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The Effect of Pulse Laser Ablation Method on the Morphology of Ta_2O_5 Nanoparticles

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Abstract — In this study, tantalum pentoxide (Ta_2O_5) nanoparticles were synthesized using the pulsed laser ablation method with deionized water (DIW) as liquid medium. The pulse laser ablation method produces nanoparticles with high purity due to its lack of reactant contamination. Ta_2O_5 nanoparticles were successfully synthesized with a UV-Vis wavelength of 293 nm. FESEM images produced excellent images with an average nanoparticle size of 16.92 nm.

Keywords— Tantalum Pentoxide Nanoparticles; Pulsed Laser Ablation; Deionized Water.

I. INTRODUCTION

Tantalum pentoxide (Ta_2O_5) nanoparticles have attracted significant attention in the fields of materials and nanotechnology research due to their unique characteristics. Ta_2O_5 nanomaterials are widely studied due to their excellent dielectric and electrochemical properties [1]. Ta_2O_5 nanoparticles have good biocompatibility, low ion release, corrosion resistance, low toxicity, and can be used for biomedical applications [2-4]. In addition, Ta O_5 nanoparticles have been widely applied in various fields, including orthopedics, electronics industry, energy, and catalysts [5-6].

Several researchers have conducted research on Ta_2O_5 nanoparticles with various different synthesis methods. Ta_2O_5 nanoparticles can be synthesized using the hydrogen arc plasma method conducted by Wang et al. (2004). The results of the study showed that tantalum nanoparticles have high activity and are easily oxidized, as confirmed by UV-Vis, XRD, TEM, and HRTEM analysis [7]. Streetwong et al. (2013) synthesized Ta_2O_5 nanoparticles using the sol-gel method. The synthesis results showed that Ta_2O_5 nanoparticles were most thermally stable at an optimum temperature of 700°C. In addition, Ta_2O_5 nanoparticles can show very good resistance in repeated use [8]. Nagaraju et al. (2019) synthesized Ta_2O_5 nanoparticles using the ultrasound-assisted synthesis method. The results showed that Ta_2O_5 nanoparticles have beneficial activity against antibacterial and anti-breast cancer [9].

In this study, we will be producing Ta_2O_5 nanoparticles using the pulse laser ablation method with deionized water as the liquid media. Ta_2O_5 nanoparticles were subsequently examined using UV-Vis and FESEM methods. This study aims to evaluate the effect of the pulsed laser ablation technique on the obtained Ta_2O_5 nanoparticles.

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II. Experimental Procedure

2.1 Materials

Tantalum plate (Ta) 99%, deionized water (DIW), Nd:YAG Laser (Q-smart 850 by Quantel).

2.2 Methods of Synthesis of Tantalum Nanoparticles

Figure 1 shows the synthesis method of Ta_2O_5 nanoparticles. Preparation was carried out before data collection. After cutting the Ta plate to 1.5 cm x 1.5 cm, we placed it on the bottom of a petri dish and added 10 ml of liquid medium, specifically deionized water. We used a pulse Nd:YAG laser for the synthesis of colloidal nanoparticles. During the synthesis process, a silver mirror deflected the laser beam towards a convex lens with a focal length of 10 cm, directing it towards the target at the bottom of the petri dish.

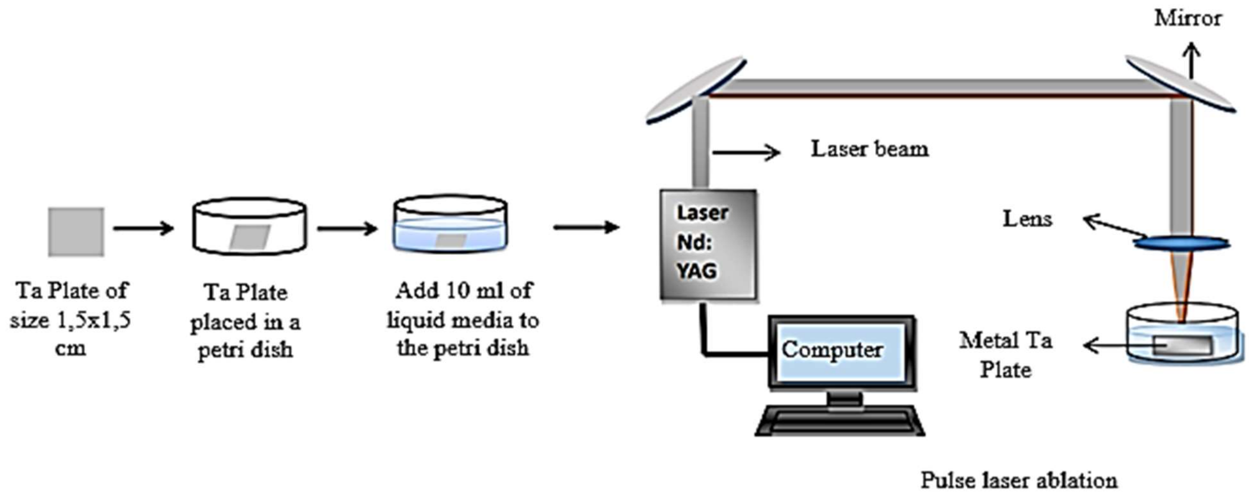

Figure 1 Synthesis method of Ta_2O_5 nanoparticles

2.3 Nanoparticles Characterization

Ultraviolet visible (UV-Vis; Shimadzu UVmini-1240) spectroscopy is used to determine the absorption of a material or sample. The sample is inserted into a quartz cuvette with as much as 2 ml. We use deionized water as the blank solution, utilizing the same cuvette for the analysis. Set the tool with an absorbance of around 3 AU and a wavelength between 200 and 700 nm. We analyze the morphology of nanoparticles using the Field Emission Scanning Electron Microscope (FESEM; JSM-IT 700 HR) and process the FESEM data using ImageJ software.

III. Results And Discussion

Colloidal nanoparticles of Ta_2O_5 in deionized water are shown in Figure 2. The colloidal image of Ta_2O_5 nanoparticles before synthesis has a clear color, while after synthesis it has a gray color.

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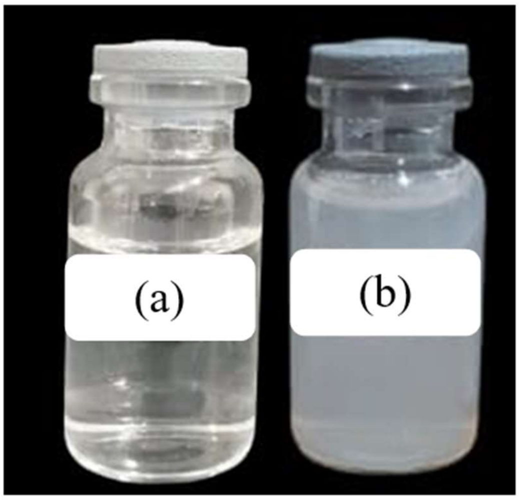

Figure 2 Ta_2O_5 nanoparticles in deionized water liquid media (a) before synthesis and (b) after synthesis

Figure 2 represents a color transition from clear before synthesis to gray post-synthesis, indicating the formation of Ta_2O_5 nanoparticles. According to a study by Gomes et al. (2018), the produced Ta_2O_5 nanoparticles have a gray hue [10]. The Ta_2O_5 nanoparticle colloid will then be studied by UV-Vis spectroscopy and field emission scanning electron microscopy (FESEM). The resulting colloid of Ta_2O_5 nanoparticles was studied using UV-Vis spectroscopy.

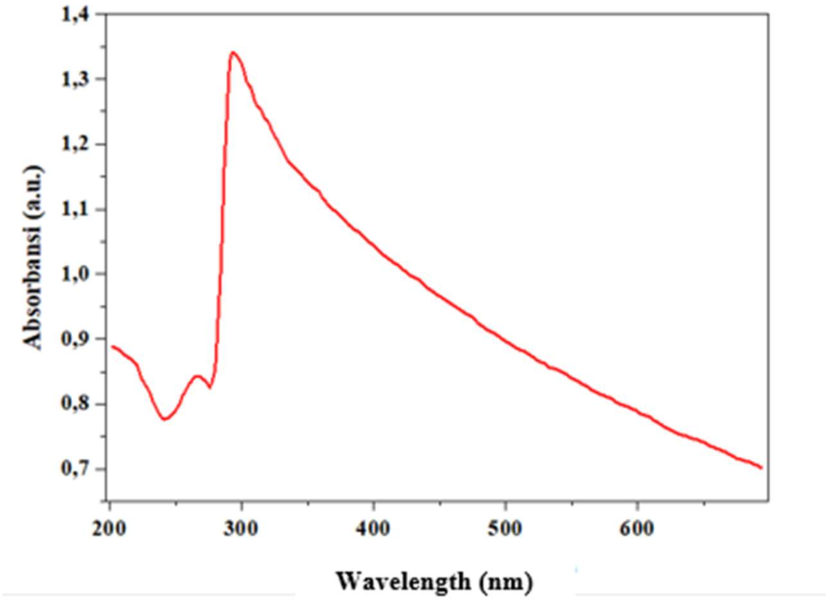

Figure 3 UV-Vis spectrum of Ta_2O_5 nanoparticles

Figure 3 shows the UV-Vis spectrum graph of the nanoparticle colloid that was made using the pulse laser ablation method. After synthesizing the nanoparticle colloid for 30 minutes, we observed an absorption peak at a wavelength of 293 nm, resulting in an absorption of 1.341. This study demonstrates the successful formation of Ta_2O_5 nanoparticles in the sample. Gomes et al. (2018) found that the solvothermal synthesis method, which involves the reaction of Ta(V) chloride with benzyl alcohol, produces an

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absorption peak at a wavelength between 250 and 318 nm. Increasing the temperature increases the absorption value, resulting in a greater concentration of particles formed at the absorption height [10].

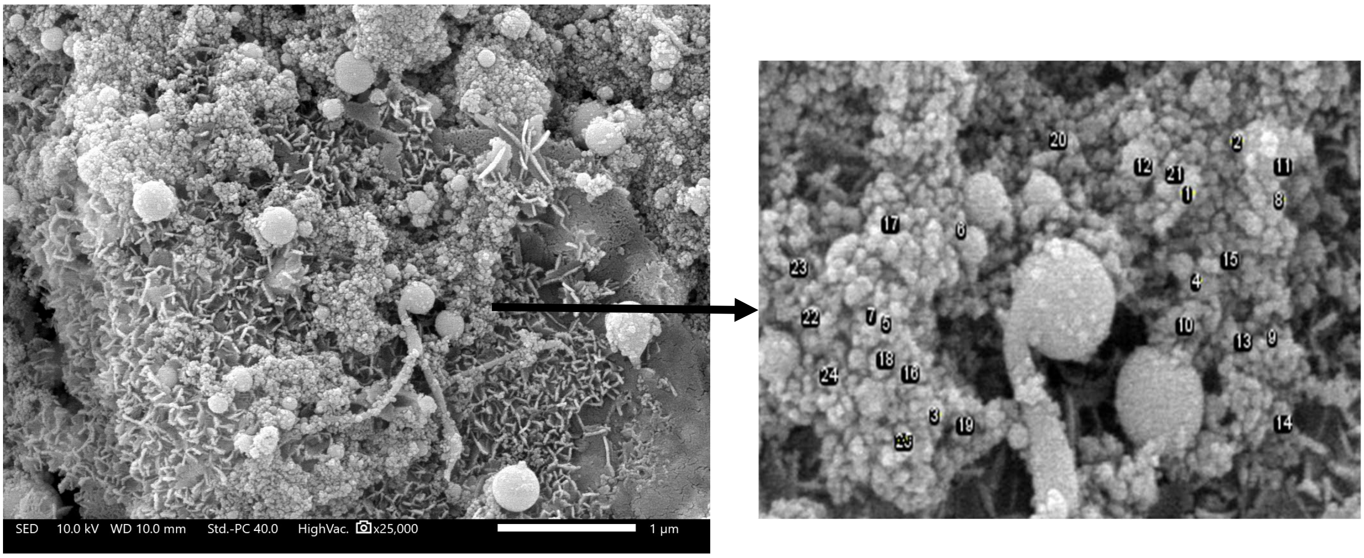
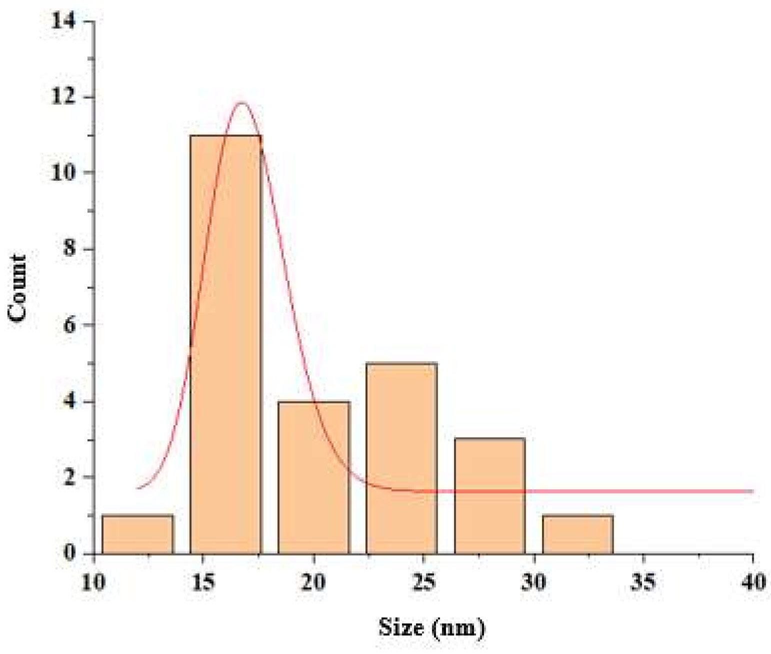


Figure 4 FESEM image Ta_2O_5 nanoparticles



Figs. 5. Size distribution of Ta_2O_5 nanoparticles

Furthermore, characterization analysis was carried out using *field electron scanning emission microscope* (FESEM). The FESEM image results in Figure 4 clearly illustrate the morphology of the sample, with a scale of 1 µm. When heated by the laser, the Brownian motion effect causes the Ta_2O_5 nanoparticles that were made with deionized water to stick together. In addition, agglomeration can be caused by the liquid media used; although deionized water only contains a few ions in it, nanoparticle interactions can still occur through van der Waals forces. This leads to the attraction and self-agglomeration of the nanoparticles [11]. For the distribution of Ta_2O_5 nanoparticles, it was processed using ImageJ software, so that a histogram was obtained that describes the size distribution. We achieve this by measuring the diameter of the nanoparticles visible in the FESEM image. Figure 5 produces a histogram analysis of the size distribution of tantalum nanoparticles. The diameter of the nanoparticles ranges from 12.01 to 32.03 nm, with an average diameter of 16.92 nm.

In this study, the diameter of the nanoparticles was much smaller compared to previous studies on Ta_2O_5 nanoparticles. For example, Lu et al. (2021) found that using cathode glow discharge electrolysis (CGDE) at 500 volts to make Ta_2O_5 nanoparticles with a size of 325 nm was one way to do it [12]. This study shows that the use of the pulse laser ablation method produces a smaller size compared to other methods in the synthesis of Ta_2O_5 nanoparticles.

IV. Conclusions

Synthesis of Ta_2O_5 nanoparticles using the pulse laser ablation method has been successfully carried out. The results showed that the formed Ta_2O_5 nanoparticles had a nanoparticle diameter ranging from 12.01 to 32.03 nm, with an average diameter of 16.92 nm.

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