New method to control of size and yield Silver Nanoparticles Synthesized by Rotational Disk Electrode Arc Discharge

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Abstract— Controlled sized Silver nanoparticles were efficiently synthesized by arc discharge powered by micro-electronic system method in deionized water using rotational disk electrode. Results of using rotational disk cathode leading to control silver nanoparticles size also maximize purification mass to 42mg\min by rotating cathode discharge. The silver Nano metal was characterized in terms of stability, morphology and particle size. All characterizations show that the prepared spherical silver nanoparticles have moderate stability (10 days) with controlled size 17nm at rotational speed 950 rpm produced by using rotating cathode.

Keywords — arc discharge, controlled silver nanoparticles size, rotating cathode, silver nanoparticles.

1 INTRODUCTION

Now day's nanomaterial's applications play a vital role in our life either maximize benefits or minimize disadvantage so scientists competed in last years to use this special characteristic to improve life style of human rights [1-6]. The excellent physical and chemical properties of the nanomaterial depend upon the size, shape and composition of particles [7]. Many preparation methods of silver nanoparticles fabrication exist [8]. Current preparation methods used to produce silver nanoparticles are usually divided into chemical and physical methods [9].

Electrical arc discharge immersed in liquid is an attractive method because of simplicity of apparatus building; no need for complicated vacuum equipment and low impurity yield [10].There is lot of scope for improvisation by modifying the arc discharge parameters to produce high quality and quantity yield. The most significant parameters of arc discharge synthesis are the arc current, power supply, temperature, pressure, medium and electrode geometry [11].DC power supply usually used for arc discharge. However, effect of use of different types of power supply (AC and pulsed) has not been researched in large numbers [12, 13].The role of atmosphere has been studied vastly and similar observations between pressure and nanoparticles yield have been reported [14-16].the current has a great effect on the product, as the current increases the diameter of nanoparticle yield also increases [17-18]. The nucleation and growth of nanoparticles in arc discharge technique depends on temperature, and the relation between them needs considerable studies to understand [19-20]. Electrode geometry is a decisive parameter in the production of NPs where smaller anode diameters increase the yield [21-23].Organic solvents acetone in arc discharge technique results high particle size but deionized water produces spherical and smallest product [24]. The exact mechanism for synthesis of nanoparticles needs to be elucidated [7,11].Ag NPs has low stability easily when storage in damp and moist area [25-26].In the preparation of silver nanoparticles, the key lies in avoiding the formation of aggregates. In the previous work This problem can also be solved chemically by using stabilizing agent to increase stability e.g. (PVP or sodium citrate) [27, 28] from days to few months of the sample where zeta potential exceeded -50mV which indicates good stability [10] when using sample in long term duration.

In this work a new method technique is used to study the effect of using non-traditional rotating cathode on preparing the silver nanoparticles with controlled size. This method strongly depends on the strong electric field between electrodes plasma produced when low voltage and high current between electrodes is applied. The quick and efficient arc discharge process applied by AC-power supply. Particle size analyzer, SEM, TEM, XDR and Zeta potential were studied to characterize the product.

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2 MATERIALS AND METHODS

2.1 Materials

Silver rods (turkey, 99.99%) were used as electrodes submerged in deionized water (pH = 6, conductivity = 0.8-0.9 µS) using Aqua solutions, water purification, pure and simple ™ Instrument at Institute of Graduate Studies and Research. whatman filter paper, steeper motor, arduino uno, photo sensor, motor with different speeds, ball bearing supports, monitor controller, cathode holder, T-ARC 530 deca, Italy power supply and cooling system with pump and ultracentrifuge model (Hettich MIKRO, German).

2.2 Experimental system

The system designed to prepare this control Ag NPS size shown in Figure (1) composed of High purity silver electrodes, microcontroller system, AC-power supply, an open vessel and motor.

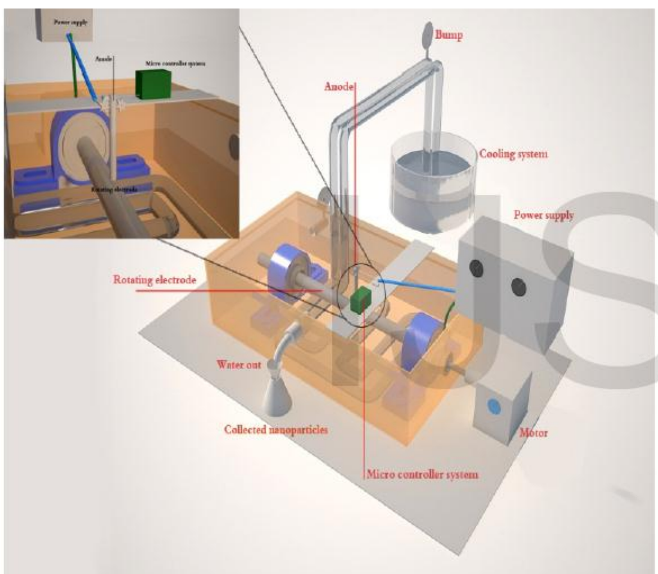

Figure (1): electric arc discharge system.

Silver cathode is taken in large dimension with respect to the anode (see table 1) to increase the yield [10]. The rotating disk cathode connect to a steeper motor produces more homogenous distribution. The rotational force accelerates silver clusters and prevents it from condensation on cathode surface.

The using design is reduced the forces on the cathode cylinder connecting the axial motor, this helps to increase the rotational speed of the cathode electrode. The produced nanoparticles will spread over in the collecting medium (deionized water to yield fine shape with small size) [21-22] instead of trapping the particles on the electrode itself.

The microcontroller system used to make the arc discharge process continuous by feeding the anode electrode vertically towards the cathode to increase the product. The microcontroller system composed of three main parts (a) a photo sensor to detect variance of distance gap (b) feedback loop and computing unit (c) a servo unit for translation anode as shown in figure (2).

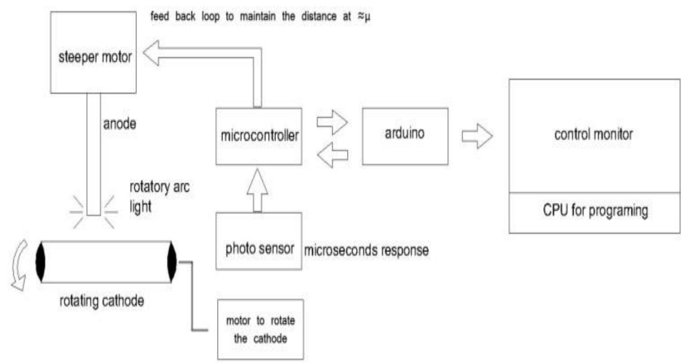

Figure (2): the concept and major components for the microcontroller feeding system.

The low voltage 70V and high current 15A produces by AC power supply causes the silver electrode poles to vaporize or melt into silver clusters. The clusters are then quenched by the deionized water at 3°C; there by forming the nanoparticles. There are two holes to inlet and outlet ethylene glycol with constant flow rate to maintain the temperature constant. The formed nanoparticles are quickly removed from the discharge area to filtration unit system retention down to 400nm, the filtered amount carried out in centrifuge set up with some specific parameters as follows: the radius and rotating speed were 7.5 cm and 18,000 rpm, respectively [29] while objects denser than a liquid settle spontaneously due to gravity using ultracentrifuge model (Hettich MIKRO, German) for 30 min and repeated four times. Eventually, the suspended metal nanoparticles left over in water were found to be pure enough and no further separation process was needed.

TABLE 1
The important parameters used in the arc discharge method

Key parameters	Values
Discharging voltage(average value)	70 volt
Discharging current(average values)	15A
cathode disk(diameter, length)	16mm,10cm
anode(diameter, length)	2mm,3cm
Discharging Duration time	30min
Temperature of solution(before& After)	5^0C
Pressure	atmospheric
PH	6
Volume of solution	3 liter

The resulting yield were analyzed by using a UV–Vis spectrometer (Thermo Scientific™ Evolution 300), electrophoric dynamic light scattering (Malvern

Instruments nano ZS-90), JSM-6360 scanning electron microscope at an accelerating voltage of 20 kV ,JEOL JEM-2100 high resolution transmission electron microscope and X-ray diffraction analyzer .

3 RESULTS AND DISCUSSION

3.1 UV–vis spectroscopy

The interesting phenomena observed in this study was the slightly increasing intensity of the plasmonic peak of prepared silver nanoparticles during 30 min arc discharge and 15 A arc current, as a function of rotation disk speed. The increase in speed indicates a slight increase in concentrations of the collected sample. an examining the results of UV absorbance (Figure 3) it is observed that the Ag NPs samples prepared at different speeds have a maximal absorbance peak positions around 399–450 nm and gradually shifted to low wave lengths as rotational speed increase which reveals a good indication of producing more spherical shape of silver nanoparticles with smallest size [30]. The full width at half maxima determines the size and shape dispersity [31] of nanoparticles which changes from 47.21±2.61 at 0 RPM to be 26.54±2.46 at 950RPM, the results indicates that the distribution of particle size at higher speed is more homogeneous and spherical from that at low speed rotation speed.

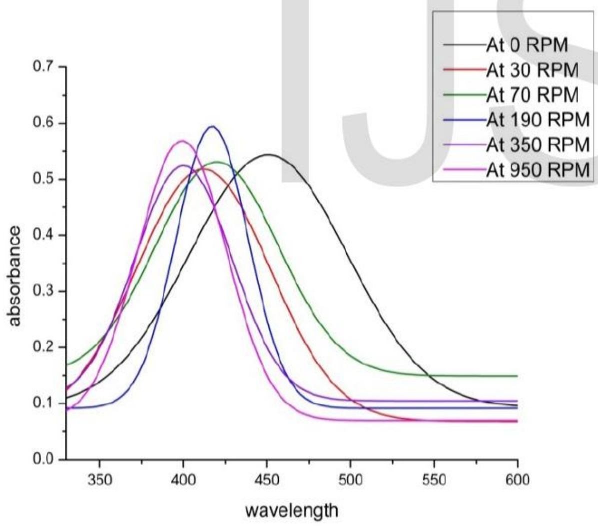

Figure (3): The UV–Vis spectra of colloidal silver nanoparticles.

3.2 XRD analysis of the products

The product At 950 Rpm was prepared as powder form analyzed by X-ray diffraction (XRD) at Egypt-Japan University of Science and Technology to find the crystalline phase of the product as depicted in Figure 4. The obtained spectrum reveals main peaks of silver phase at 2θ = 38, 44, 64, 77, and, which is in close agreement with the 04-0783 standard card from the JCPDS [32-33]. The result for the as-prepared powder sample indicates formation of silver nanoparticles. Average crystalline domain, determined by Debye-Scherrer formula, was approximately 17 nm according to four peaks (111,200,220,311) given from the XRD pattern.

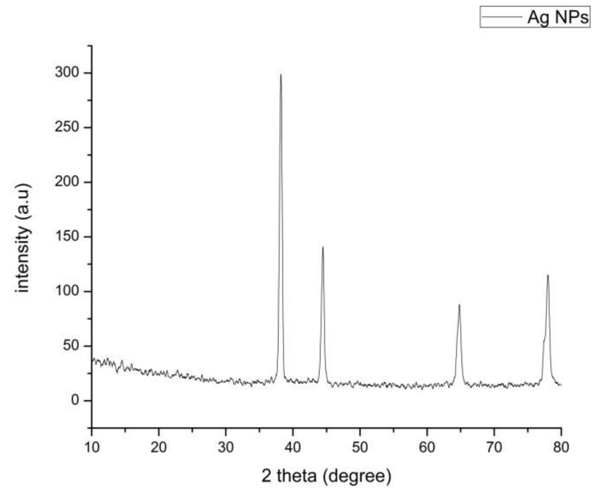

Figure (4): XRD patterns of silver nanoparticles obtained by the arc discharge method

3.3 Particle size and zeta potential

The diameters of the prepared particles were measured by a laser particle-size analyzer (Malvern Instruments) to get average diameter of the silver nanoparticles after 30min sonication. The size was measured with relevant analyzers. Data are reported as the average of three measurements for every rotational electrode speed (table 2) with PdI <1 showing significant decrease of particle size with increasing the rotational speed of cathode.

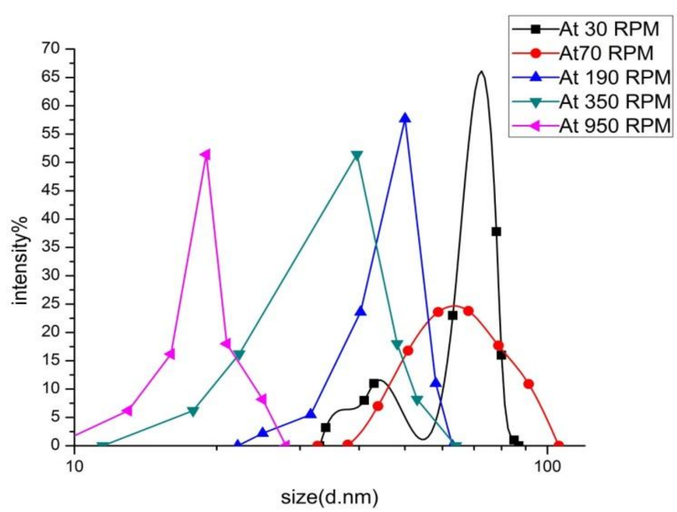

Figure (5-a): The size of silver nanoparticles at different speeds obtained by the arc discharge method.

TABLE 2
Size of average particles and rotation speeds

Rotational speed (rpm)	0	30	70	190	350	950
Diameter (nm)	94	66	65	47	38	17

The interesting results clarify that the peak position is shifted to low size as the rotation speed increases (figure 5-a) which means that the distribution of particles is condensed in small diameter range and silver nanoparticles become homogenous comparing with 0 rpm (figure 5-b) which have two main peaks the smallest one is at 64nm and the highest peak is at129nm which depicts a non-homogenize distribution of particles size. Zeta potential was measured by using a Zetasizer Nano ZS 90 which approximately founded at -25.8mV that indicates incipient instability [34] and not effected by rotational speed.

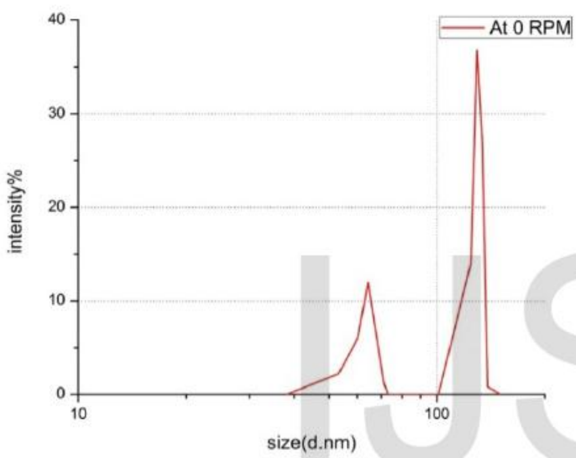

Figure (5-b): The size of silver nanoparticles at zero speed obtained by the arc discharge method.

3.4 SEM

SEM was performed on JSM-6360 scanning electron microscope at an accelerating voltage of 20 kV, showing spherical particle shape with nonhomogeneous distribution of particle size and strongly aggregated at lower rotational speed.

3.5 TEM

TEM were performed on JEOL JEM-2100 high resolution transmission electron microscope at an accelerating voltage of 200 kV, showing spherical particle shape at size with quite small average diameter 15nm and uniform particle size at higher rotation speed.

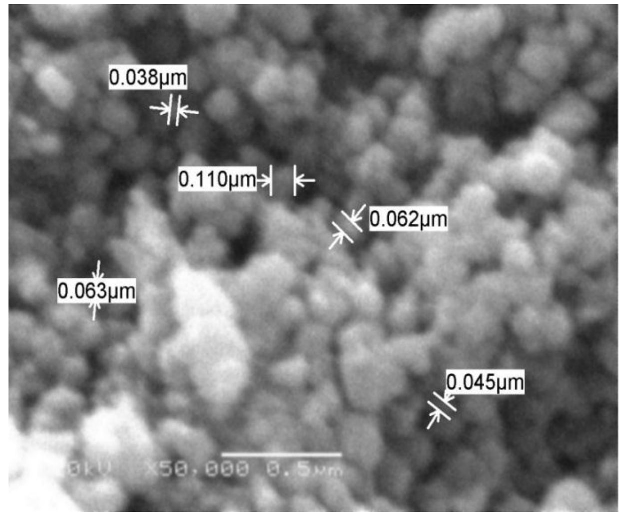

Figure (6-a): SEM image of silver nanoparticles at 0 RPM

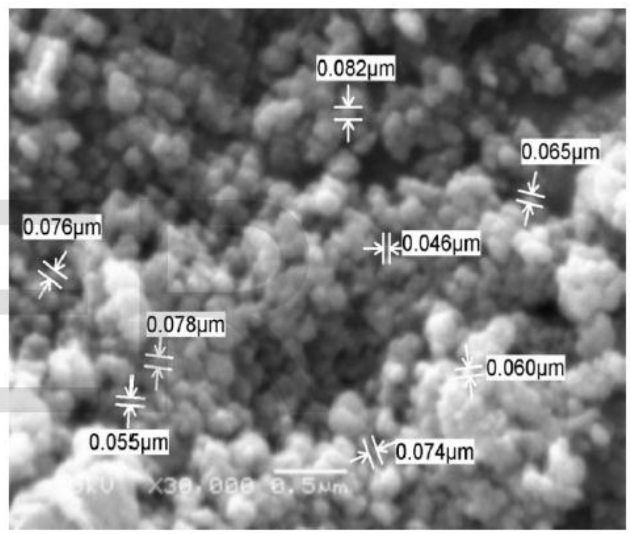

Figure (6-b): SEM image of silver nanoparticles at 30 RPM

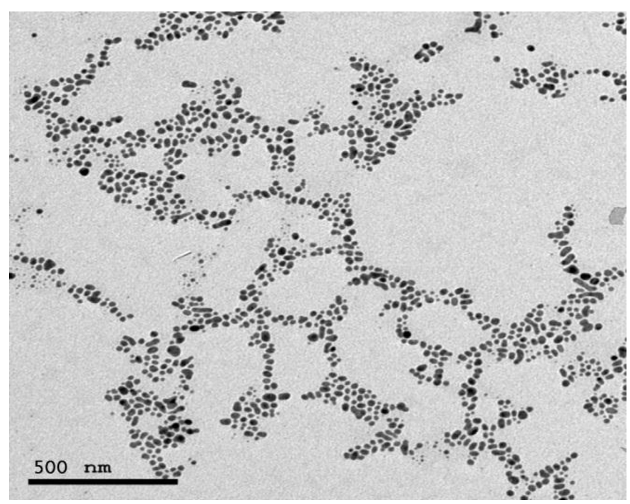

Figure (7-a): TEM image of silver nanoparticles at 350 RPM

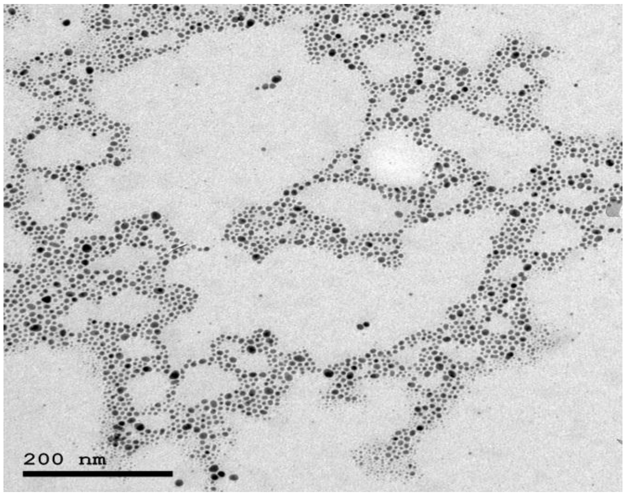

Figure (7-b): TEM image of silver nanoparticles at 950 RPM

CONCLUSION

The rotation of the silver electrode distributes arc discharges uniformly and generates stable plasma using microcontroller system. The rotational force accelerates silver clusters and prevents it from condensation on cathode surface which is an intrinsic factor in minimizing particle size of Ag NPs. This newly method condense distribution in low particle size region. The rotational disk electrodes arc discharge process is a persistent process of the steady discharge and the results show a good performance with high quality perform high quality purification of mass production at 950 rpm.

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