

# The Effect of Electric and Magnetic Field on Silver Nanoparticles Prepared by Pulse Laser Ablation

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**Abstract—** Silver nanoparticles (Ag NPs) were prepared by pulse laser ablation in distilled water with assistant of electric and magnetic field at various laser power and 300 pulses. The synthesized nanoparticles are characterized using X-ray diffraction (XRD), transmission electron microscopy (TEM) and ultraviolet-visible (UV-Visible) spectroscopy. The X-ray diffraction pattern showed that the structure of Ag NPs film is polycrystalline with preferential orientation of Ag in (111) direction. Nanoparticle size measured by TEM shows that the average diameter of nanoparticles is around 14 nm and the particle size increase to 25 nm by applying electric field, while the particle size is around 10 nm by applying magnetic field. The results show the intensity of surface Plasmon resonance (SPR) increases there is red shift with applying electric field, while the intensity of SPR decreases and has blue shift with applying magnetic field.

**Index Terms—** silver nanoparticle, surface Plasmon resonance, pulse laser ablation in liquid.

## 1 INTRODUCTION

SILVER nanoparticles (Ag NPs) are one of noble metal nanoparticles, which have the unique physical and chemical properties make them excellent candidates for a number of day-to-day activities, and also the antimicrobial and anti-inflammatory properties make them excellent candidates for many purposes in the medical field, cryogenic superconducting materials, cosmetic products, biosensor materials, composite fibers, and electronic components. Several physical and chemical methods have been used for synthesizing and stabilizing silver nanoparticles [1,2]. The superior characteristics of Ag metal such as ductility, malleability, thermal and electrical conductivities, catalytic activity, photosensitivity. The antimicrobial activity of Ag is also much higher than other metals, such as mercury, copper, lead, chromium and tin [3]. The surface Plasmon resonance (SPR) absorption of those metal NPs were dependent on their size, shape and composition[4]. Metal NPs show brilliant colors owing to the surface Plasmon resonance absorption[5,6]. The color of metal nanoparticles is found to rely on the size, shape of the nanoparticle and dielectric constant of the surrounding medium[7]. Pulse laser ablation in liquids (PLAL) is promising technique

as a rapid, simple, with one step, free from contamination and most versatile technique to prepare noble metal nanoparticles for analytical chemical and biological sensing applications[8]. In addition, laser ablation offers a technique to control size of nanoparticles by control of the laser parameter.

## 2 EXPERIMENTAL

Silver nanoparticles were prepared by pulse laser ablation of a silver plate (99.9% in purity) placed in a glass vessel with 3 ml of distilled water (DW), the Nd-YAG laser (type RS BPW 21) was set in Q-switching mode of 1064 nm to give laser pulses of 10 ns duration with repetition rate of 6 Hz, at laser power (100,300,500 mJ) per pulse, and 300 pulses with a positive lens having a focal length of 110 mm, was utilized as an ablation source, the distance between laser source and target is 15cm. The electric field used 30 V/cm, figure (1) show schematic diagram of electric field, the magnetic field is 0.327 Tesla, figure (2) show magnetic field used in this work. Ag NPs suspension was studied using an ultraviolet-visible (UV-Vis) (SP-8001-Metertech) spectrophotometer. X-ray diffractions using a (Philips PW) X-ray diffractometer system. A high resolution transmission electron microscope HRTEM (CM 30, Philips-Germany) was employed to study the structure of nanoparticles and to know the size of nanoparticles.

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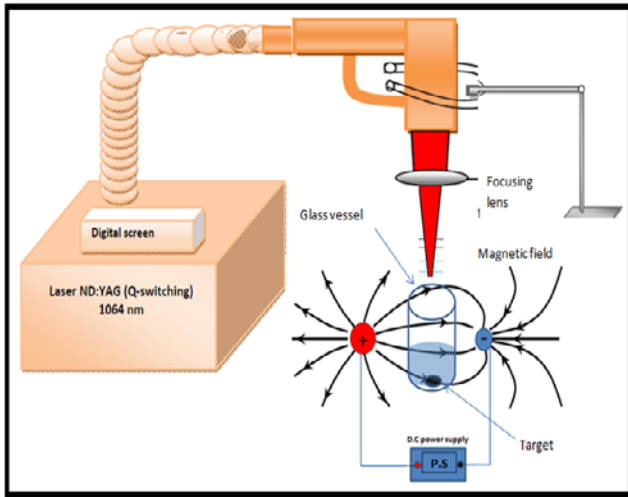


Figure (1): shows electric field scheme.

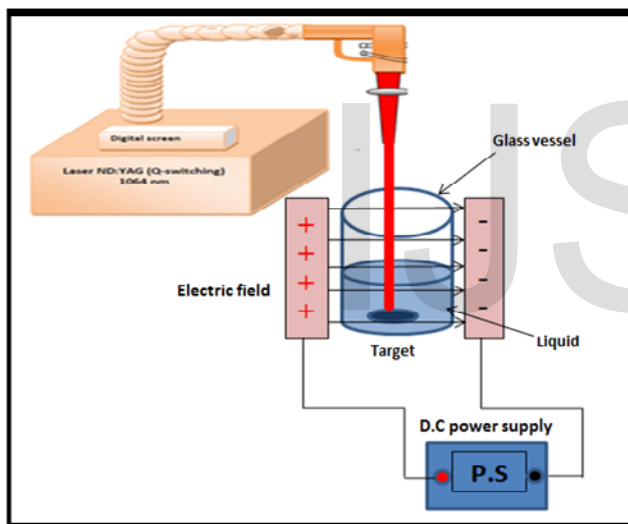


Figure (2): shows magnetic field scheme.

### 3 RESULTS AND DISCUSSION

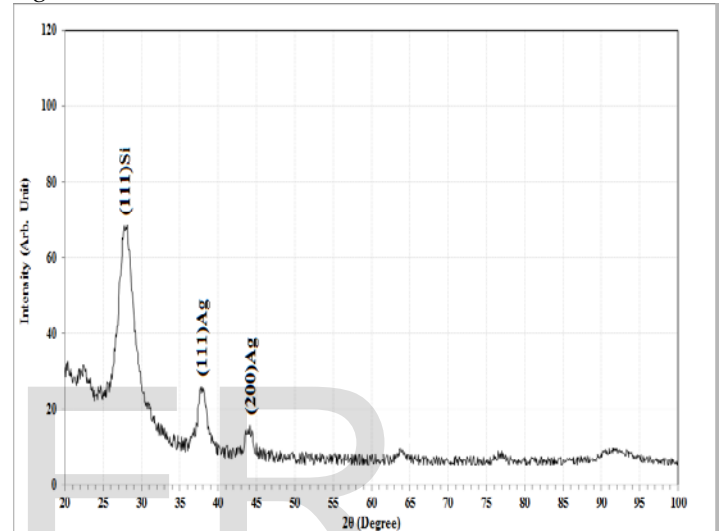
#### 3.1 X-ray Diffraction

Diffraction pattern gives information on translational symmetry - size and shape of the unit cell from Peak Positions and information on electron density inside the unit cell, namely where the atoms are located from Peak Intensities.

The thin film was obtained by direct spraying of the solution in order to spray the collide liquid on a silicon substrate heated to 80° C to obtain an uniform distributed nanoparticles thin film. X-ray diffraction of the Ag NPs prepared by pulsed laser

ablation in 3 ml of DW ,at laser power 500 mJ/pulse and 300 pulse.

Figure(3) shows the structure of our experimental for Ag NPs have a polycrystalline structure and cubic phase for Ag NPs. The strongly peak represent the peak of silicon (as a substrate by the deposition upon) with (111) plane that peak at ( $2\theta=27.892^\circ$ ) agreement with the JCPDS standard card No. (#96-901-3108), and (111), (200) planes that peaks at ( $2\theta=37.93^\circ, 44.03^\circ$ ) for Ag NPs agreement with the JCPDS standard card No. (#96-901-3049). Table (1) shows Structural Parameters viz. Inter-planar Spacing, crystalline size for the Ag NPs.



Figure(3) XRD spectrum of Ag NPs.

Table (1) shows Structural Parameters viz. Inter-planar Spacing, Crystalline Size of Ag NPs.

$2\theta$ (Deg.)	FWHM M (Deg.)	$d_{hkl}$ Exp.( Å)	C.S (nm)	Phase	$d_{hkl}$ Std.(Å)	hkl	card No.
27.892 0	1.9860	3.1962	4.1	Si	3.1454	(111)	96-901- 3108
37.930 0	1.2300	2.3702	6.8	Ag	2.3821	(111)	96-901- 3049
44.030 0	1.1340	2.0550	7.6	Ag	2.0630	(200)	96-901- 3049

#### 3.2 Absorption of Ag Nanoparticles

Figure (4) shows the absorbance spectra of Ag NPs, which is varied with laser power(100, 300,500)mJ and 300 pulses . The SPR peak position is at (405, 402, 401) nm at laser power (100, 300, 500) mJ respectively , and is shifted to short wavelength (blue shift) which indicates of formation Ag NPs with smaller size.

TEM image of the silver NPs at laser power 500 mJ and 300 pulses is shown in figure (5), the average size diameter is around 14 nm and spherical shape is observed.

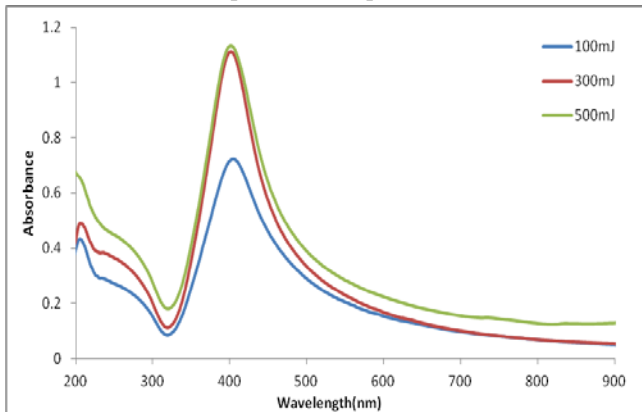


Figure (4): Optical absorbance as a function of wavelength for prepared Ag NPs.

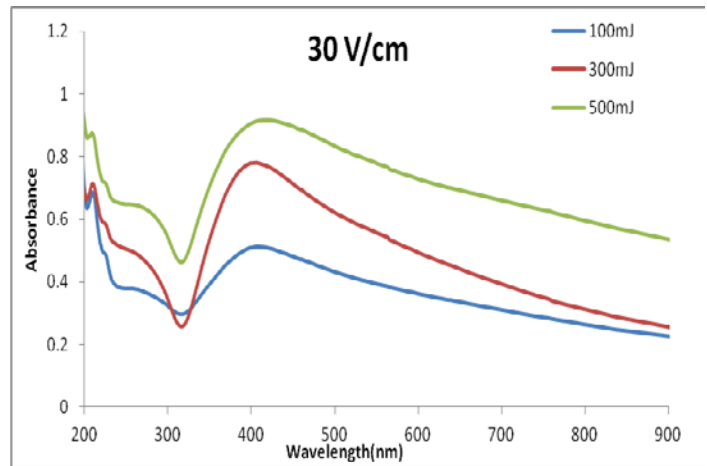


Figure (6) Optical absorbance as a function of wavelength for Ag NPs, at various laser power with existence electric field.

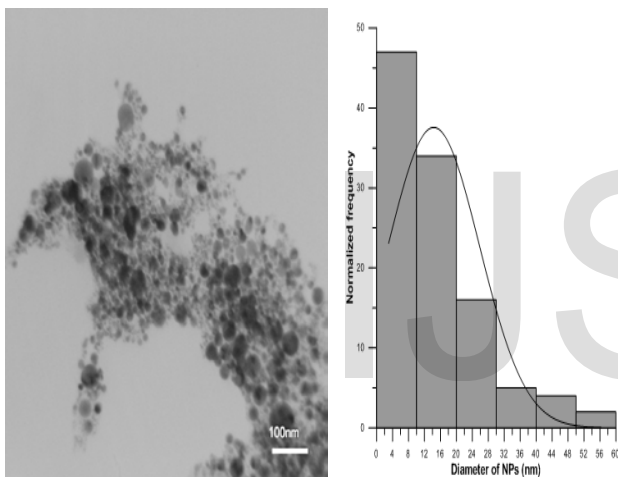


Figure (5): TEM image of Ag NPs at 500 mJ and 300 pulses.

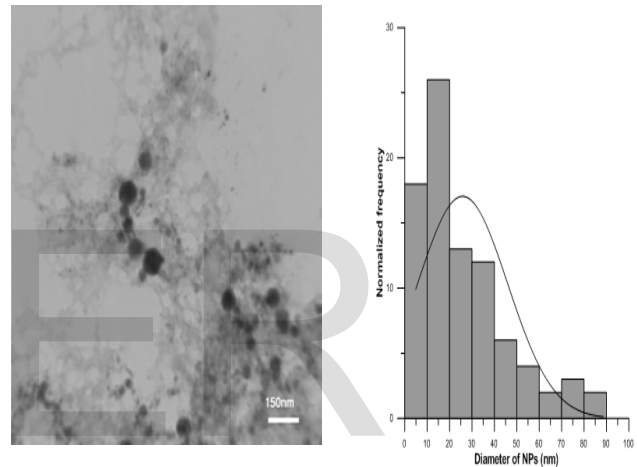


Figure (7): TEM image of Ag NPs with electric field at 500 mJ and 300 pulse.

### 3.3 Electric Field Effect on Silver NPs

Silver nanoparticles prepared by PLAL with the D.C electric field( 30 V/cm ) at various laser power and 300 pulse. The absorption spectrum of silver nanoparticles suspension by applying electric field is observed in figure(6), where there is red shift with increasing laser power that means the particle size becomes larger under the electric field.

TEM image of the silver NPs with electric field at laser power 500 and 300 pulse is shown in figure (7), the average size diameter is around 25 nm and have a spherical shape. It's clear from this figure that by using electric field the particle size diameter of Ag NPs is larger than that without electric field.

The reason of this effect is a great influence of electric field on laser induced plasma plume. In the electrical field assisted PLAL, the plasma expansion in the water layer will be delayed. This can be ascribed to the following reasons: Initially, the laser-induced plasma is firstly generated at the liquid-solid interface, when the pulsed-laser has ablated the silver particles, a dense region will form in the vicinity of the solid-liquid interface. Then, due to the absorption of the incident laser radiation and the laser-induced pressure, the plasma plume is driven into a state of high temperature, high density, and high pressures (HTHDHP) state, in which the phase transitions would happen. In other words, the silver species will impact with each other drastically to form the metastable phase, which may make some anisotropic nanoparticle seeds form from the ablated substance simultaneously when they are ejected from the target. Finally, a rapid quenching of the plasma plume will lead to the nucleation of the forming phases and the growth of the nuclei. The formation of the silver NPs under effect of suitable electric field could stabilize and enhance the growth of the specifically crystalline planes. Fur-

thermore, as a result of the liquid confinement, the growth time (the plasma quenching time) of the synthesized particles is very short. Thus, the size of the grown particles is usually in the micro-and nanometer range. Generally, a crystal shape is determined by the crystallographic planes. When crystals form under the equilibrium conditions, their crystalline habits are determined by the surface energies. Thus, the fastest growing plane always occurs in the direction that is perpendicular to the face with the highest surface energy, which leads to the weakening of the high-energy surfaces while the low-energy surfaces enhance. On balance, this evolution of planes causes the final shape of the crystals.

### 3.4 Magnetic Field Effect on Silver NPs

Silver nanoparticles prepared by PLAL with magnetic field( 0.327 Tesla ) at various laser power and 300 pulses. The absorption spectrum of silver nanoparticles under the effect of magnetic field observed in figure(8) show when laser power increases there is increase in absorbance peak where the peak position is 399nm.

TEM image of the silver NPs with magnetic field at laser power 500 and 300 pulses is shown in figure (9), the average size diameter is around 10 nm and have a spherical shape, so particle size of Ag NPs by applying magnetic field is smaller than that without magnetic field, that means there is blue shift.

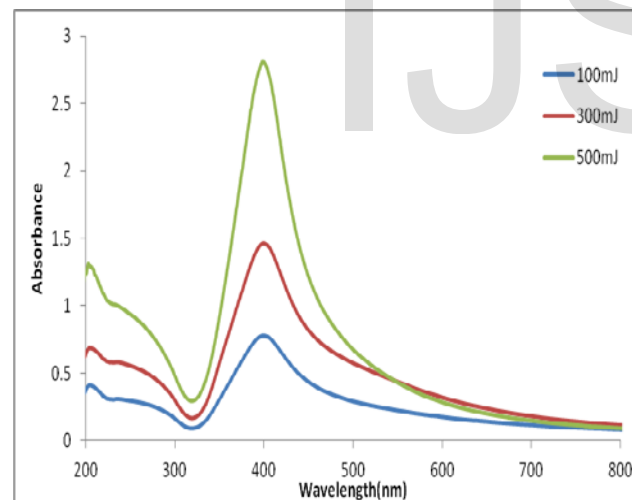


Figure (8): Optical absorption as a function of wavelength for Ag NPs with applying magnetic field.

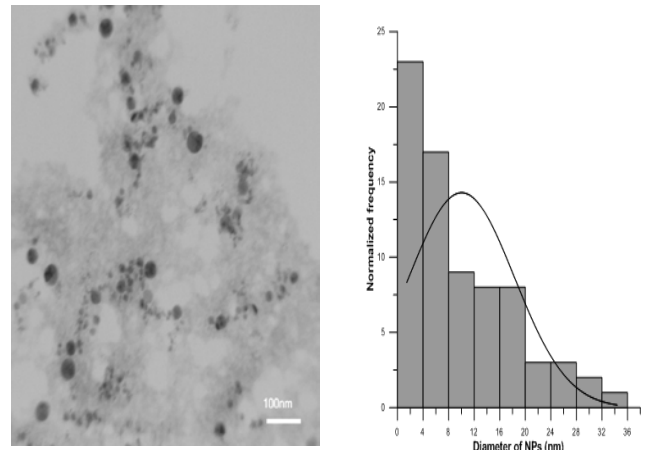


Figure (9): TEM image of Ag NPs with magnetic field at 500 mJ and 300 pulse.

These results can be attributed to the effect of the constant magnetic field with the plasma (plasma plume formation due to laser impact). The plasma frequency ( $\omega_p$ ) is [9]:

$$\omega_p = \sqrt{\frac{n e^2}{m \epsilon_0}} \approx 9000 \sqrt{n} \text{ rad/sec} \quad (1)$$

where  $n$  is the number of particles per cubic centimeter in the last term and  $(e)$  is the particle charge ( $q$ ). But in oscillations of plasma in a constant magnetic field ( $B$ ) would cause frequency to appear which is called the cyclotron frequency ( $\omega_c$ ) from equation [10]

$$\omega_c = qB/m \quad (2)$$

Then the "upper hybrid frequency" for such oscillations is  $\omega$ , where

$$\omega^2 = \omega_p^2 + \omega_c^2 = \left(\frac{n e^2}{m \epsilon_0}\right)^2 + \left(\frac{qB}{m}\right)^2 \quad (3)$$

The frequency is greater than either  $\omega_p$  or  $\omega_c$  separately, resulting in energy be greater than that where there is no magnetic field. That means we gain energy enhancement of laser which shows the absorption peak values in the presence of magnetic field are increased more than the peak values without magnetic field, since these peak values could be increased either by increasing laser shots or pulse energy as explained before, so we can say the applied constant magnetic field can enhance the energy. Due to the presence of constant magnetic field the particle moves in a circular orbit at cyclotron frequency, the radius of the circular orbit, Larmor radius, radius of gyration, or gyroradius is given [11] as in equation:

$$r_{\perp} = v_{\perp} / \omega_p \quad (4)$$

It is clear from this equation that the radius of the circular orbit is inversely proportional to the cyclotron frequency ( $\omega_c$ ) which appears only by applying constant magnetic field, consequently the movement path of the noble nanoparticles would be confined and reduced when the magnetic field exists which results in the collisions of each nanoparticles in this specific and limited confinement path with others be less or reduce to keep them from agglomerating and from having tendency to aggregate resulting in the size of nanoparticles being smaller than that when no magnetic field is applied.

#### 4 CONCLUSIONS

PLAL is simple method to create Ag NPs which is affected by using with electric and magnetic field. The particle size of Ag NPs with electric field larger than Ag NPs without electric field, while the particle size of Ag NPs with magnetic field is smaller than Ag NPs without magnetic field.

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