Synthesis of nickel nanoparticles by pulse laser ablation method using Nd:YAG laser

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Abstract. Nickel nanoparticles have interesting future prospect in various fields such as sensors, catalysts, and medical applications. The synthesis of nickel nanoparticles (NiNPs) using the pulse laser ablation method has been successfully performed by using low laser energy Neodymium Yttrium Aluminum Garnet (Nd:YAG). A high-purity nickel plate was immersed in 10 ml deionized water in a petri dish and a pulsed Nd:YAG laser (1064 nm, 30 mJ, 15 Hz) was then irradiated on the nickel surface for 20 minutes. Light grey color of colloidal NiNPs were successfully synthesized. The morphology of NiNPs shows that the spherical shape of NiNPs was produced with an average diameter of 25 nm and standard deviation of 3 nm. The surface plasma resonance was around 290 nm.

1. Introduction

Recently, synthesis of nanoparticles has interested many scientists for various applications such as drugs and medications, manufacturing and materials, electronics, energy harvesting, and mechanical industries [1]. Nanoparticles are particles having very small size ranging from 1-100 nm. One of the nanoparticles having good future prospects is nickel nanoparticles (NiNPs). The NiNPs have been employed for biomedical application [2], electrochemical glucose sensor [3], catalyst electrode [4], super capacitor [5], and medical application [6]. In medical application, NiNPs can be used for antibacterial agent [7], and antitumor [8]. Therefore, the synthesis of NiNPs is very urgent.

Conventional methods used for NiNPs synthesis are chemical control reduction [9], ethanol water system [10], polyol [11], hydrazine reduction [12], solution reduction [13], and ultrasound reduction [14]. These techniques are low cost in equipment. However, they involve complex processes, and require certain room temperature conditions to perform reduction and also give environmental problems. Furthermore, high-purity NiNPs cannot be synthesized by those methods because agents are used during experiments.

In this study, synthesis of NiNPs was made by using the pulse laser ablation (PLA) method. PLA method has been used for synthesis gold metal to produce nanoparticles with average diameter 23.5 [15]. Production of NiNPs colloid is starting when the high-purity nickel is ablated in liquid medium by laser beam bombardment. Compared to conventional methods described above, PLA only needs very simple preparation, low cost system, while high-purity NiNPs can be produced effectively. The high-purity of NiNPs are necessary especially for medical applications such as antibacterial agent and
antitumor. Characterizations of NiNPs including their morphology and optical characteristics are presented in this paper.

2. Method
In this experiment, a neodymium yttrium aluminum garnet (Nd:YAG) laser beam (New Polaris II model, fundamental wavelength 1064 nm, energy 30 mJ) was directed and focused onto high-purity nickel plate (99.95%). Prior to the laser bombardment, the nickel plate was washed with alcohol 70% to kill bacteria and other contamination. Fig. 1(a) shows the experimental setup used in this research. High-purity nickel plate (99.95%) was immersed in 10 ml of deionized water in a petri dish. A Nd:YAG laser was focused on sample surface and bombarded for 20 minutes by a 15 Hz laser pulse to produce a colloidal nickel nanoparticles. During the bombardment process, the plate in a petri dish was rotated slowly and periodically.

![Figure 1. (a) Experimental setup, (b) Colloid of NiNPs](image_url)

The morphology of NiNPs was characterized by using Scanning Electron Microscopy – Energy Diffraction X-ray (SEM-EDX, JEOL JED-2300). The size of nanoparticle was analyzed from the photograph obtained by SEM-EDX. Optical characteristics of the produced NiNPs was analyzed by using Ultraviolet Visible (UV-Vis) light spectroscopy.

3. Result and discussion
Colloidal nanoparticles with light grey color was produced when a Nd:YAG laser (30 mJ, 15 Hz repetition rate) was irradiated on a high purity nickel for 20 minutes as shown in Fig. 1(b). The change of color from transparent (deionized water) to light grey color certified that the nanoparticles are produced in the deionized water.

Figure 2 shows the photograph of NiNPs obtained by using SEM-EDX method. The photograph was obtained by preparing 1 ml colloidal NiNPs on Si surface. The colloid was then kept at room temperature for 24 hours to get dry nanoparticle on Si surface. It could be clearly seen that spherical nanoparticles of nickel have successfully been synthesized. The spherical shape of the produced nano certified that the absorption spectrum has single surface Plasmon resonance (SPR) peak.
Figure 2. the morphological photograph of NiNPs using SEM

Size distribution of NiNPs was further measured and analyzed by using SEM-EDX. The result shows that the average diameter of NiNPs is 25 nm with a standard deviation of 3 nm as shown in Figure 3.

Figure 3. Average diameter of NiNPs

The surface plasma resonance (SPR) of NiNPs was then obtained by using UV-Vis spectroscopy. Figure 4 shows the absorption spectra of NiNPs colloid. It can clearly be seen that the surface plasma resonance is centered at 290 nm of wavelength. This result is in keeping with the result published by Chandra et al. in synthesis of NiNPs [13]. The UV spectrum of Ni ranged from 250-370 nm.
4. Conclusion

Based on the results, high-purity NiNPs in deionized water were synthesized by using pulse laser ablation method at low energy Nd:YAG 1064 nm. The characterization of NiNPs was successfully performed by using SEM-EDX to indicate the morphology characteristic shows spherical shape of NiNPs was successfully produced. The average diameter of NiNPs is 25 nm with standard deviation at 3 nm. The absorption spectrum of NiNPs colloid prepared by using UV-Vis shows that the surface plasma resonance is centered at 290 nm.

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