

## SILVER NANOPARTICLE SYNTHESIS THROUGH ARC-DISCHARGE IN DEIONIZED WATER MEDIUM

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Silver nanoparticles attracted attention by their common use in nanotechnology and nano-silver environment-friendly compared to other methods. The fields of use for the synthesized pure silver nanoparticles are quite vast. The reason why it is particularly used in the field of medicine is that the silver nanoparticles are extremely toxic against micro-organisms. In this study, graphite powder and catalyst substances were used in the production of silver nanoparticles. The graphite-coated silver particles obtained as a result are considered a significant product in surface coating technology. Characterization of the synthesized materials will be expressed through Transmission Electron Microscope (TEM), X-ray diffraction (XRD), Visible Region Absorption Spectroscopy (UV-VIS), Fourier Transform Infrared Spectroscopy (FT-IR) and the particle size analyses. Biotechnology applications, many physical and chemical synthesis methods are available in the synthesis of the silver nanoparticles. In our project, silver nanoparticle synthesis through arc-discharge method is faster, more economic and more was carried out in the deionized water medium through arc-discharge method.

(Received May 15, 2017; Accepted October 2, 2017)

*Keywords:* Deionized water; Arc-discharge; Silver nanoparticle; Fast synthesis; Graphite film layer

### 1. Introduction

The silver nanoparticles include a vast field of use in medicine, bio-engineering, modern chemistry, physics and electronics. The characteristic structure of the silver nanoparticles attracted attention in nano-technology and nano-biotechnology applications. The most important characteristic of the silver nanoparticles is being anti-bacterial [1]. This characteristic has been known since the Ancient Greece [2]. The silver nanoparticles are effective against over 650 pathogen bacteria [3]. In addition, it does no harm to human skin and does not cause irritation. Due to these reasons, it is being used in medicine fields such as treatment of burnt, arthroplasty (to prevent the colonies of bacteria that may be formed in prosthetics), catheter making, dentistry [4], cancer therapy [5], HIV treatment [6]. Silver nanoparticles differ from other anti-bacterial materials by their high temperature endurance and long-term anti-microbial activity characteristics. They are used in the production of many materials (textile, metal, ceramic, plastic, glass, tile, dye, etc.), which feature dense harmful micro-organisms used in daily life due to their strong anti-bacterial effect, and within the structure or in the surface coating following the production.

Another significant field of use is water filters. It is known that 80% of the diseases in India stems from the bacteria in potable waters. Therefore, it is quite suitable to use it in water filters [7]. Through the use of the silver nanoparticles, it is possible to protect Archive documents by silver-reinforced chitosan nano-fibre [8]. Nanoparticles are divided into two, which are physical and chemical, in terms of the method of production [9]. UV and VIR radiations [10], aerosol technology and lithography, evaporation [11] or laser ablation [12] can be sorted as the physical method. The reduction of metal ions in neutral metal clusters in metal particles is carried out through the chemical method. These are chemical production methods belonging to one or two-

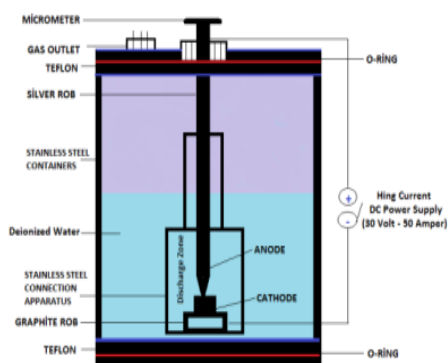
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phase systems such as photochemical [13], sonochemical [14], electrochemical [11] and radiolytic reduction [15]. The arc-discharge method and the synthesis of silver nanoparticles came into the literature as a new method [16]. The nanoparticles can be synthesized rapidly, economically and in an environment-friendly way by this method [16]. The synthesis of silver nanoparticles through the arc-discharge method is carried out in vacuum and non-vacuum ways. Deionized water and liquid nitrogen are used as the medium. Furthermore, these experiments can be carried out with the use of graphite powder and catalyst, or without them. In our study, the nanoparticle synthesis was carried out by using graphite powder along with a catalyst in deionized water and in a non-vacuum medium. The geometry of the silver nanoparticles synthesized this way are more spherical, less agglomerated and have a uniform shape. These properties are similar to the previous works [17, 18].

## 2. Experimental

The whole silver nanoparticle synthesis was carried out in a liquid medium and being open to atmosphere. The liquid material used in the arc medium (deionized water) constitutes the arc medium and provides the necessary cooling. The fact that it is open to atmosphere is for enabling the gases to be discharged and for cooling purposes. Silver and graphite sticks are used as electrodes in the silver nanoparticle synthesis. These experiments can be carried out with or without using graphite powder along with catalyst. In our experiment, graphite powder and catalyst were used. In this experiment, a silver stick of high purity (99.98%) (6 mm in diameter and 60 mm in length) was used as anode and a graphite stick of 99.99% purity (10 mm in diameter and 25 mm in length) as cathode. A hole of 5 mm diameter and 25 mm depth was bored on the anode stick. The hole bored was filled with 171 mg graphite powder, and 5.4 mg Ferrosin and 3.6 mg yttrium substances as catalyst. The purpose in adding graphite powder into the silver sticks is to enable the silver nanoparticles formed during the arc to be synthesized with carbon nanoparticles in a common structure. The Ferrosin and yttrium substances put inside the graphite powder were used to make the nanoparticles geometric and the structures more uniform. The reason why graphite sticks were used as cathode in both experiments is to prevent the silver nanoparticles produced of anode during the experiment from sticking onto the cathode. Both electrodes are placed vertically into a 6litres stainless steel container which was filled with 4 liters of deionized water. In Figure 1, the arc-discharge device used for the steel nanoparticle synthesis is schematically shown.



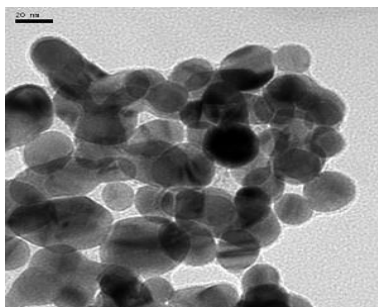
*Fig. 1. Schematic display of the arc-discharge device used for the synthesis of the steel nanoparticles*

The arc-discharge inside the deionized water is initiated by the contact of anode and cathode. For a stable arc-discharge, the space between the electrodes is manually controlled until it is 1 mm. The current between the electrodes is enabled to remain of 50 Ampere level during the whole experiment by taking the discharge voltage in approximately 30 Volt intervals. The arc

current is supplied through a current source of current. The duration of arc is 5 minutes. At the end of this duration, the steel nanoparticle synthesis occurs. A glass beaker was used as the carrier container. The reason why a glass beaker was used is to enable the arcs and products formed to be observed during the arc discharge, and to interfere in the negative effects that may occur during the reaction. It is waited for a while for the deionized water to reach thermal balance with the beaker before the arc is formed. As a result of the evaporation of the deionized water during the arc, deionized water corresponding to the amount of deionized water lost is added into the beaker to protect the stability of the arc. The particles formed as a result of the arc discharge are accumulated on top of the deionized water, on top of the cathode as a precipitate or on the bottom of the container as per their structural characteristics. The samples formed as a result of the experiment carried out inside the deionized water are taken into glass beakers with the help of glass pipettes and glass plates from the top of the liquid. The cathode-top precipitate from the top of the cathode and the particles on the bottom are collected with the help of the pipettes and glass plates. In order to obtain the TEM images of the samples collected, the silver nanoparticles are carefully put into the test tube with deionized water, and the deionized water is eliminated through vaporization. The nanoparticle products were characterized by the use of SEM, TEM, X-ray diffraction (XRD) and UV-VIS spectrophotometer and photoluminescence spectroscopy. The SEM images of the synthesized products are made via JEOL /JSM-6335F-EDS SEM, while TEM images by the use of JEL 2100 HRTEM at 300 kV. The elemental analyses were carried out by SEM energy distribution X-ray spectrometer (EDS), which is a screening method. The optical absorption spectra of the steel nanoparticles were carried out by using an UV-VIS spectrophotometer (Ocean Optics HR4000).

### 3. Discussion

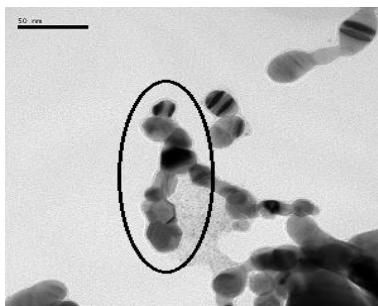
The particles with an average size of 30-40 nm, as seen in the Figure 2 below, vary between 20-150 nm. Here, it can be seen that the nanoparticles are surrounded with a graphite film layer. The particles become agglomerated with one another spherically and partially.



*Fig. 2. The image of TEM of 20 nm size taken from the experiments carried out by the use of graphite powder and catalyst in deionized water*

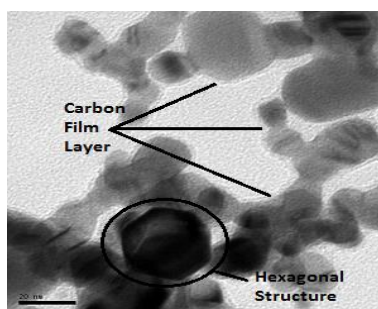
In Fig. 3, the image of TEM of 50 nm size taken from the experiments carried out by the use of graphite powder and catalyst in deionized water is shown.

If we look closely, it can be seen that the spherical nanoparticles inside the circle have resemblance to the previous [19, 20, 21, 22] studies.



*Fig. 3. The image of TEM of 50 nm size taken from the experiments carried out by the use of graphite powder and catalyst in deionized water*

In Fig. 4, the graphite films around the nanoparticles are clearly visible. It can be clearly seen that some of the particles of 20 nm size in average are in hexagonal form. It was observed that the particles first took the cubic, then hexagonal and then spherical forms during the arc. It is considered that the nanoparticles consisting of hexagonal, cubic and spherical forms are nanoparticles that are separated from the arc area before completing their formations.



*Fig. 4. The image of TEM of 20 nm size taken from the experiments carried out by the use of graphite powder and catalyst in deionized water*

#### **4. Conclusions**

In experiments that can be carried out in deionized water by arc-discharge, a synthesis which is faster, more abundant, more economic and more environment-friendly than other production methods can be performed. The results of this experiment were carried out by using graphite and catalyst in a deionized water medium. The experiment results show that the synthesis of nanoparticles with more spherical and uniform geometrical structures can be performed in the experiments carried out by using graphite powder and catalyst in deionized water. Particularly the graphite layer formed around the nanoparticles in spherical, cubic and hexagonal geometrical structure can be used in surface hardening process in the production of data processing, composite, metal, ceramic, textile and bio-medical materials [23]. As a result of the studies carried out, it was determined that the anti-bacterial activity of the silver increases as the particle size decreases [6]. It is suggested that the nanoparticles coated with graphite film be used industrial products with anti-bacterial characteristic. In this study, the particle sizes can be controlled with the help of a catalyst and graphite powder.

#### **References**

- [1] J. P. Abid, A. W. Wark, P. F. Brevet, H. H. Girault, *Chemical Communications* (7), 792 (2002).

- [2] D. Babonneau, T. Cabioc, A. Naudon, J. C. Girard, M. F. Denanot, *Surface Science* **409**, 358 (1998).
- [3] M. G. Bawendi, W. L. Wilson, L. Rothberg, P. J. Carroll, T. M. Jedju, M. L. Steigerwald, L. E. Brus, *Physical Review Letters* **65**(13), 1623 (1990).
- [4] J. S. Chapman, *International Biodeterioration and Biodegradation* **41**, 241 (1998).
- [5] X. Chen, H. J. Schluesener, *Nanosilver: A nanoparticle in medical application*. *Toxicology Letters*. (2008).
- [6] Y. H. Chen, C. S. Yeh, *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, **197**(1-3), 133 (2002).
- [7] P. Das, C. J. Williams, R. R. Fulthorpe, M. E. Hoque, C. D. Metcalfe, M. A. Xenopoulos, *Environmental Science & Technology* **46**(16), 9120 (2012).
- [8] R. Dastjerdi, M. R. M. Mojtahedi, A. M. Shoshtari, *Fibers and Polymers* **9**(6), 727 (2008).
- [9] R. D. Glover, J. M. Miller, J. E. Hutchison, *ACS Nano* **5**(11), 8950 (2011).
- [10] B. Gutarowska, D. Rembisz, K. Zduniak, J. Skóra, M. Szykowska, E. Gliścińska, A. Koziróg, *International Biodeterioration and Biodegradation* **75**, 167 (2012).
- [11] A. Henglein, *J. Phys. Chem. B* **104**(10), 2201 (2000).
- [12] L. R. Hirsch, R. J. Stafford, J. A. Bankson, S. R. Sershen, B. Rivera, R. E. Price, et al. *Proceedings of the National Academy of Sciences of the United States of America* **100**(23), 13549 (2003).
- [13] H. H. Huang, X. P. Ni, G. L. Loy, C. H. Chew, K. L. Tan, F. C. Loh, et al. *Langmuir* **12**(4), 909 (1996).
- [14] P. Jain, T. Pradeep, *Biotechnology and Bioengineering* **90**(1), 59 (2005).
- [15] P. Kovvuru, P. E. Mancilla, A. B. Shirode, T. M. Murray, T. J. Begley, R. Reliene, *Nanotoxicology* **9**(2), 162 (2015).
- [16] B. Li, Y. Xie, J. Huang, Y. Liu, Y. Qian, *Chemistry of Materials* **12**(9), 2614 (2000).
- [17] J. Li, Y. Lin, B. Zhao, *Journal of Nanoparticle Research* **4**(4), 345 (2002).
- [18] J. R. Morones, J. L. Elechiguerra, A. Camacho, K. Holt, J. B. Kouri, J. T. Ramírez, M. J. Yacaman, *Nanotechnology* **16**(10), 2346 (2005).
- [19] V. K. Sharma, R. A. Yngard, Y. Lin, *Advances in Colloid and Interface Science* **145**(1-2), 83 (2009).
- [20] L. Sr, C. Fe, R. Song, S. Park, H. Kim, *Journal of the Korean Physical Society* **59**(6), 3648 (2011).
- [21] D. C. Tien, C. Y. Liao, J. C. Huang, K. H. Tseng, J. K. Lung, T. T. Tsung, et al. *Reviews on Advanced Materials Science* **18**(8), 752 (2008).
- [22] D. Werner, S. Hashimoto, T. Tomita, S. Matsuo, Y. Makita, *Journal of Physical Chemistry C* **112**(5), 1321 (2008).
- [23] Y. Y. Yu, S. S. Chang, C. L. Lee, C. R. C. Wang, *J. Phys. Chem. B* **101**(34), 6661 (1997).