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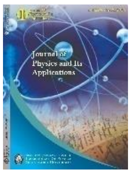

Characterization of Optical Properties of Colloidal Gold Solution based on Changes in Concentration using Light Polarization Method

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ABSTRACT

This research was conducted to determine the effect of concentration on the characteristics of changes in the polarization angle of colloidal gold solutions. The method used in this research is natural polarization. The light source used was a green laser with a wavelength of 532 nm. The colloidal gold solution was obtained using the laser ablation method and then dissolved in aquabidest. The characteristics of changes in the angle of light polarization in the gold colloidal solution were obtained by varying the concentration of the gold colloidal solution (40 ppm, 30 ppm, 20 ppm, and 10 ppm). The results showed that gold colloids have optical activity because the orientation of the gold colloid molecules allows them to interact asymmetrically with linearly polarized light. In the range of concentration from 10 to 40 ppm, the polarization angle in gold colloids shows a linear pattern as a function of concentration. Within one month the colloidal gold sample showed stable properties. This method allows us to further analyze the quality of other types of colloids using the same method. This will improve our understanding of the interaction of polarized light with nanoparticles.

1. Introduction

In recent years, gold nanoparticles have become an interesting concern for scientists and researchers because of their unique optical, electronic, and molecular properties so they have many potential applications in various fields, such as nanotechnology, materials science [1], electronics, electron microscopy [2], and biomedicine [3-4]. Voliani [5] defines colloidal gold as a sol or colloidal suspension of gold nanoparticles in a liquid, usually distilled water. The potential application of colloidal gold depends greatly on its size and shape [6]. Gold colloids with a diameter of less than 100 nm are usually burgundy in color, while larger spherical particles or nanorods are usually blue/purple in color [7].

Various types of gold particles have been investigated for their practical applications due to their easy synthesis and high stability. Colloidal gold is a label that is often used for antigens in biological electron microscopes. They can be attached to many traditional biological probes [8] and can be transferred to various mineral substrates to be observed under Atomic Force Microscopy [9]. Colloidal gold is also used to increase the dose delivered to tumors [10], improve and target drug biodistribution to diseased organs or tissues [11], target tumors, and enable detection via SERS (Surface Enhanced Raman Spectroscopy) in vivo [12], improving the stability, sensitivity, and selectivity of biosensors [13], photothermal agents for in-vivo applications [14], detecting hydrogen sulfide H_2S based on anti-aggregation of gold nanoparticles [15], and making gold nanoparticle-based optical fibers for sensors [16].

Although the application of gold colloids has been developed in various fields, there is another interesting aspect that has not been widely studied, namely the development of optical characteristics through changes in light polarization. Optical characteristics are properties that explain how a material interacts with light, such as transmission, absorption, fluorescence, and scattering. Optical characteristics are very important in various fields, such as physics, chemistry, materials science, and engineering. In the context of colloidal gold solutions, optical characteristics such as their absorption spectrum and surface plasmon phenomena are of great importance to help in improving applications in fields such as sensory and medicine. Optical characteristics have previously been used to identify the quality of cooking oil [17-19]. This method has been proven effective in separating cooking oil that is still safe for consumption from oil that has expired [17-18]. Apart from that, this method is also used as an initial detection to determine the halal level of food products made from animal fats [19].

Typically, gold colloids have strong absorption bands in the visible light region due to the influence of small particles [20]. Gold nanoparticles that absorb light cause the phenomenon of localized surface plasmon resonance (LSPR), where the conduction electrons on the surface of the nanoparticles oscillate collectively with the incident light, resulting in various colors, ranging from bright red (smaller particles), blue, black, to become clear and colorless (larger particles). This depends on the particle size, shape, local refractive index, and state of aggregation

[21]. This research aims to determine the effect of concentration on the characteristics of changes in the polarization angle of colloidal gold solutions using the natural polarization method. In this study, the characteristics of gold colloids were evaluated using Ultraviolet-Visible Spectroscopy (UV-Vis) to ensure that the solution contained gold nanoparticles by looking at the absorption spectrum. This is important for optimizing applications in various fields and understanding the behavior of gold colloids in general, which has broad implications in the field of nanotechnology. The information obtained from this research can be the basis for further research in developing innovative and useful nanotechnology applications. In addition, control over the optical properties of gold colloids is an important aspect in designing more efficient optical systems, especially for trace detection applications. By understanding how concentration affects the optical properties of gold colloids, we can optimize detection systems for better sensitivity and specificity. It is hoped that this research will lead to a more comprehensive understanding of the interaction of light with optically active materials.

2. Method

The equipment components used in this research are shown in Figure 1. The light source uses a green laser pointer with a wavelength of 532 nm which functions as a polarized energy source. Polarizer with a scale of 0˚ to 360˚ which functions to convert unpolarized light into linear polarized light. Linearly polarized light is transmitted to the sample in a cuvette made of glass with transparent sides and an optical path length of 1 cm. After hitting the sample, the light is transmitted to the analyzer which has a scale from 0° to 360°. The analyzer functions to measure changes in the angle of light polarization formed by the polarizer. A screen to capture polarized laser light after it interacts with the sample and passes through the analyzer. Measurements are made by looking at the numbers displayed on the analyzer when the light intensity captured by the screen is minimum. Changes in spectrum intensity occur because the polarization orientation of the light passing through the sample can affect how much light the sample absorbs, depending on how the molecules in the sample are oriented and interact with the plane of light polarization. This can produce distinct absorption spectra that reveal information about the molecular structure and optical properties of the material, which is very beneficial for material characterization.

The sample used in the research was a colloidal gold solution obtained from the laser ablation method at 40 ppm, then diluted again using aquabidest to 10 ppm, 20 ppm, and 30 ppm. In the initial stage of the research, UV-Vis Spectroscopy testing was carried out to ensure that the solution contained gold nanoparticles by looking at the absorption spectrum. Next, tests were carried out using the natural polarization method which aimed to determine the characteristics of colloidal gold solutions in various concentrations. To examine the stability of the solution, four measurements were carried out over four weeks.

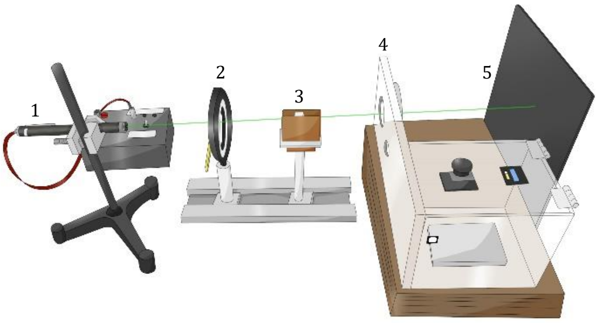

Fig. 1: The components of equipment, 1) light source, 2) polarizer, 3) cuvette, 4) analyzer, 5) screen.

3. Results and Discussion

The test results shown in Figure 2 show that colloidal gold solution samples with different concentrations have the greatest absorption value at a wavelength of 526 nm. The graph shows typical values of gold colloids with sizes between 35 nm to 40 nm as reported by Thobhani et al. [22], Sharma et al. [23], and Amini et al. [24]. The results of this test also show that the higher the concentration of the gold colloid solution, the greater the absorption value. This is by previous research by He et al. [25] which states that when the size of gold nanoparticles is constant, the absorption is proportional to the concentration of gold colloids. From the test results, it can be concluded that the sample used in this research was a solution containing colloidal gold.

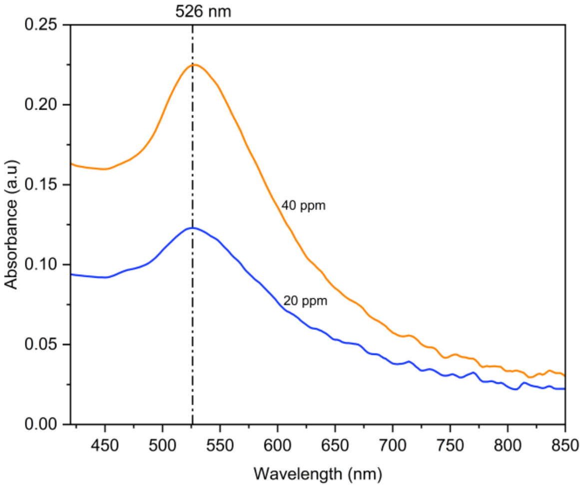

Fig. 2: Absorption spectrum of colloidal gold solutions at different concentrations.

Long-term stability testing of nanoparticles is very important because it can show changes that can occur due to environmental influences or internal processes in the colloid, such as oxidation, changes in pH, temperature, light, and interactions between particles. For four consecutive weeks, this research used the light polarization method to test the colloidal stability of gold nanoparticles. Changes in polarization for concentrations of 10 ppm and 40 ppm over four weeks are shown in Figs. 3 and 4.

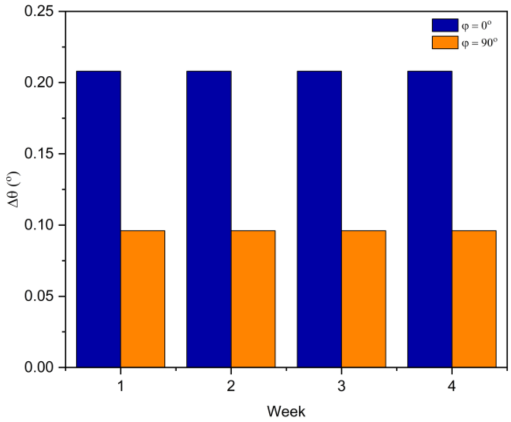

Fig. 3: Polarization in four weeks of measurements to check sample stability for a concentration of 10 ppm.

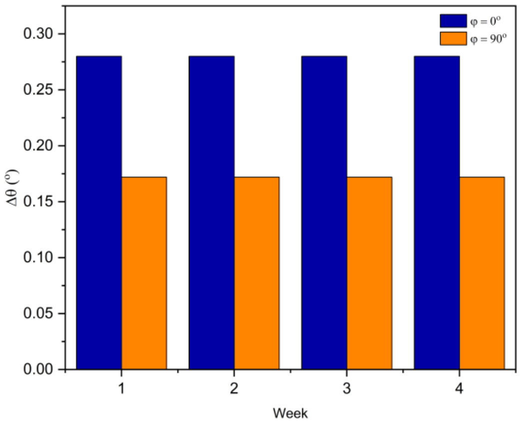

Fig. 4: Polarization in four weeks of measurements to check sample stability for a concentration of 40 ppm.

The test results showed that the polarization angle value of the gold colloid did not change for four weeks. Other concentration measurements also showed stable results. From these results, it can be concluded that colloidal gold has good quality and is relatively stable. A previous study did not examine the stability conditions of gold colloids, especially how colloid stability affects changes in polarization angle [26]. The study with similar colloidal samples showed that the value of the change in polarization angle did not depend linearly at low concentrations, namely 0 ppm to 2 ppm. Therefore, the results of our study are more thorough than the results of previous research. Thus, the polarization method can be used to test the quality and stability of gold colloids, and further developed to other relevant samples. To clarify this argument, we can use the analogy of evaluating the quality of expired cooking oil [17] [18]. Expired cooking oil has a higher polarization angle change value than usable cooking oil, which indicates that the sample has undergone a phase change.

In our experiments, the gold colloids had the same polarization angle change values after being tested for four weeks, indicating that the samples did not experience phase changes. This shows the stability of the gold colloid in this experiment. Testing the stability of nanoparticles over a short period such as a few hours is not necessary because previous results showed no significant changes over that time. Meanwhile, long-term stability testing of nanoparticles, such as after one month, is important because it can reflect changes that may occur as a result of environmental influences or internal processes in the colloid, such as oxidation, the influence of pH, temperature, light, and interactions between particles.

Figure 5 displays changes in the polarization angle of gold colloids as a function of the polarizer angle for various concentrations.

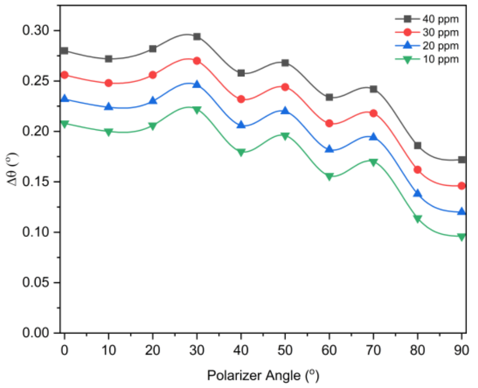

Fig. 5: Changes in the polarization angle of gold colloids as a function of the polarizer angle.

Based on the test results on the graph, it can be seen that the gold colloid has active optical properties because there are asymmetrical molecules, resulting in a non-linear graphic pattern. Asymmetrical molecules produce the largest change in polarization angle which is shown at a polarizer angle of 30°. Meanwhile, symmetrical molecules produce the smallest change in polarization angle, which is shown at a polarizer angle of 90°. This is also because the colloidal gold solution clusters have an internal plasmon resonance and are naturally oriented with the main axis of the cluster. The orientation of the plasmon induction in the same direction as the light's electric field produces optimal polarization changes when the light is linearly polarized [27]. The resulting optical characteristics are homogeneous for all concentrations at each polarizer angle. This strengthens the argument that the sample used is stable, which is different from previous research by Kirono et al. [26]. This is because at low concentrations there are usually very large fluctuations due to the lack of checking sample stability.

Figure 6 displays the effect of concentration on changes in the polarization angle of gold colloids.

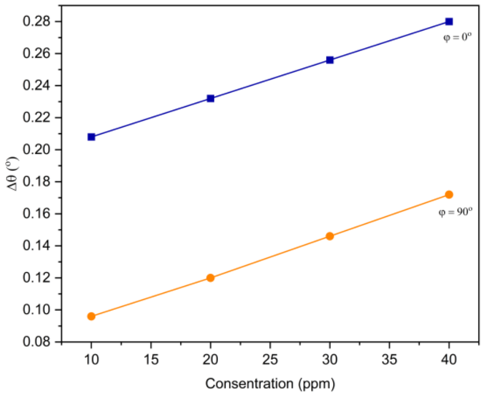

Fig. 6: Changes in polarization angle with concentration values at 0° and 90° angles.

By using a transmission polarization tool, we can see changes in the polarization angle relatively linear to the concentration value. The results are shown in Figure 6, where the natural polarization curve as a function of concentration produces a linear change in polarization angle at concentrations of 10 to 40 ppm. All polarizer angles between 0° and 90° angles result in the same gradients (see Table 1). From a polarizer angle of 0° to 90° a linear regression equation is obtained from the change in polarization angle ($\Delta\theta$) vs concentration, and the gradient is tabulated in Table 1.

Table 1. Gradient values for changes in polarization angles for all polarizer angles.

Polarizer Angle (°)	Gradient (°/ppm)	R^2
0	0.0024	1
10	0.0024	1
20	0.0025	0.9996
30	0.0024	1
40	0.0026	1
50	0.0024	1
60	0.0026	1
70	0.0024	1
80	0.0024	1
90	0.0025	0.9996
Average	0.00246 ± 0.00008	

Table 1 shows the gradient values for changes in polarization angles for all polarizer angles. From this table, a linear graph is obtained at all polarizer angles with a gradient of 0.00246 ± 0.00008. The linear change in polarization angle with concentration at all polarizer angles shows that the gold colloidal solution is stable and homogeneous.

4. Conclusion

The results showed that colloidal gold nanoparticles showed active optical properties from the graph of changes in polarization vs. polarizer angle and concentration. There is also an asymmetry axis at a polarizer angle of 30° and an axis of symmetry at a polarizer angle of 90°. Gold colloids have optical activity because the orientation of gold colloid molecules allows them to interact asymmetrically with linearly polarized light. The research results also show that in the range from 10 to 40 ppm, the characteristics of changes in the polarization angle of gold colloids show a linear pattern. This method can be used to test the quality and stability of optically active samples. This method allows us to further analyze the quality of other types of colloids using the same method. This allows a more detailed analysis of the interaction of light with nanoparticles, which could help in the design of more advanced materials for future technologies.

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