Effect of voltage and anodizing time on nano colloidal silver

N Ravendran¹ and P M Chou²*

¹, ² School of Computer Science and Engineering, Taylors University Lakeside Campus, Malaysia
*Corresponding author: puimay.chou@taylors.edu.my

Abstract. The objective of the present study was to investigate the effect of voltage and anodizing time on the average particle size of nano colloidal silver. The results of the zeta sizer analysis showed that the average particle size of the nano colloidal silver increased with increasing the voltage. On the other hand, anodizing time did not show a specific effect on the average particle size of the nano colloidal silver. The results also show that the samples prepared at 20 V with anodizing time of 2 hours exhibits an average particle size of less than 100 nm, which is potential to be used as disinfectant spray. Also, it shows that electrolysis is a suitable method to produce nano colloidal silver.

1. Introduction

Nano colloids are known as a homogenous, non-crystalline substances that have insoluble particles which are dispersed in another substance. Nano colloids have unique and interesting optical, electrical, chemical and magnetic properties and these make them a part of many modern products such as a part of health remedies, as well as in the cosmetic industry and in the food industry [1-2].

Silver is a type of metal that is shiny and relatively soft and one of the main applications of silver are for jewelries and silver tableware. A significant feature of silver is it has antibacterial property that has led silver to be used in clothing, to prevent sweat to be absorbed by the bacteria [3-4]. Silver is well known for its antibacterial property and therefore makes nano colloidal silver a very good example when it comes to being used in real world application because it can be used as an antibiotic and antibacterial agent.

Nano colloidal silver are very fine, less than 100 nm, but have a high surface area and a high dispersion rate which makes it very effective in optimizing the antibacterial property [5-6]. The antibacterial property also makes it safe and non-toxic to animal cells [7-8]. This makes nano silver colloids suitable to be used as an antibacterial agent and has been used as wound dressings and antiseptic spray [6].

Nano colloids can be produced using electrolysis, laser ablation, phase transfer and through a chemical reduction method [5-15] However after evaluating the advantages and disadvantages of the methods, electrolysis is a commonly used method to produce nano colloids because it is the least labor intensive and the most economically viable method [5, 9, 16-17]. Electrolysis is a process that occurs when the use of a direct electric current (DC) drives a non-spontaneous chemical reaction. This chemical reaction is called a oxidation-reduction reaction. The method of electrolysis uses conventional apparatus such as beakers and a power supply and the experimental set up is not complex. Therefore, the method of choice to produce nano colloidal silver is electrolysis.

Theoretically, the particle size of nano colloids increases with the increase of voltage and anodizing time. As shown in Figure 1 and Figure 2, the effect that voltage and anodizing time have on the particle
size of the nano colloidal silver developed can be seen. According to the findings from Jaewoo et al. [18], the particle size increases in diameter when there is an increase in voltage from 7.5 V to 12.5 V. Studies conducted by Javad et al. [19] and Ahmet et al. [20] have also resulted in a similar outcome where the particle size increases with the increase of voltage. Furthermore, the particle size increases with anodizing time until a certain point before decreasing [21]. This pattern be seen in Figure 3 where the particle size increases with anodizing time. However, a significant feature that can be seen is that after a certain point, the particle size decreases when the anodizing time continues to increase.

![Figure 1](image1.png)

**Figure 1.** The use of different voltages and the effect on the particle diameter [18].

![Figure 2](image2.png)

**Figure 2.** The comparison of anodizing time and particle size [21].

The research gap that exists is that there is no ideal and conventional method to produce nano colloidal silver. Thus, this main objective of this study is to determine the effectiveness of the electrolysis method to develop nano colloidal silver as well as to investigate the effect of voltage and anodizing time on the particle size of nano colloidal silver prepared by electrolysis.
2. Research Methodology

2.1. Preparation of Nano Colloidal Silver

For nano colloidal silver to be prepared, the procedure began with placing two silver electrodes of chosen size inside a beaker that is filled with distilled water and this set up is connected to a direct current (DC) power supply. Figure 3 shows the experimental set up of the experiment that was conducted.

As the electrodes were placed in a beaker, the beaker was set in a dark area and the results are monitored [5,16]. The changes that occurred throughout the process were recorded and the samples were kept safely without any exposure to light. This is because silver nano particles are very sensitive towards light and may lead to the particles being damaged and disrupting its physical properties [5]. Therefore, the exposure to light was kept as low as possible. During the electrolysis process, constant stirring at 100 rpm was done to inhibit the formation of precipitate. The voltage that was set on the DC charger varied from 20 V and 30V and the anodizing time varied from 1 to 6 hours [10,16-17].

![Figure 3. The experimental setup for electrolysis.](image)

2.2. Characterization Techniques of Nano Colloidal Silver

After the nano colloidal silver samples have been prepared, particle size measurements were performed. Particle size measurement was done through using a Malvern zeta sizer. The zeta sizer measures the Brownian motion inside the mixture and relates it to the size of the particle. A laser beam acts as a light source and is used to illuminate the particles. A detector measures the intensity of the scattered beams to determine the size of the particle [22]. 3.5 ml of the nano colloidal silver sample was placed into a cuvette, which was then inserted inside the machine.

3. Results and Discussion

A total of eighteen samples were prepared via electrolysis using different voltages and anodizing times. Table 1 presents the change in weight of the silver rods at anode and cathode after electrolysis.
Table 1. The change in weight of the silver rods at cathode and anode after electrolysis.

| Experiment No. | Voltage (V) | Duration (h) | Weight gain at Cathode | Weight loss at Anode |
|----------------|-------------|--------------|------------------------|----------------------|
| 1              | 20          | 1            | (+0.01g)               | (-0.04g)             |
| 2              | 20          | 2            | (+0.02g)               | (+0.03g)             |
| 3              | 30          | 2            | (+0.02g)               | (-0.02g)             |
| 4              | 30          | 4            | (+0.15g)               | (-0.03g)             |
| 5              | 30          | 6            | (+0.19g)               | (-0.07g)             |
| 6              | 25          | 3            | (+0.11g)               | (-0.06g)             |
| 7              | 25          | 4            | (+0.11g)               | (-0.04g)             |
| 8              | 25          | 2            | (+0.05g)               | (0.01g)              |
| 9              | 25          | 5            | (+0.07g)               | (-0.03g)             |
| 10             | 25          | 6            | (+0.21g)               | (-0.06g)             |
| 11             | 20          | 3            | (+0.02g)               | (-0.04g)             |
| 12             | 20          | 4            | (+0.03g)               | (-0.01g)             |
| 13             | 20          | 6            | (+0.16g)               | (-0.03g)             |
| 14             | 20          | 5            | (+0.08g)               | (-0.01g)             |
| 15             | 25          | 1            | (+0.01g)               | (+0.01g)             |
| 16             | 30          | 5            | (+0.17g)               | (-0.03g)             |
| 17             | 30          | 1            | (+0.02g)               | (-0.02g)             |
| 18             | 30          | 3            | (+0.13g)               | (-0.05g)             |

It can be seen from Table 2 that the weight gain of the silver rod at the cathode increases when the voltage used for each sample increases. A similar pattern is also observed when the anodizing time increases, the weight of the silver rod at the cathode also increases. In contrast, the silver rod at the anode experiences weight loss as the voltage and anodizing time increases.

These observations of weight loss are consistent with the working principle of electrolysis. The process works with one silver rod connected to the positive terminal (anode) and one silver rod connected to the negative terminal (cathode). As the electric current flows from the positive terminal to the negative terminal, the particles will accumulate at the rod which is known as the cathode. This accumulation of
particles results in the increase of weight of the rod at the cathode while the weight of the rod at the anode decreases.

The average particle size result obtained from the zeta sizer analysis is presented in Table 2.

**Table 2.** The particle size measurements of the nano colloidal silver prepared at different voltages and different anodizing time.

| Anodizing Time (h) | Voltage |          |          |          |
|-------------------|---------|----------|----------|----------|
|                   | 20 V    | 25 V     | 30 V     |
| 1                 | 88.71 ± 18.32 nm | 132.49 ± 53.146 nm | 102.23 ± 16.84 nm |
| 2                 | 88.39 ± 33.06 nm | 94.4 ± 54.463 nm | 95.93 ± 48.00 nm |
| 3                 | 130.6 ± 68.90 nm | 139.37 ± 53.64 nm | 305.00 ± 262.97 nm |
| 4                 | 66.04 ± 15.85 nm | 143.1 ± 84.97 nm | 138.37 ± 87.44nm |
| 5                 | 174.1 ± 58.26 nm | 136.83 ± 73.8 nm | 172.13 ± 53.95 nm |
| 6                 | 133.7 ± 49.51 nm | 141.83 ± 56.03 nm | 148.53 ± 53.03 nm |

Figure 4 shows the effect of voltage and anodizing time on the average particle size of the prepared nano colloidal silver. The 20 V and 30 V samples show a steady increase in particle size from 88 nm to 174 nm when the anodizing time increases from 1 hour to 5 hours. However, the average particle size decreases to 133 nm and 148 nm as the anodizing time increases up to 6 hours.
Figure 4. The effect of voltage and anodizing time on the average particle size of nano colloidal silver.

In Figure 4, it can be seen that the average particle size of the nano colloidal silver increased by increasing the voltage from 20 V to 30 V. This observation is in agreement with the studies performed by Jaewoo et al. [18] and Ahmet et al. [20], which states that the particle size of nano colloids will increase with the increase of voltage. A similar pattern of where the particle size increases with the increase of voltage was found in a study done by Javad et al. [19].

The effect that anodizing voltage has on the particle size of nano colloids in general is that with a higher voltage, a greater diameter or size is able to be achieved. The reason believed to cause this increase in diameter size is that the higher voltage may control the rate of the reaction occurring. The increase in voltage increases the rate of reaction which in turn leads to an increase in the diameter size of the nano colloids obtained. A conclusion obtained is that the higher the applied voltage, the larger the pore diameter. This increase in voltage also has a limit as a voltage too high can damage the structure of the nano particles formed.

However, it can also contribute to reducing the density of the particles obtained [23]. The effect of the increase in voltage was clearly seen when the voltage was manipulated from 40 V to 60 V and the particle size of the nano particles developed increased from 54 nm to 101 nm [19]. The reason for this occurrence in this experiment is that the increase in voltage subsequently increases the oxidation reaction and the oxide layer dissolution [24].

A similar outcome has been seen throughout other experiments conducted, which supports the statement where with the increase in anodizing voltage results in an increase in particle size of the nano colloid. An important note is that there is a limit to the voltage used. The voltage can only be increased to a particular figure before the pore structure is damaged due to the high voltage [18]. It can be seen in the experiment conducted that there were signs of the agglomeration of nanoparticles and the particle size was increased [25].

As observed in Figure 4, there is no specific trend of the effect of anodizing time on the average particle size of the nano colloidal silver. This is probably due to a possibility that there was an occurrence of agglomeration. Agglomeration is when the particles become a cluster and form larger particles and occurs due to the adhesion of particles to each other by formation of covalent or metallic bonds.

However, according to the finding reported in a study of tungsten oxide nano particles by Yang et al [26] and Ng et al [27], the particle size increased with increasing anodizing time. This is because when the dissolution rate decreases, at the same time the oxide growth rate increases at low anodizing voltage with prolonged duration. Similar findings were reported by Mateusz et al. [22] in a study of zinc oxide nano colloids which found that as the anodizing time increases, the particle size increased. As for the peculiarities that have been encountered when testing the samples produced, further improvements such as performing the experiments in a more controlled environment could be done to ensure that the results obtained could be more accurate.

4. Conclusion

Nano silver colloid was prepared successfully via the electrolysis method. The average particle size of the nano colloidal silver increases as the voltage increases. However, the effect of anodizing time on the particle size is not specific. In conclusion, electrolysis is a suitable method to be used to produce nano colloids. This is because the electrolysis method is the least labor-intensive method and does not require hard to obtain materials to be conducted.

5. References

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