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# Silver Nanoparticles Prepared by Electrical Arc Discharge Method in DIW

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## ABSTRACT

In this work, Silver nanoparticles prepared by arc discharge method in deionized water by applying stablized direct current between two silver rods which are submerged in deionized water at room temperature without any heat exchanger, vacuum equipment and gas handling equipment. During electrical discharge the temperature between electrodes can reach several thousand Celsius degrees. This leads to etch of silver electrodes in deionized water, silver vapor condensed in water creats a stable silver aqueous suspension.

The silver nanoparticles were characterized by UV-Visible photometer, X-Ray Diffraction (XRD), and Atomic Force Microscope AFM. The optical absorption measurement shows that the spectrum exhibits a Plasmon absorption band at ~ 400 nm which is the characteristic of silver nanoparticles.

X-Ray Diffraction of the resulting NPs indicated that the particles had a crystalline structure and the average particle size determined from AFM, is about 78.75 nm.

**Keywords:** arc discharge in liquid, silver nanoparticles.

## INTRODUCTION

The synthesis and applications of metallic nanoparticles have been attracting widespread attention because of the unique properties of such particles. These properties are different from those of the corresponding bulk materials because of the quantum size effect [1], Metal nanoparticles are defined as isolated particles between 1-100 nm diameters that do not represent a chemical compound with a metal-metal bond and a particular nuclearism. The nanoparticles represent cluster of atoms that are involved in a protective layer to prevent or stabilizing agglomeration. [2]

As noble metal materials, silver nanoparticles exhibit significantly distinct physical, chemical, and biological properties. Silver nanoparticles have attracted attention in a wide range of application fields. Their unique properties result from particles on the nanoscale that are monodispersed and unagglomerated. [3]

Silver (Ag) is a versatile element used in photographic, textile and semiconductor industries and especially it has been used to prevent and treat a variety of diseases causing microorganisms. Silver nanoparticles (Ag NPs) are highly toxic to microbes while there is a low toxicity towards animal cells. They have been commonly used in dental resin formulations, in bone cement and in medical devices coatings [4].

Several methods of silver nanoparticles fabrication exist. Current techniques used to produce silver nanoparticles are usually divided into chemical and physical methods. Reduction of metal ions into neutral metal clusters is a commonly used treatment in chemical synthesis. This includes conventional chemical (one or two phase system), photochemical, sonochemical, electrochemical and radiolytic reduction. Metal bulk samples are used to generate nanoparticles by physical methods include: lithography, evaporation, and laser ablation. Although these



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methods may successfully produce silver nanoparticles, they require the use of stabilizer or surfactants to protect the silver particles against agglomeration (maintain colloidal suspension) leaving these undesired chemicals in the solution after fabrication is complete. Additionally, these methods are usually expensive and potentially dangerous for the environment. In order to overcome the problems a novel and easy method for the preparation of silver nanoparticles using the arc discharge method (ADM) was presented [5].

Electrical arc discharge immersed in liquid is an attractive method because of simplicity of apparatus building, no need for complicated vacuum equipment, low impurity introduction, high-throughput, and cost-effective procedure to generate a high yield of nanoparticles[6], also several metal microcrystals , nanoparticles and composite can synthesis by this method [7] .

The arc discharge method in liquid simply requires a DC power supply and an open vessel full of ultra-pure water, deionized water, or alcohol [8]. Ishigami et al. has replaced vacuum pump with liquid in which the electrodes are immersed [9]. The liquid arc method has attracted great interest because the system is easy to build, there is no need of vacuum equipment, it's cheap and no corrosive material and gases are used. Moreover the temperature of the electrodes during the arc decreases and the formation of gases that can contaminate the electrodes is controlled [10].

**Experimental work**

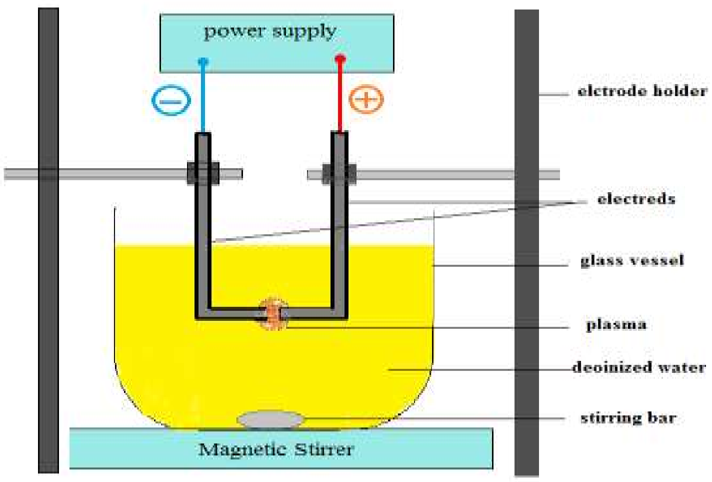
In this work, arc method was used to produce the nanoparticles described in fig (1). This work consists of

A. Materials preparation

In our experimental setup, silver wires shaped with high purity listed of (99.99%) and 1 mm in diameter with brushes ends employed as processed materials are submerged in deionized water (pH = 6.5) and used as the electrodes in preparing the Ag nanoparticle suspension.

B. Experimental System Setup.

The arc discharge system apparatus include four main parts (i) stabilized voltage supply type Farnell which regulate stabilized voltage through the electrodes in order to ionize the medium between them; (ii) a dielectric medium (water), which is used to create the silver nanoparticles suspension and to facilitate silver nanoparticles dispersion; (iii) A glass tank for containing the deionized water to collect the silver colloid (iv) a magnetic stirrer and stirring bar type Philip Harris. These are demonstrated in Figure (1), Figure 2 (a and b) show the experimental set up during operation and silver nanoparticles respectively.




**Figure(1) block diagram of experimental set up for Nanoparticles synthesis by arc discharge in DIW**

a b

**Figure(2) a:experimental set up and b: silver nanoparticles**

In this work, a 130V stabilized voltage applied between two silver electrodes immersed in deionized water with specific distance between them approximately 1mm. When rounded two electrodes of silver from each other note spark electric is formed, similar to that happen in the process of welding leads to the passage of electric current approximately 35 mA and the voltage is drop, its lead to vaporize silver atoms from the anode electrode surface. Silver vapor is condensed and is the basis in the production of primary particles which turns into silver Nps dispersed in the medium by nucleation mechanism. Then, the major part of the product was observed as sediment in the container floor and a small amount was observed as supernatant liquid, So that the transparency of the liquid decreased with the time during the discharge treatment of the liquid, After a five minute the color of the liquid become yellow to orange because of the production silver nanoparticles.

Silver nanoparticles were characterized using A double-beam spectrophotometer from Shimadzu was used in order to record the UV-Visible spectrophotometer in order to record the optical absorption spectrum of the silver NPs within the wavelength rang (300-1100 nm).

In order to explain the structural properties, the nature and the crystal growth of the film prepared by deposition of silver nanoparticles on the silicon substrate is done by X-ray diffraction measurement according to the ASTM (American Society of Testing Materials) cards, using Shimadzu X-ray diffract meter of 1.54 Å wavelength from Cu-Kα. And the average particle size and particle size distribution of the nanoparticles was analyzed using Atomic Force Microscope (AFM).

## Result and discussion

### Optical properties

UV-Visible spectroscopy is one of the most widely used techniques for optical characterization of silver nanoparticles. It is quite sensitive to the presence of silver colloids because these nanoparticles exhibit an intense absorption peak due to the surface plasmon excitation. The absorption band in the 350 nm to 450 nm region is typical for the silver nanoparticles [11]. With increasing particles size, the plasmon absorption shifts toward red region.

The optical absorption spectrum of the colloidal solution of silver Ag nanoparticles prepared by electrical arc discharge method using deionized water was observed by the UV-VIS spectrophotometer and the absorbance of the resultant solution was recorded and shown in the Figure (3).

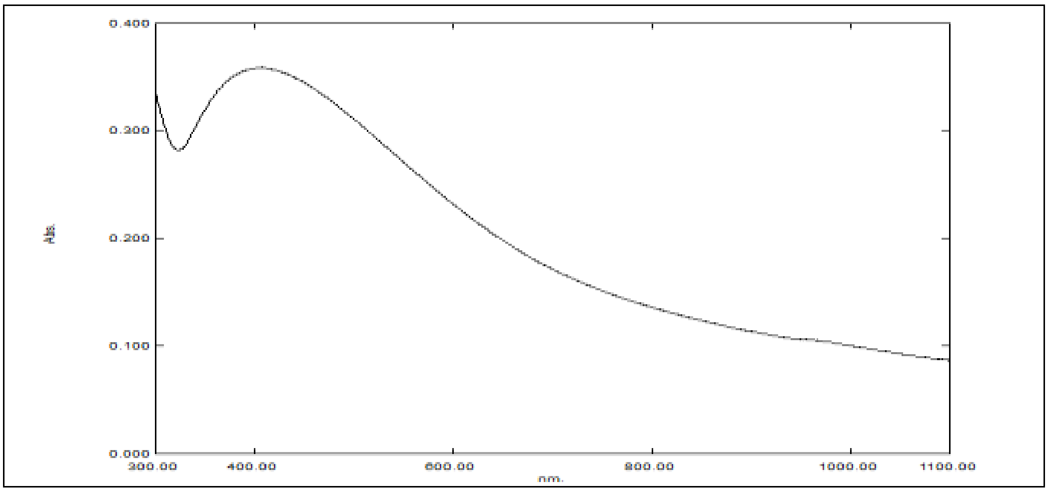



**Figure (3): Optical absorption spectrum silver nanoparticles prepared by arc discharge in DIW**

This figure shows the absorption spectrum of silver colloidal prepared by arc discharge in DIW. The spectrum exhibits a plasmon absorption band at ~ 400 nm which is the characteristic of silver nanoparticles. Such plasmon band is unique physical properties of the nanoparticles themselves. When an external electro-magnetic field such as light is applied to a metal, the conduction electrons move collectively so as to screen the perturbed charge distribution that is known as plasma localized near the metal surface [11].

**Structural investigations**

The X-Ray Diffraction analysis was used to determine the crystalline and the phase of the synthesized compound. Figure (4) shows the XRD pattern of a film deposited on silicon by dropping silver colloidal solution prepared by electrical discharge method in DIW at 130 volt.

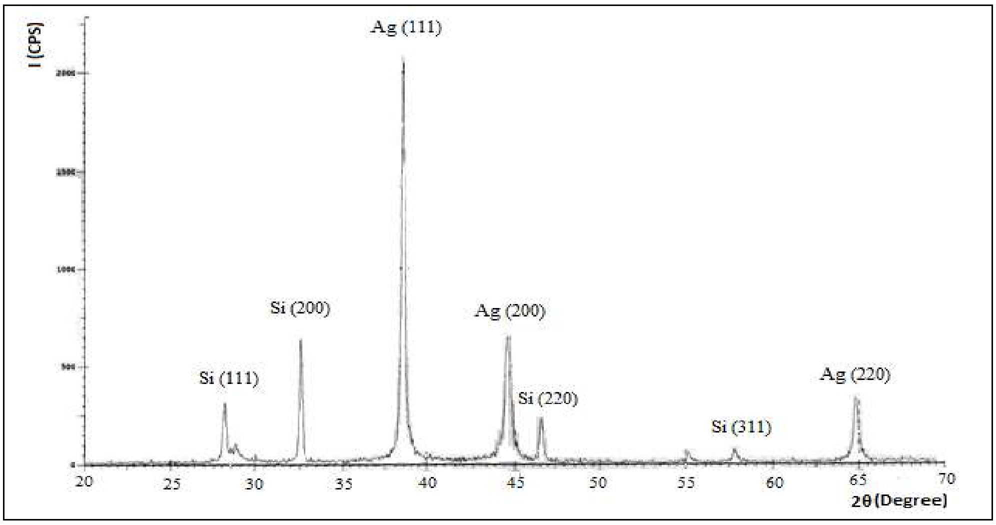



**Figure (4) XRD pattern of a film deposited on silicon by dropping silver colloidal solution prepared by electrical discharge method in DIW.**

The diffraction pattern exhibits three sharp diffraction peaks at values of 38.47º, 44.65º and 64º respectively, which correspond to the (111), (200) and (220) crystalline planes, there's match with the customary Bragg reflections of face centered cubic (FCC) silver and confirm both the identity and purity of these precipitates as reported on JCPDS file No 40783 [12].

The average particle size (D) was determined using the Scherer's eq. 1 [13]:

$$D = \frac{K\lambda}{\beta\cos\theta} \quad \ldots.(1)$$

Where D is the crystallite size, K is the shape factor, being equal to 0.9, λ is the wavelength of incident X-ray radiation (1.5404 Å for CuKa), β is the full width at half maximum of the diffraction peak, and ϴ is the Bragg diffraction angle in degree.

**Table (1) the hkl, FWHM and grain size of Ag nanoparticles from XRD investigation**

| Diffraction angles(2ϴ) degree | $I/I_1$ XRD (intensity) | d (Å) XRD | (h k l) Miller indices | Type | Structure | FWHM Degree | Grain size (nm) |
|---|---|---|---|---|---|---|---|
| 38.47 | 100 | 2.338 | 111 | Ag | face centered cubic | 0.216 | 7.98 |
| 44.65 | 30 | 2.027 | 200 | Ag | face centered cubic | 0.279 | 6.80 |
| 64 | 18 | 1.437 | 220 | Ag | face centered cubic | 0.294 | 10.47 |

The average particles size was found to be 8.4 nm.

**Surface morphology**

The surface morphology of the Ag NP is studied through Atomic Force Microscope technique as shown in figure (5). The AFM image of the surface morphology of the Ag Nps gives a good indicator that particles are spherical in shapes and grains are tightly packed. The average particle size determined from AFM, is about 78.75 nm,

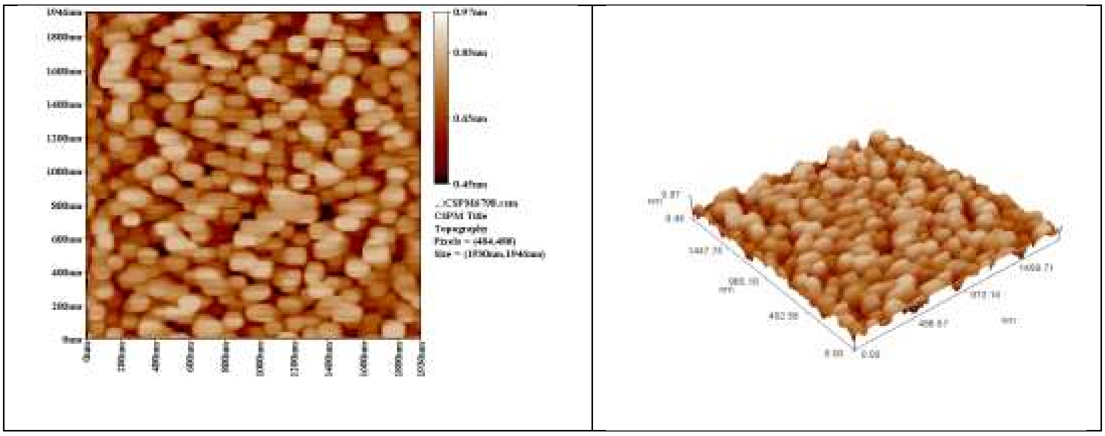


**Figure (5) Atomic Force Micoscope (AFM) of Ag nanoparticles**

Figure (6) shows the percentage of Ag Nps as a function of the grain size, this figure show the size of grains varies from 45 to 120 nm.

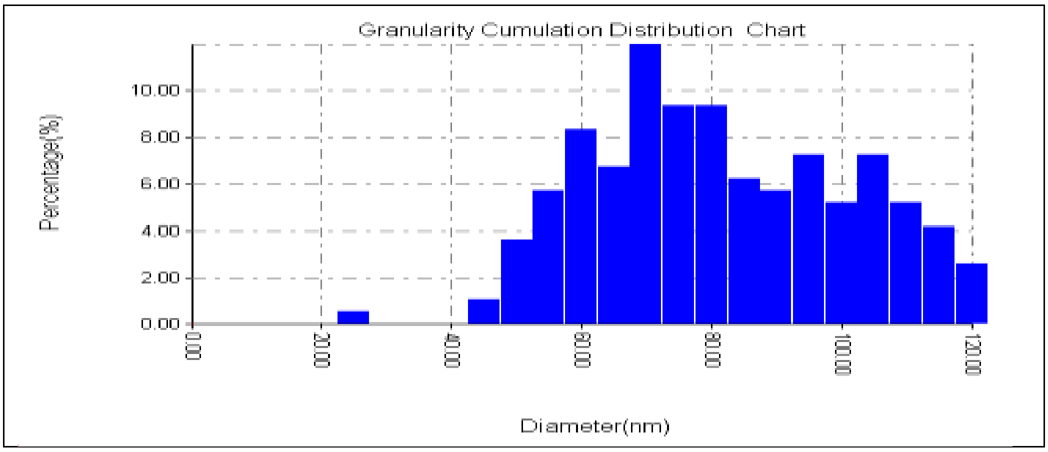



**Figure (6) Granularity Commutation distribution Chart.**

## CONCLUSIONS

Electrical arc discharge in liquid is one of the most important methods for preparation of Silver nanoparticles and its experimental set up is very simple , cheap and work at room temperature without any heat exchanger, vacuum equipment and gas handling equipment. The prepared silver nanoparticles were characterized using UV-Vis absorption measurement, X-Ray Diffraction pattern, and Atomic Force Microscope. UV –Visible shows the absorption peak at 400 nm belongs to silver nanoparticles. The X-Ray diffraction pattern exhibits three sharp diffraction peaks at values of 38º, 44º and 64º respectively, which correspond to the (111), (200) and (220) crystalline planes, there's match with the customary Bragg reflections of face centered cubic (FCC) silver and The average particle size was found to 78 nm for silver nanoparticles obtained by Atomic Force Microscope measurement.

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