platinum nanoparticles. Morphological and size characterization analysis of the nanoparticles using Transmission Electron Microscopy (TEM) revealed that the nanoparticles are spherical in shape and have a homogeneous size distribution, with diameters ranging from 0.5 to 7.5 nm and an average size of 2.49 nm.

Keywords – Pulsed Laser Ablation; Platinum Nanoparticles; Deionized Water; Transmission Electron Microscopy.

I. Introduction

Metal nanoparticles have attracted significant interest due to their wide range of applications, including in optics, electronics, biology, catalysis, and medicine [1]. Among various metals, platinum in nanoparticle form, as part of the field of nanotechnology, has gained considerable attention in recent years due to its unique properties and broad applications across different industries [2]. The small dimensions of nanomaterials and their high surface to volume ratio enhance reactivity, catalytic efficiency, conductivity, and other superior characteristics. This makes nanomaterials important components in various fields, including materials science, biology, and energy [3]. Platinum nanoparticles can be produced through various methods. Each method affects the size, morphology, and ultimately, the catalytic efficiency of the nanoparticles. Transition metal nanoparticles, particularly platinum, have been extensively studied due to their unique physical properties and potential applications in various fields, such as biology, optics, electronics, and catalysis [4,5,6]. One method for synthesizing platinum nanoparticles is by using a physical method, namely the pulsed laser ablation method or laser ablation in liquids [7]. Pulsed laser ablation has evolved into a versatile method for synthesizing various metal nanoparticles. Its main advantage is the ability to form colloids directly without the need for additional reducing or stabilizing agents [8]. The process involves focused irradiation on a platinum target submerged in a liquid medium, which triggers the release of platinum atoms. The released platinum atoms then aggregate and forming nanoparticles [9].

Analysis methods are essential for understanding the characteristics of the synthesized platinum nanoparticles. One commonly used method is Transmission Electron Microscopy (TEM), which provides detailed images of nanoparticle morphology and size distribution and can be used in conjunction with additional analytical techniques. One of the main advantages of Transmission Electron Microscopy (TEM) is its ability to produce high-resolution, three-dimensional images of a material, with a resolution down to the atomic scale. This capability makes TEM an extremely valuable technique for accurately analyzing nanoparticle size distribution, which is a crucial parameter in the synthesis, optimization, and application of nanomaterials [10]. Transmission Electron Microscopy (TEM) not only provides a comprehensive view of the morphology and size distribution of nanoparticles, but it can also be integrated with other analytical techniques to investigate the elemental composition and crystal structure of nanoparticles at the atomic scale. The application of TEM in platinum nanoparticle research facilitates a deep understanding of the influence of synthesis parameters on the structural and chemical characteristics of the nanoparticles, which is crucial for optimizing their efficiency in industrial and biomedical applications [11].

In this study, we will synthesize platinum nanoparticles using the pulsed laser ablation method in deionized water (DIW). We will utilize Transmission Electron Microscopy (TEM) to characterize the resulting nanoparticles, focusing on morphology and size distribution. Thus, this research aims to provide deeper insights into the influence of synthesis parameters on the characteristics of platinum nanoparticles, which can contribute to the development of further applications.

II. EXPERIMENTAL PROCEDURE

2.1. Materials

Platinum metal with a purity level of 99%, ND:YAG laser device at 1064 nm, beaker glass, and deionized water.

Figure 1 Platinum metal cut to approximately 2 x 1.5 cm was sterilized using 70% alcohol to eliminate any bacteria on its surface. Afterward, the metal plate was rinsed with aquadest to remove residual alcohol. The beaker intended for sample synthesis was also cleaned with alcohol and rinsed with aquadest. The cleaned platinum plate was then placed into a beaker containing 10 mL of deionized water.

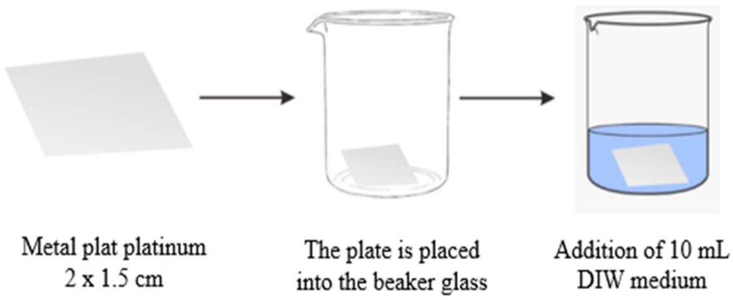

Fig. 1. Preparation of platinum metal

Platinum nanoparticles were produced through pulsed laser ablation using an Nd:YAG laser at a wavelength of 1064 nm, with an energy of 80 mJ, a focal distance of 10 cm, a pulse width of 7 ns, and a frequency of 10 Hz. The laser was directed at the surface of the platinum for 30 minutes until a color change occurred. **Figure 2** shows the schematic of the synthesis of platinum nanoparticle colloids in deionized water.

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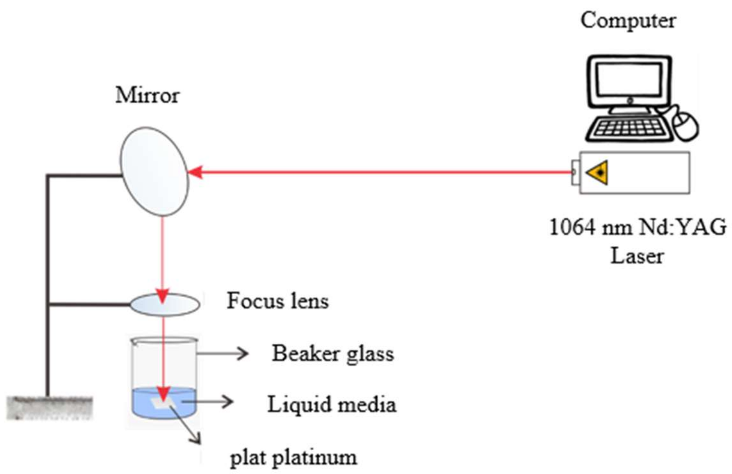

Fig. 2. Setup for Platinum Nanoparticle Synthesis Experiment

2.2. Nanoparticles Platinum characterization

The morphology and size characterization of platinum nanoparticles produced through the pulsed laser ablation method was conducted using a JEOL-JEM 1400 Transmission Electron Microscopy (TEM). The nanoparticle samples, in colloidal form with deionized water as the medium, were collected after the laser ablation procedure. The particle size distribution analysis was performed using ImageJ software based on the acquired TEM images.

III. RESULT AND DISCUSSION

Figure 3a shows platinum nanoparticles before being synthesized using deionized water (DIW), which are white in color, while **Figure 3b** shows platinum nanoparticles after being synthesized with pulsed laser ablation, which are dark brown in color.

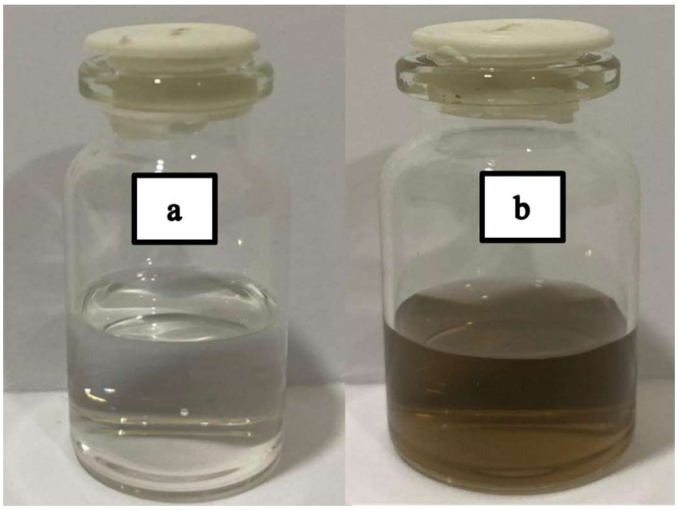

Fig. 3. Platinum nanoparticles in deionized water medium (a) before synthesis (b) after synthesis using pulsed laser ablation

Figures 3a and 3b show a color change from initially clear in deionized water to dark brown, indicating the formation of platinum nanoparticles. This result is consistent with the previous study by Posanti et al., which stated that the synthesized platinum

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nanoparticles exhibit a dark brown color [12].

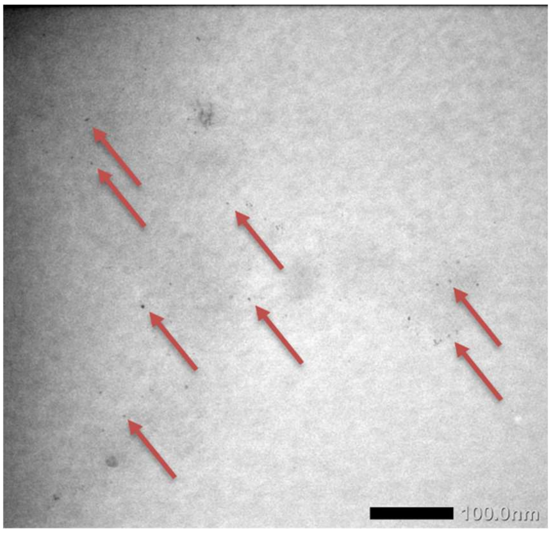

Fig. 4. TEM of platinum nanoparticles

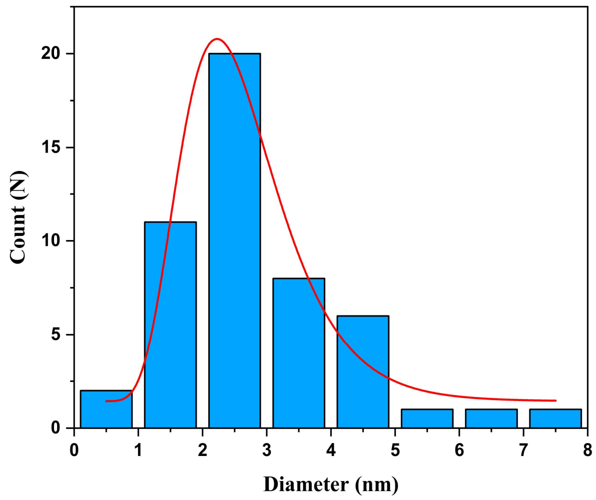

Fig. 5. Size distribution of nanoparticles platinum

Figure 4 shows a Transmission Electron Microscopy (TEM) image of platinum nanoparticles with a scale of 100 nm. The red arrow in the image indicates the position of nanoparticles randomly distributed across the entire image area. The platinum nanoparticles appear round and homogeneous, indicating that the synthesis produced particles with uniform morphology. This random distribution suggests that no significant agglomeration occurred, which shows that the stabilization of nanoparticles in the medium used is adequate. Additionally, based on visual observation, the platinum nanoparticles appear quite small, supporting applications that require nano-sized particles to enhance effectiveness. Figure 5 shows the size distribution of platinum nanoparticles based on analysis using the ImageJ software. The histogram shows the particle size distribution, with diameters ranging from 0.5 to 7.5 nm. Most particles have a diameter of around 2-4 nm, with a distribution peak at 2.5 nm, and an average diameter of 2.49 nm. These small particle sizes have the potential to improve colloidal stability and catalytic efficiency. In other studies, it was found that the size of platinum nanoparticles varies depending on the synthesis method used. For example, a study by Chu et al. (2019) showed spherical platinum nanoparticles with an average diameter of 50 nm synthesized through the microwave technique [13]. A study by Chou et al. (2010) reported platinum nanoparticles with an average diameter of 12 nm produced by the polyol method [14]. A study by Fu et al. (2020) reported nanoparticles with an average diameter of 94 nm using the conventional method [15].

IV. CONCLUSIONS

Platinum nanoparticles have been successfully synthesized using the pulsed laser ablation method. Morphological and size characterization analysis of the nanoparticles using Transmission Electron Microscopy (TEM) revealed that the nanoparticles are spherical in shape and have a homogeneous size distribution, with diameters ranging from 0.5 to 7.5 nm and an average of 2.49 nm. This small particle size has the potential to enhance colloidal stability. The study also demonstrated that the size of the nanoparticles varies depending on the synthesis method used, as reported in previous studies.

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