Microwave-Assisted Synthesis of Alginate-Stabilized Gold Nanoparticles

Foliatiini Foliatiini
Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Indonesia, Depok 16424, Indonesia, Akademi Kimia Analis, Bogor 16158, Indonesia

Yoki Yulizar
Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Indonesia, Depok 16424, Indonesia, yokiy@ui.ac.id

Mas Ayu Elita Hafizah
Postgraduate Program of Material Science, Faculty of Mathematics and Natural Sciences, Universitas Indonesia, Jakarta 16440, Indonesia

Follow this and additional works at: https://scholarhub.ui.ac.id/science

Recommended Citation
Foliatiini, Foliatiini; Yulizar, Yoki; and Hafizah, Mas Ayu Elita (2014) "Microwave-Assisted Synthesis of Alginate-Stabilized Gold Nanoparticles," Makara Journal of Science: Vol. 18: Iss. 4, Article 3.
DOI: 10.7454/mss.v18i4.4281
Available at: https://scholarhub.ui.ac.id/science/vol18/iss4/3

This Article is brought to you for free and open access by the Universitas Indonesia at UI Scholars Hub. It has been accepted for inclusion in Makara Journal of Science by an authorized editor of UI Scholars Hub.
Microwave-Assisted Synthesis of Alginate-Stabilized Gold Nanoparticles

Cover Page Footnote
This work was funded by Hibah Penelitian Kompetensi (No.2478/H2.R12/HKP.05.00/2013), Directorate General of Higher Education, Ministry of National Education Indonesia through The Directorate of Research and Community Services, Universitas Indonesia, Indonesia, and The Training and Education Center, Ministry of Industry, Indonesia.
Microwave-Assisted Synthesis of Alginate-Stabilized Gold Nanoparticles

Foliatini¹,², Yoki Yulizar¹*, and Mas Ayu Elita Hafizah³

¹. Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Indonesia, Depok 16424, Indonesia
². Akademi Kimia Analis, Bogor 16158, Indonesia
³. Postgraduate Program of Material Science, Faculty of Mathematics and Natural Sciences, Universitas Indonesia, Jakarta 16440, Indonesia

*E-mail: yokiy@ui.ac.id

Abstract

An efficient and rapid method for preparation of Au nanoparticles (Au-NP) has been developed by direct microwave irradiation of metal precursor and alginate mixed solution in a single step. Here, alginate molecules act as both the reducing and stabilizing agents of Au-NP. The obtained nanoparticles were characterized by ultraviolet-visible (UV-Vis) spectroscopy, particle size analyzer, fourier transform infrared spectroscopy, and transmission electron microscopy. The nanoparticles have a spherical form and perfectly capped with alginate when using alginate and chloroauric acid (HAuCl₄) precursor in the concentration range of 0.50 to 0.75% (w/v) and 0.40 mM, respectively. The use of a lower concentration of alginate and/or higher concentration of HAuCl₄ caused agglomeration to occur, thereby resulting in a bigger size of Au-NP and red shifting of surface plasmon resonance (SPR) peak to a higher wavelength.

Keywords: alginate, Au nanoparticle (Au-NP), microwave irradiation, stabilizing mechanism

1. Introduction

Due to their excellent optical, electrical, thermal, chemical, and/or catalytic properties, Au-NP colloids have received a great deal of attention in recent years for various potential applications, such as in catalysts [1], sensors [2], surface-enhanced raman scattering (SERS) substrate [3], targeting delivery [4], and photothermal agent [5]. Recent studies have showed the use of Au-NP as a potential Pickering emulsion stabilizer [6-7].

The agglomeration of metal nanoparticles is a serious problem that can limit their application; thus, in metal nanoparticles synthesis, the presence of a stabilizing agent is rather necessary for protecting these nanoparticles from aggregation by several mechanisms, which includes steric, electrostatic, or electrosteric stabilization. Various stabilizing agents have been exploited in nanoparticles synthesis, such as ligands, surfactants, and polymers. Many polymers have been reported as stabilizers in the synthesis of Au-NP, such as poly(sodium acrylate) (PSA) [8], polyethylene glycol (PEG) [9], polyvinylpyrrolidone (PVP) [10], polyacrylamide [11], polyvinylalcohol (PVA) [12-13], and polymethylmethacrylate (PMMA) [14-15]. Those polymers have been proved to be excellent materials for enhancing the stability of Au-NP.
Apart from the capability of stabilizing, polymers should be biocompatible and nontoxic to be considered as safe material for biomedical fields. The biodegradability of polymers was another additional prerequisite for developing a clean synthetic approach as demanded by the concept of green chemistry. Biopolymers are one of the stabilizing agents that meet these criteria. Chitosan [16], agarose [17-18], hyaluronic acid [19], fucoidan [20], and alginate [21-25] were reported as biopolymers suitable for stabilizing Au-NP.

Alginate is an anionic polysaccharide extracted from marine brown algae and comprises (1→4) linked β-D-mannuronic acid (M) and α-l-guluronic acid (G) residues (Figure 1) of widely varying composition and sequence. The ratio of these acids greatly depends on their variety of the algae. Alginate was widely applied in targeting the delivery of many protein based drugs [26].

Some polymers or biopolymers such as PSA, polyacrylamide, PVP, chitosan, alginate, hyaluronic acid, and fucoidan were reported to act not only as stabilizers but also as reducing agents for metal precursor salts to obtain zero valence metal nano particles. The capacity of the reducing agent was favorable due to the absence of any chemical reducing agent that possesses some toxicity. Moreover, a material that has the dual function of functioning both as a reducing and stabilizing agent can reduce the synthesis steps into simpler and faster ones.

The synthesis of Au-NP using alginate as the stabilizing agent can be conducted under gamma irradiation [21], UV photoactivation [22], and conventional heating techniques [23]. To the best of our knowledge, there are no reports on the synthesis of Au-NP using alginate as both a reducing and stabilizing agent with the aid of microwave irradiation.

Microwave irradiation is a novel technique developed for synthesis of solid nanomaterials. The main advantages of the microwave irradiation technique is that it produces a uniform heating of the solution that leads to a more homogeneous nucleation is obtained and shorter crystallization time as compared to conventional heating. Therefore, it is very useful for the formation of monodisperse metal nanoparticle colloids. Additional advantages are short thermal induction period, absence of convection process, ease of control, and low cost [27].

In this study, we provide a detailed description of the synthesis of Au-NP in the presence of alginate as both a reducing and stabilizing agent using the aid of microwave irradiation. Various parameters in optimizing reaction conditions such as precursor concentration, alginate concentration and pH were studied in this research. The stability of the resulting Au-NP was also evaluated to reveal the role of alginate in stabilizing Au-NP.

2. Methods

HAuCl$_4$ was prepared by dissolving a certain amount of solid gold (99.9%) into aqua regia; double distilled water was added until a total volume of 100 mL. The solution was evaporated to remove the aqua regia, and then redissolved in double distilled water with the same volume as the initial volume. A series of HAuCl$_4$ solution was prepared (0.20, 0.40, 0.60, 0.8, and 1.00 mM). Sodium alginate was obtained from Himedia. The structure is illustrated in Figure 1. A certain amount of this salt was dissolved with double distilled water until solutions with concentrations of 0.10, 0.25, 0.50, 0.75, and 1.00% (w/v) were obtained. HCl and NaOH were used to adjust the pH solution.

Synthesis of Au-NP was conducted in a domestic microwave oven with a total power of 800 watts, adjusted at 30%, 50%, 80%, and 100% of total power. Briefly, 10 mL of HAuCl$_4$ solution was poured into a 100 mL beaker glass and 10 mL of alginate solution was added to it. The mixture was irradiated in the microwave oven at 2,450 MHz for a few min until the color of the solution changed. The final solution was cooled at room temperature before further characterization. The optical extinction spectra were measured by an UV–Vis spectrophotometer (UV-1700, Shimadzu) with a wavelength ranging from 190 nm to 1,100 nm. The morphologies of the Au-NP were observed by transmission electron microscopy (TEM) on JEM-1400 electron microscope JEOL instrument by operating at an accelerating voltage of 120 kV. The particle size and particle size distribution were evaluated using Particle Size Analyzer (Malvern Zetasizer, ZEN-1600). The interaction between Au-NP and alginate was confirmed by Fourier Transform Infrared Spectroscopy (FTIR), IR-Prestige-21, Shimadzu.

3. Results and Discussion

Figure 2a shows that UV-Vis a spectrum of AuCl$_4^-$ alginate and Au-NP synthesized using alginate. SPR spectrum of Au-NP revealed peak absorption at $\lambda$, 530 nm region. The TEM image of Au-NP at the same experimental condition as at the SPR spectrum shown in Figure 2a is depicted in Figure 2b. The spherical shape of Au-NP was confirmed by the following image.

![Figure 1. Structure of Sodium Alginate](image-url)
Figure 3a illustrates the comparison between SPR spectrum of Au-NP synthesized by conventional heating and that synthesized by microwave irradiation. SPR spectrum of Au-NP synthesized by conventional heating was deconvoluted using Gaussian fitting analysis and the result revealed that the peak actually consisted of two overlapped peaks (Figure 3b).

The two synthesis techniques of Au-NP (with and without microwave irradiation) that results in different particle sizes and their distribution (described as % volume) are presented in Table 1. The size distribution of Au-NP synthesized by microwave irradiation was more homogeneous than that by conventional heating, with monomodal size curve and percentage volume of over 90%.

Figure 4a displays the change in the solution color with the increasing of initial AuCl$_4^-$ concentration. For relatively low concentration of AuCl$_4^-$, 0.10 mM, the color of the solution did not change, but as the initial AuCl$_4^-$ concentration increased to 0.20 mM, the color changed from colorless to light pink. Color change to violet occurred at an AuCl$_4^-$ concentration of higher than 0.20 mM.

SPR spectra of Au-NP at various initial concentrations of AuCl$_4^-$, as presented in Figure 4b, showed an increase of absorbance and red shift to a higher wavelength with an increase in the initial concentration of AuCl$_4^-$. Figure 3b also shows that at an AuCl$_4^-$ concentration of 0.30 mM and above, there was another peak absorption at an $\lambda$ of higher than 600 nm. The peak at the initial AuCl$_4^-$ concentration of 0.50 mM was deconvoluted using Gaussian fitting analysis and revealed two peaks that

### Table 1. Particle Size of Au-NPs Synthesized by Alginate using Conventional Heating and Microwave Irradiation

<table>
<thead>
<tr>
<th>Preparation technique</th>
<th>[AuCl$_4^-$] (mM)</th>
<th>[alginate] (w/v)</th>
<th>Particle size (nm)</th>
<th>% volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional heating</td>
<td>0.40</td>
<td>0.375%</td>
<td>8.351</td>
<td>37.03</td>
</tr>
<tr>
<td>Microwave irradiation</td>
<td></td>
<td></td>
<td>501.9</td>
<td>88.2</td>
</tr>
<tr>
<td></td>
<td>0.40</td>
<td>0.25%</td>
<td>8.965</td>
<td>96.6</td>
</tr>
</tbody>
</table>

Figure 4. Au-NP Colloid Solution (a) and SPR Spectra (b) of Au-NP Synthesized by Alginate at Various Initial Concentrations of AuCl$_4^-$. Deconvoluted SPR Spectra (c) and TEM Image (d) of Au-NP at Initial AuCl$_4^-$ Concentration of 0.50 mM (scale bar = 100.0 nm). Particle Size of Au-NP at an Alginate Concentration of 0.25% (▲) and 0.375% (w/v) (●) (e)
overlapped each other (Figure 4c). The TEM image of Au-NP at this condition showed large spherical particles that were also anisotropic. The PSA analysis showed that the higher the initial AuCl₄⁻ concentration, the larger the particle size for both alginate concentrations (Figure 4e).

The SPR spectra of Au-NP at various alginate concentrations is depicted in Figure 5b. The trends of absorbance and wavelength depicted in Figure 5c show a blue shift to a lower wavelength with an increase in alginate concentration. The absorbance increases until a certain value is attained and then decreases at higher alginate concentration. The particle size of Au-NP drastically decreased when the alginate concentration increased from 0.05 to 0.125% (w/v); however, at a higher alginate concentration, the decrease was not significant.

Influence of the solution pH on the formation of Au-NP was studied in the pH range of 2.0–10.0. The solution made at pH 2.0 showed noticeable differences in color and remained colorless just after irradiation in the microwave oven for three minutes. At pH 4, the solution readily grew to violet, and at a higher pH the resulting Au-NP was red (Figure 6a). The SPR spectrum at pH levels 2 and 4 has a higher wavelength than that at a higher pH (Figure 6b). The particle size reduced significantly when the pH increased from 2 to 4; at pH > 4, the particle size reduced to a certain extent (Figure 6c). TEM images revealed the presence of non-spherical particles at pH 4, which was not found at pH 10 (Figure 7).

The FTIR spectra of sodium alginate (Figure 8) present some major absorption bands at wave numbers 3,094–3,547, 2,930, 2,145, 1,593, 1,412, 1,150, 1,078, and 1,016.5/cm. The broad bands observed at wavelengths 3,100–3,540 and 2,145/cm could be assigned to respective stretching vibrations of O-H and carbonyl groups of alginate. The bands at 2,930 correspond to asymmetric
and symmetric stretching vibrations of methylene groups. The bands found at 1,593 and 1,412/cm could be assigned to characteristic asymmetrical and symmetrical stretches of the carboxylate group. Further, C-O stretching for alcoholic groups was found at 1,150/cm. The peaks at 1,078 and 1,016.5/cm correspond to C-O stretching of carboxylic acids and ether.

After reduction by alginate, the Au-NP spectrum was compared with alginolate spectrum and a large shift was observed in the absorbance peak with decreased band intensity. The broad peak at 3,293–3,381/cm slightly shifted to 3,248–3,358/cm, accompanied by a significant decrease in percentage transmittance. The peak at 1,600/cm largely shifted to 1,641.4/cm, and the sharp peak at 1,412/cm drastically decreased in intensity and became a broad, small peak at wave numbers 1,458–1,294/cm. Figure 9 depicts the enlarged TEM image of Au-NP, which showed that the alginate molecules perfectly capped the Au-NP.

In this research, Au-NP was synthesized using alginates as both the reducing and stabilizing agent. During the synthesis, with the aid of microwave irradiation, the solution changed color from clear to ruby red, thereby indicating the formation of Au-NP. Visual observation was followed by characterization using UV-Vis spectrophotometry, which showed peak absorption at λ 530 nm region, which is a typical SPR for spherical Au-NP (Figure 2, left).

The HAuCl₄ solution showed a peak absorption band at λ 217 nm (not shown) and λ 300 nm, both of which were due to the ligand to metal charge transfer (LMCT) bands of AuCl₄⁻ ions between gold and chloro ligands. This peak disappeared in the Au-NP UV-Vis spectrum, thereby indicating the reduction of gold precursor salts and subsequent conversion to Au⁰. The characteristic peak shoulder of alginate at λ 280 nm was also reduced in the Au-NP UV-Vis spectrum, thereby indicating that alginate was consumed during this synthesis.

Microwave irradiation provides the momentum to overcome activation energy and complete the reaction more rapidly than conventional heating methods. In this experiment, the formation of Au-NPs was completed in only 2–3 min, depending on the experimental condition. Without the aid of microwave irradiation, the reaction needed 20–30 min to proceed completely.

At optimum condition, the resultant Au-NPs have a particle size of approximately 4–8 nm and were in an almost spherical form and separated each other, as shown in the TEM image (Figure 2, right). Enlarging the image scale clarified that alginate capped the Au-NP surface that induced the stability of the Au-NP. An experiment revealed that the Au-NP was stable for eight months without any signs of aggregation.

**Figure 9.** Enlarged TEM Image of Au-NP at AuCl₄⁻ Concentration of 0.20 mM, Showing the Capping of Alginate around the Surface of Au-NP

**Effect of AuCl₄⁻ concentration.** Many studies have shown that metal precursor concentration greatly influences the morphology of resultant nanoparticles, such as particle size, shape, and polydispersity [28]. We observed that AuCl₄⁻ concentration as gold metal precursor of Au-NP has an effect on the particle size and shape of Au-NP, as can be visually observed in the color of the colloid solution (Figure 4a).

At a constant alginate concentration, the change in AuCl₄⁻ concentration caused a significant change in the color of the solution. For a relatively low concentration, the color of the solution did not change, thereby indicating that the formation of Au-NP was not effective. As the AuCl₄⁻ concentration increased, Au-NP was formed in a significant amount as can be observed from the formation of a light pink solution. The color change into violet at higher AuCl₄⁻ concentration indicated the red shift to a higher wavelength, as depicted in the SPR spectra.

It is well known that the SPR wavelength has a strong correlation with particle size—a wavelength shift to a higher value implies a larger particle. Based on the result of the experiment (Figure 4b), we can predict that at a AuCl₄⁻ concentration higher than 0.20 mM, particle size increases. The increase in particle size resulted from the increase in nucleation number and the agglomeration of high density of nuclei, forming a larger particle.

Two peaks in the SPR spectrum of Au-NP at high AuCl₄⁻ concentration indicated the presence of the anisotropic shape of Au-NP. The first SPR peak at λ 524 nm is the characteristic SPR of the spherical Au-NP colloid, and the second SPR peak (λ 614 nm) at near-infrared region is attributed to nonspherical Au-NP [29]. Many reports indicate that the anisotropic and flat Au-NP absorb the wavelength in the NIR region of the electromagnetic spectrum, which accounts for the in-plane vibration component (longitudinal component of SPR band) [30-31]. The representative TEM images of Au-NP presented in Figure 2 (right) and 4D illustrate that at low AuCl₄⁻ concentration (Figure 2) almost all the Au-NP were in spherical form, whereas at high AuCl₄⁻ concentration (Figure 4d) some particles formed aggregates and other forms of Au-NP such as triangle,
rod, and prism were present. The presence of aggregates was also confirmed by particle size measurement (Figure 4e).

The effect of polymer/metal precursor ratio on particle size, shape, and particle size distribution has been widely reported. Carutenuto and Nicolais [32] reported an increase in the size of Au-NP for lower PVP/AuCl₄⁻, whereas Hoppe et al. [33] found that a low PVP/AuCl₄⁻ ratio causes not only an increase in particle size but also the presence of non-spherical form of particles. In the latter case, PVP has a double function as both a reducing and stabilizing agent; therefore, the changes in the PVP/metal ratio cause a stronger effect on the shape and size of nanoparticles in comparison with that produced in the synthesis in which an external reducing agent is used. At a constant alginate concentration, increasing AuCl₄⁻ concentration implies a decrease in alginate/AuCl₄⁻ ratio. As is evident in the UV-Vis spectrum and TEM image, our results were in agreement with these previous studies.

**Effect of alginate concentration.** The alginate/AuCl₄⁻ ratio can be changed by varying alginate concentration, while keeping the AuCl₄⁻ concentration constant. The synthesis of Au-NP at different alginate concentrations created different characteristics in the resultant Au-NP, caused by a difference in the reduction and stabilization capacity of alginate at different concentrations. As the alginate concentration increases, a number of the functional groups that are available to reduce AuCl₄⁻ also increase, thereby making the nucleation more intensive. Moreover, increasing alginate concentration implies increasing the steric effect, which can effectively prevent the agglomeration of Au-NP.

At a low alginate concentration, the reduction capacity of alginate was relatively low and with an increase in alginate concentration, the nucleation in the Au-NP formation was more intense. However, this concentration was too low to stabilize the resultant Au-NP effectively, so that agglomeration could not be avoided. Visual observation showed that at this alginate concentration, the color of the Au-NP colloid was violet, which was supported by a red-shift in the UV-Vis spectra (Figures 5b and 5c); this indicated a large particle size. Ruby red Au-NP at an alginate concentration of 0.25% (w/v) and the sharp SPR peak at 531 nm (Figure 5b) indicate that reduction capacity of alginate was optimum in the Au-NP formation. The stabilizing effect was stronger than that at a lower alginate concentration. At this condition, the Au-NP can be protected from forming large aggregates. Therefore, the particle size was smaller (Figure 5d) and a red shift in SPR spectrum did not occur. These results are in good agreement with those obtained in the synthesis of Au-NP using gamma irradiation in the presence of alginate as stabilizer. At an alginate concentration of 0.125% (w/v), the particle size was larger than that produced at a higher alginate concentration (0.25 and 0.50% (w/v) [21].

The faint red of Au-NP at an alginate concentration of 0.375% (w/v) and the decrease in absorbance compared to that at a lower alginate concentration suggested that the reduction rate was slower. A blue shift was observed in the UV-Vis spectrum, thereby showing that stabilization of Au-NP was effective. There is a greater probability of steric stabilization to occur at a higher concentration of alginate due to the capability of the biopolymer to arrange themselves and form a dense shell at the Au-NP surface. Thus, the higher concentration of alginate resulted in a smaller particle size (Figure 5d). The trend in blue shift of SPR spectrum was also found in the synthesis of bionano composite of Au-NP alginate films coated on a glass slide [25]. On the other hand, excessively high alginate concentration results in an excessively viscous colloidal solution. This condition was possibly responsible for decreasing the reduction capability, because the interaction between the reducing functional group with AuCl₄⁻ became less effective. In this case, size distribution becomes wider, as shown by the decrease in percentage volume at an alginate concentration of 0.50% (w/v) (Figure 5d).

In the synthesis of Au-NP using gamma irradiation technique where alginate acts as a stabilizer, for a high concentration of alginate to as much as 1.00% (w/v), the formation of Au-NP was effective and with the same particle size as that produced with an alginate concentration of 0.50% (w/v) [21]. In this experiment, with an alginate concentration of 0.50% (w/v), the absorbance of SPR peak at around 530 nm was smaller than that produced with lower alginate concentration. This small quantity of Au-NP was probably due to the functioning of alginate as a reducing agent that was less effective at an excessively high alginate/metal precursor concentration ratio. In the synthesis of Au-NP using gamma irradiation [21], alginate acts only as stabilizer, so that the reducing capability does not depend on the alginate concentration.

**Effect of pH.** The slow color change at a low pH level indicated that the reaction occurred slowly. Consequently, the particle size grew larger, as confirmed by the SPR peak at a relatively high wavelength of 542 nm (Figure 6b) and the result of PSA analysis (Figure 6c). When the pH was increased to 4.0, the formation of Au-NP was more effective, but the particle growth rate was so fast that it finally formed large particles. This was supported by the change in the colloidal solution to deep violet and high absorbance peak in the SPR spectra at a wavelength of 536 nm. At a higher pH, the particle growth was slower, thereby resulting in a smaller particle size, as confirmed by the blue shift of the SPR peak and the result of PSA analysis.
At a very high pH, the particle size distribution was less homogeneous, thereby indicating that nucleation and growth rate of Au-NPs strongly depended on the acidity. At a high acidity condition, protonation was more effectively yielded in a larger amount of hydrogen bonds between alginate molecules. This resulted in shorter distances between alginate molecules and AuCl₄⁻. Thus, the reducing functional groups of alginate interacted more easily with AuCl₄⁻, causing the subsequent reduction to occur effectively. In this case, the growth rate was so fast that it was more likely that there was aggregation. This was confirmed by the TEM analysis that showed large particles as well as anisotropic particles, such as triangular and rod-shaped ones (Figure 7 left). As the pH was increased, the anionic form of alginate was more dominant than the protonated form. This resulted in increasing the distance between alginate molecules and AuCl₄⁻ due to electrostatic repulsion. This condition led to a slower reduction rate; thus, with the same duration time of reaction, the amount of Au-NP was significantly lower than that at lower pH. This is confirmed by the lower absorbance in the SPR spectrum (Figure 6b) at pH 10. On the other hand, the anionic form of alginites can also induce the stability of the resulting Au-NP due to the capability of avoiding interparticle interaction by electrostatic repulsion. This phenomenon also resulted in low yields of Au-NP due to longer distance between particles. This is in agreement with the particle size analysis by both PSA and TEM. Figure 7 revealed that smaller and more homogeneous form of Au-NP could be yielded at a higher pH.

FTIR characterization. Interaction between alginate and Au-NP was confirmed using FTIR. The shifts in wavelength for O-H and C-O carboxylate groups in the FTIR spectrum supported the binding. The hydroxyl functionalities in alginate can also play a role in stabilization. The disappearance of the LMCT band of AuCl₄⁻ in the presence of alginate indicates the possible chelation of Au (III) ion by hydroxyl groups present in alginate [22]. Alginate coating on the surface of Au-NP is observable in the TEM image (Figure 9). This coating is able to protect the Au-NP from interparticle interaction so that the aggregation can be avoided.

4. Conclusions

Au-NP can be synthesized in a green, simple, and fast technique without a chemical reducing agent, using alginate as both reducing agent and stabilizer. This synthesis was conducted with the aid of microwave irradiation as a better alternative to a conventional heating technique. Alginate was able to function as an effective capping material for the resultant Au-NP and therefore induced high stability of the Au-NP. Alginate/ metal precursor concentration ratio and pH strongly influence particle size and shape, as well as the mono-dispersion of the resultant Au-NP.

Acknowledgements

This work was funded by Hibah Penelitian Kompetensi (No.2478/H2.R12/4HKP.05.00/2013), Directorate General of Higher Education, Ministry of National Education Indonesia through The Directorate of Research and Community Services, Universitas Indonesia, Indonesia, and The Training and Education Center, Ministry of Industry, Indonesia.

References


Makara J. Sci.