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Synthesis of Titanium Oxide Nanoparticles Using Pulsed Laser Ablation Method in Deionized Water

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ABSTRACT
The synthesis of titanium oxide nanoparticles (TiO_2NPs) has been successfully carried out using pulsed laser ablation in deionized water to produce titanium oxide nanoparticles. This synthesis is included in the top-down method which aims to produce high-purity nanoparticles synthesis. Experimentally, an Nd:YAG laser beam (with 1064 nm, 85 mJ and 10 Hz) was focused on the surface of a high-purity (99.9%) titanium plate placed in deionized water. The high energy pulsed laser Nd:YAG laser makes the titanium plate ablate for 30 minutes. This is because the melting of the titanium plate surface causes the formation of small titanium oxide particles. When these particles hit deionized water this synthesis titanium oxide will form a colloid. Furthermore, colloidal titanium oxide nanoparticles have been successfully produced with a bluish-white color. The absorbance of TiO_2NPs was shown at 239.75 nm as the appearance of colloidal TiO_2NPs and the average diameter at 73.47 nm. Therefore the synthesis of TiO_2NPs by pulsed laser ablation method can produce nanoparticles.

Keywords: TiO_2NPs, pulsed laser ablation, deionized water, titanium plat

I. INTRODUCTION

Nanoparticle describe material in range nanometer size, at least under 100 nm[1]. The nanoparticles had developed in many field section such as biomedical, environment, industries, etc[2], [3]. Synthesis nanoparticles can produce by bottom-up method and top-down method. The bottom-up method produced by chemical and biological agents from molecules and atoms shapes that combine until nanoparticle size while the top-down method using bulk material for reducing material in micrometer size to nanoparticle size[4].

Bottom-up synthesis is classified under biological and chemical methods containing natural or chemical solutions to produce nanoparticles. The biological method actually uses green synthesis which uses leaves, flowers, fungi etc. and combine with some chemical agent in the process of forming nanoparticles[5]. Chemical method in synthesis nanoparticles such as chemical vapor deposition, sol-gel, solvothermal and hydrothermal methods that contains chemical material to generate nanoparticles. These methods have side effects because of using hazardous materials[6].

Top-down synthesis is classified in physical method which include mechanical milling, sputtering and laser ablation that produce nanoparticle by using high temperature, high pressure and other properties [7]. This study used pulsed laser ablation because it is one of the most common top-down approaches for nanoparticle synthesis and can produce high-purity nanoparticles. Laser ablation in liquids is applied to the synthesis of nanoparticles, the advantages of using this method are that it reduces the heat effect of the sample source, reduces preparation time, and is environmentally friendly[6].

Synthesis nanoparticle using metal to find physical and chemical properties such as using titanium metal because of high melting, resistance of corrosion and low conductivity[8], [9]. Synthesis nanoparticles of titanium plat in liquid with pulsed laser ablation can make titanium oxide nanoparticles (TiO_2NPs) that had been popular in commercial section because of biocompatibility properties, low cost, non-toxicity and high chemical stability[10]. Due to that advantages, titanium oxide nanoparticles can apply as anti-microba, water purify, coating, etc[10], [11]. This study purpose to produce titanium oxide nanoparticles that it can apply in many sections.

II. METHODS AND MATERIAL

This study uses a neodymium-doped yttrium aluminum garnet laser (Nd:YAG laser) by Quantel with the Q-smart 850 model, the basic wavelength of the Nd:YAG laser is 1064 nm. The Nd:Yag laser uses 85 mJ and repeats at 10 Hz as a device to synthesize titanium oxide which can produce colloidal nanoparticles of high purity. The laser beam is focused on the surface of a titanium plate with a high purity 99.9% titanium plate which is placed in a beaker containing deionized water as a liquid medium and the ablation process happens. This study operates an Nd:YAG laser to ablate titanium plates in deionized water for 30 minutes. Then the set-up of this study is presented in Fig. 1 to produce titanium oxide nanoparticles by pulse laser ablation method in deionized water medium.

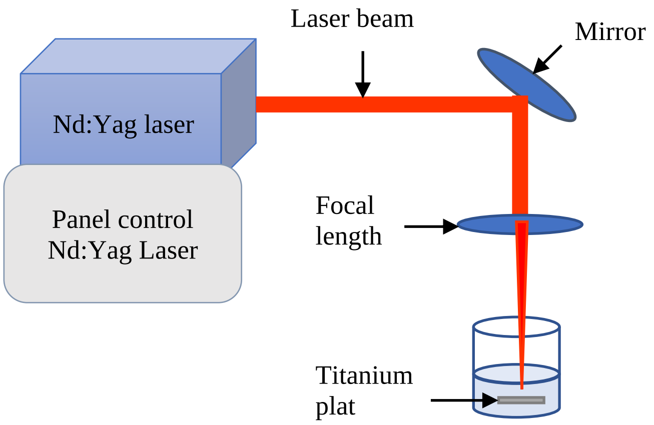

Figure 1. Set-up pulsed laser ablation method in deionized water

III. RESULTS AND DISCUSSION

The laser beams of Nd:YAG laser (85 mJ and 10 Hz) was focused onto pure titanium (99.9%) in deionized water. The interaction between the target surface (titanium 99.9%) and the laser results in the excitation of electrons on the target surface in the liquid. When the target surface of titanium is given high energy by laser photons, the photon energy is absorbed. The amount of photon absorbed depends on the intensity of the laser light source and the thickness of the target surface according to Beer Lambert's law. This energy absorption causes heating of the target surface so that the target surface melts and then evaporates[12]. This explains that laser ablation will erode the target surface in the liquid microscopically. The transition of the ablated material from the solid to the gas phase produces a plasma plume.

Figure 2. Colloidal titanium oxide nanoparticles in deionized water

During the irradiation process in the target surface, charged particles (electron and ion) in the plasma plume are induced by laser pulses. Pulse laser contribute to the process of ionization and subsequent plasma formation. After the plasma plume is not irradiated by the pulse laser, the plasma plume will explode due to the temperature difference between the plasma plume and deionized water so as to produce colloidal nanoparticles[13]. Colloidal TiO2NPs as synthesis product of synthetic titanium oxide nanoparticles in deionized water media are shown in Figure 2 which produces TiO2NPs with a bluish-white color. The color of deionized water was transparent then changes to bluish white color due to use of titanium plate ablation with a pulse laser method.

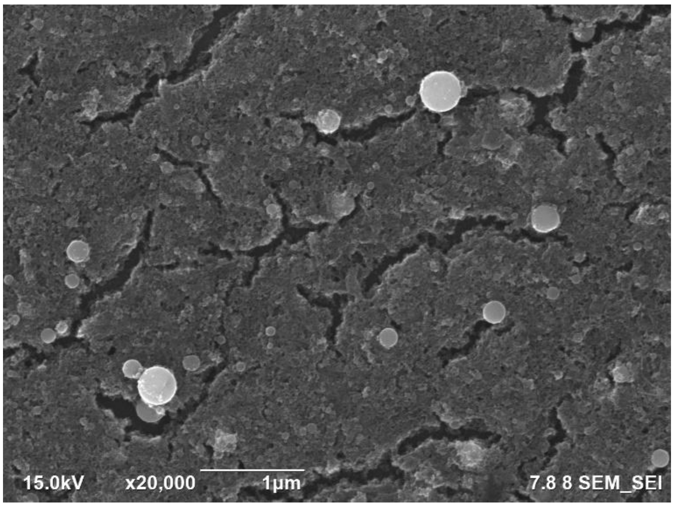

Figure 3. Morphology of titanium oxide nanoparticles in deionized water by FESEM analysis

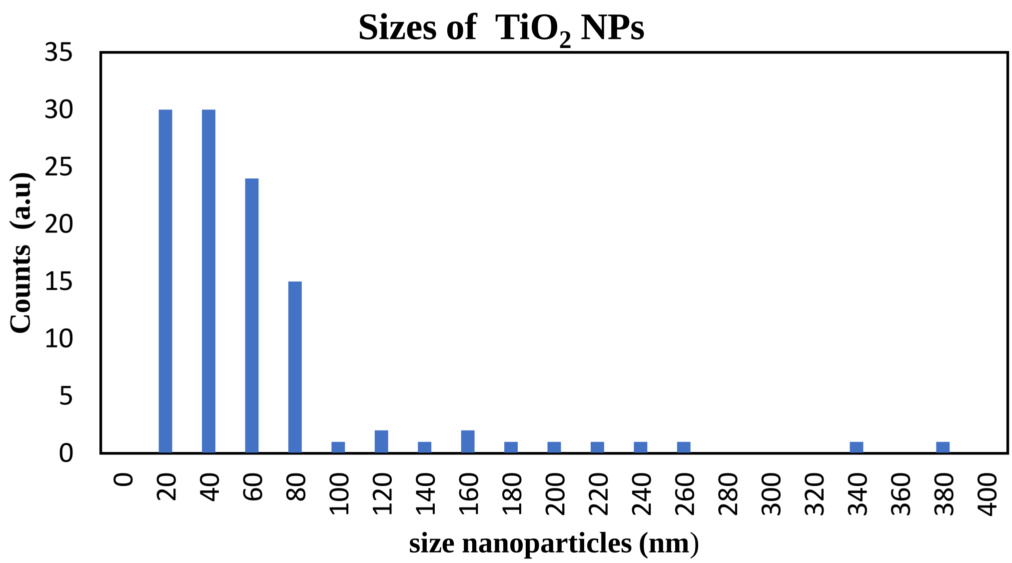

Figure 4. The histogram of titanium oxide nanoparticles in deionized water by FESEM analysis using ImageJ Software

The morphology of titanium oxide nanoparticles in deionized water had shown in Fig. 3 which produces spherical. These nanoparticles are displayed in various sizes. The largest ones are higher than 100 nm because they agglomerate in this liquid. The distribution of various sizes nanoparticles had been shown in the Fig. 4 in histogram form. Most of the nanoparticles were found in the diameter range of 20-80 nm. Then the average diameter of the TiO_2NPs in 73.47 nm.

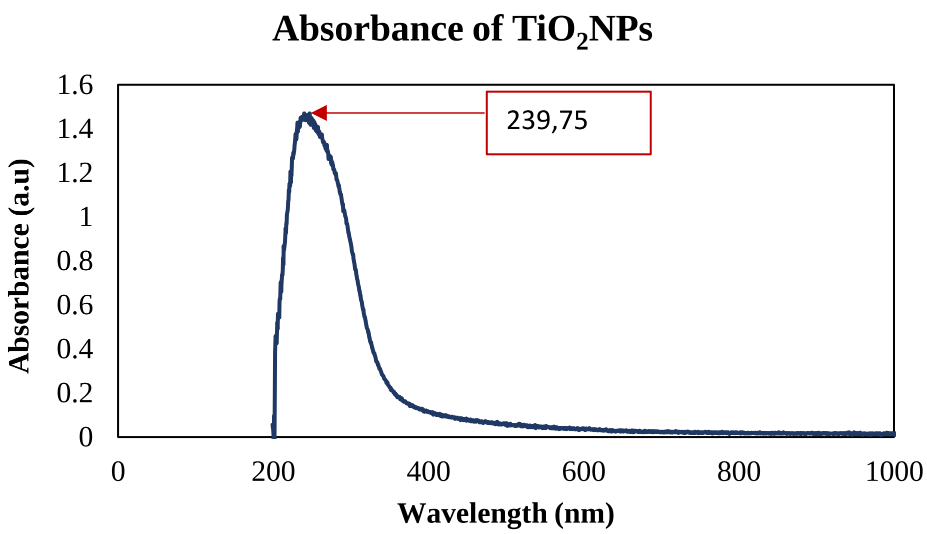

Figure 5. Spectrum of titanium oxide in deionized water

The optical characteristics of TiO_2NPs are shown in Fig. 5 which illustrates the presence of TiO_2NPs in colloids. The absorbance of TiO_2NPs using ultraviolet-visible (UV-Vis) spectroscopy was 239.75 nm with a maximum absorption of 1.47 arbitrary units (a.u). Thus, TiO_2NPs can exist in the optical spectrum of 258.78 nm with the average diameter size of the nanoparticles at 73.47 nm.

IV. CONCLUSION

Pulse laser ablation method is capable of producing high-purity nanoparticles characterized by a bluish-white color. The titanium dioxide nanoparticles produced by this method have a wavelength of 239.75 nm and can produce small nanoparticles with an average diameter of 73.47 nm. However, the nanoparticles formed will experience an increase in the size of the particle diameter because the deionized water causes agglomeration so that the deionized water cannot stabilize the nanoparticle size. Therefore, a stabilizer or surfactant is needed to stabilize the nanoparticle size.

V. REFERENCES

[1]. M. A. Sofi, S. Sunitha, M. A. Sofi, S. K. K. Pasha, and D. Choi, 'An overview of antimicrobial and anticancer potential of silver nanoparticles', J. King Saud Univ. - Sci., vol. 34, no. 2, p. 101791, 2022, doi: 10.1016/j.jksus.2021.101791.

[2]. M. Ilyas et al., 'Biological synthesis of titanium dioxide nanoparticles from plants and microorganisms and their potential biomedical applications', Inorg. Chem. Commun., vol. 133, no. October, p. 108968, 2021, doi: 10.1016/j.inoche.2021.108968.

[3]. S. Ashraf, A. Siddiqa, S. Shahida, and S. Qaisar, 'Heliyon Titanium-based nanocomposite materials for arsenic removal from water : A review', Heliyon, vol. 5, no. March, p. e01577, 2019, doi: 10.1016/j.heliyon.2019.e01577.

[4]. S. Shukla, R. Khan, and A. Daverey, 'Synthesis and characterization of magnetic nanoparticles, and their applications in wastewater treatment: A review', Environ. Technol. Innov., vol. 24, p. 101924, 2021, doi: 10.1016/j.eti.2021.101924.

[5]. R. Vennila et al., 'Biosynthesis of ZrO Nanoparticles and Its Natural Dye Sensitized

Solar Cell Studies', Mater. Today Proc., vol. 5, no. 2, pp. 8691–8698, 2018, doi: 10.1016/j.matpr.2017.12.295.

[6]. A. Ashfaq, N. Khursheed, S. Fatima, Z. Anjum, and K. Younis, 'Application of nanotechnology in food packaging : Pros and Cons', J. Agric. Food Res., vol. 7, no. January, p. 100270, 2022, doi: 10.1016/j.jafr.2022.100270.

[7]. G. M. Nair, T. Sajini, and B. Mathew, 'Advanced green approaches for metal and metal oxide nanoparticles synthesis and their environmental applications', Talanta Open, vol. 5, p. 100080, 2022, doi: 10.1016/j.talo.2021.100080.

[8]. H. A. Kishawy and A. Hosseini, 'Titanium and Titanium Alloys', in Machining Difficult-to-Cut Materials, Springer International Publishing AG, 2019, pp. 55–93. doi: 10.1007/978-3-319-95966-5.

[9]. K. D. Jena, Y. Xu, M. D. Hayat, W. Zhang, and P. Cao, 'Aiming at low-oxygen titanium powder : A review', Powder Technol., vol. 394, pp. 1195–1217, 2021, doi: 10.1016/j.powtec.2021.09.029.

[10]. A. J. Haider, Z. N. Jameel, and H. M. I. Al-Hussain, 'Review on : Titanium Dioxide Applications', Energy Procedia, vol. 157, pp. 17–29, 2019, doi: 10.1016/j.egypro.2018.11.159.

[11]. J. Ye, B. Li, M. Li, Y. Zheng, S. Wu, and Y. Han, 'Formation of a ZnO nanorods-patterned coating with strong bactericidal capability and quantitative evaluation of the contribution of nanorods-derived puncture and ROS-derived killing', Bioacive Mater., vol. 11, no. August 2021, pp. 181–191, 2022, doi: 10.1016/j.bioactmat.2021.09.019.

[12]. S. Ravi-Kumar, B. Lies, H. Lyu, and H. Qin, 'Laser ablation of polymers: A review', Procedia Manuf., vol. 34, pp. 316–327, 2019, doi: 10.1016/j.promfg.2019.06.155.

[13]. M. H. Mahdieh and A. Khosravi, 'Colloidal brass nanoparticles produced by pulsed laser ablation in deionized water and the effect of external electric field on particle size characteristics and ablation rate', Nano-Structures and Nano-Objects, vol. 24, p. 100580, 2020, doi: 10.1016/j.nanoso.2020.100580.

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