CHARACTERIZATION OF SILVER NANOPARTICLES PREPARED BY LASER ABLATION IN DISTILLED WATER

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Abstract

Silver nanoparticles (Ag-NPs) due to the chemical, physical, biological and optoelectronic properties have applications in many scientific areas. In this work, Ag-NPs were synthesized by the pulsed laser ablation of a high purity silver target in distilled water. Pulsed Nd:YAG laser with wavelength of 1064 nm and pulse repetition rate of 1, 3 and 12 kHz were employed to irradiate the silver target in water. Effect of laser pulse repetition rate, on structure, morphology and nanoparticles size was studied by different analysis such as XRD, DLS and UV-Visible absorption spectrum. The results show that the spherically (Ag-NPs) sizes are decreased in distilled water by enhancing of laser pulse repetition rate, and nanoparticles surface Plasmon absorption peak intensity is increased and shifted toward lower wavelength. Also, using ultrasonic bath the (Ag-NPs) sizes is reduced.

Keywords: Silver nanoparticles, laser ablation, pulse repetition rate, surface Plasmon

1. INTRODUCTION

Nanoparticles (Nps) of noble metals have recently become very interesting materials because of their unique properties and important applications in many scientific areas [1-12]. Among the noble metal Nps, Silver nanoparticles (Ag-NPs) have attracted much attention due to the chemical, physical and optoelectronic properties and can be applied in diverse field such as, catalic, optical and antibacterial applications[5,7-12]. Several chemical and physical methods have been employed to prepare metallic nanoparticles [7-12], but laser ablation (LA) of metal plate in a liquid medium is an alternative method. In contrast to chemical nanofabrication methods, the Laser ablation is a very clean physical method that can be performed in a clean well-controlled environment, such as deionized water, giving rise to the production of ultrapure nanomaterials [8-11]. In this paper, the Ag-NPs were synthesized by the pulsed laser ablation of a high purity silver target in distilled water. Effect of laser pulse repetition rate, on structure, morphology and nanoparticles size was studied by different analysis such as XRD, DLS and UV-Visible absorption spectrum. The structure of the paper is as follows. Following the introduction in section1 we present the experimental details for the preparation and characterization of the Ag-NPs in section 2. Section 3 devoted to our results and discussions and we conclude the paper in section 4.

2. EXPERIMENTS

Silver nanoparticles were prepared by laser ablation of high purity silver (99.999%) target in distilled water. The silver target was first washed in ultrasonic bath with ethanol and deionized water to remove organic compounds and then placed at the bottom of a glass vessel containing 8ml of distilled water. Height of water on the silver target was 4mm. A pulsed Nd: YAG laser with fundamental wavelength of 1064 nm and pulse width of 150 ns was used for ablation of target. The laser was operated at different repetition rates of 1, 3 and 12 kHz for samples 1-3 respectively. The optical absorption spectra of samples were measured by UV-Visible spectrophotometer (Lambda 35 model). Dynamic light scattering (DLS) measurement was done using (ZEN 3600.MAlveran) for studying of the hydrodynamic size distribution of each sample. X- ray diffraction (XRD) was measured by (X pert Pro MPD). Ultrasonic treatment of Solution was done by Ultrasonic bath (S60H, Elma).

3. RESULTS AND DISCUSSION

Figure 1 shows the images of prepared samples. We can observe that the color of silver nano particles solution in water varied from yellow to brown as is shown in (**Fig. 1**). The color of sample1 is light yellow which changes gradually to brown in sample 3. The color changes can be due to the amount and sizes of nanoparticles.

Fig.1 Ag nanoparticles samples in distilled water.

The XRD analysis is employed to determine the phase distribution and crystallinity of the synthesized nanoparticles. Typical XRD pattern of dried powder of prepared Ag- NPs is shown in (**Fig. 2**).The peaks appear in figure 2 namely the (111), (200), (220), (311) and (222) are due to the Ag cubic structure (JCPDS data file No.4-0783) which also indicates a high purity of prepared silver nanoparticles. The sharpness of the reflection peaks provides a clear evidence for the enhanced crystallinity of Ag nanostructures. The mean crystallite sizes of Ag-NPs are estimated from Debye- Scherer formula:

$$D = 0.89\lambda/\beta\cos\theta \quad (1)$$

Where D is the mean crystallite size, λ is the wavelength of the X-ray radiation, ɵ is the diffraction angle, β is the full width at half maximum (FWHM). The structural parameters of Ag-NPs are shown in(**Table 1**).

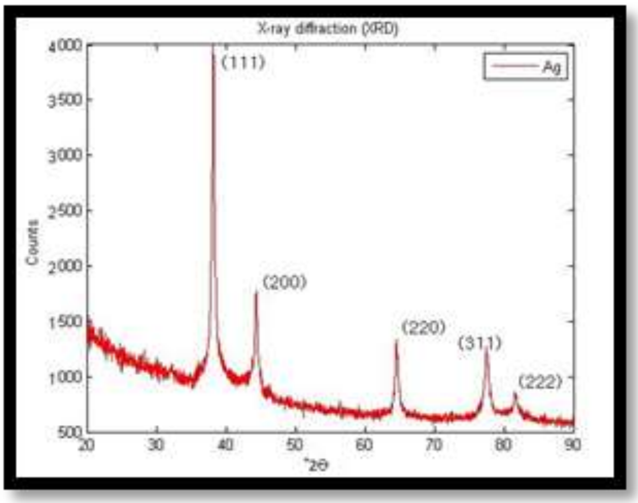

Fig.2 X-ray diffraction pattern of Ag- NPs after drying

Table 1: The Structural Parameters of Ag-NPs

Phase	2ɵ(deg)	(hkl)	d- spacing (A°)	FWHM	Average Crystalline Size D (nm)
Ag	38.177	111	2.36	0.53	35.06
Ag	44.330	200	2.04	0.65	28.43
Ag	64.529	220	1.44	0.48	38.50
Ag	77.462	311	1.23	0.79	23.39
Ag	81.56	222	1.18	1.39	13.29

The absorption spectra of nanoparticles solutions are exhibited in (**Fig 3**). The absorption peaks around 400nm are due to Ag-NPs Surface Plasmon Resonances (SPR). As it is clear from the figure, the maximum wavelength shifted to lower wavelength by increasing of laser pulse repetition rates. According to the Mie theory, this blue shift is related to the reduction of particle diameter [11, 12]. Therefore we can conclude that the particles size decreases by increasing of laser pulse repetitions. The reducing particles size with increasing laser pulse repetition rates can be explained by the way that at longer repetitions rates the interaction of produced NPs from the target with laser light will increase. The result of this interaction is the fragmentation of NPs to smaller sizes, and therefore the obtained particles at longer repetitions rates are smaller. Furthermore only a single SPR peak is expected in the adsorption spectra of spherical nanoparticles, whereas anisotropic particles could give rise to two or more SPR peaks depending on the shape of the particles. The experimental results were in good agreement with Mie theory.

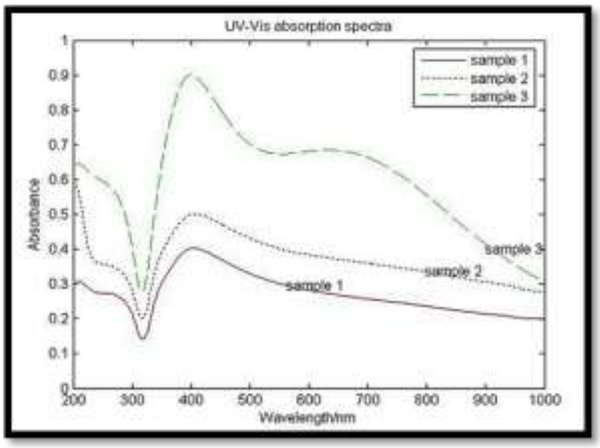

Fig.3 UV-Vis absorption spectra of Ag- NPs in distilled water.

The DLS study provides detail knowledge about particle disperse. The hydrodynamic size distribution of samples measured by DLS is shown in (**Fig 4**) and (**Fig 5**). The results show that with increasing of laser pulse repetition rates, the nanoparticles synthesized in solution increases and the size of nanoparticles changes. After ultrasonic treatment of solution the size of nanoparticles decreases. We can observe that ultrasonic treatment of solution cased the reduction of nanoparticles sizes. The peaks of hydrodynamic size distribution function are shown in (**Table 2**).

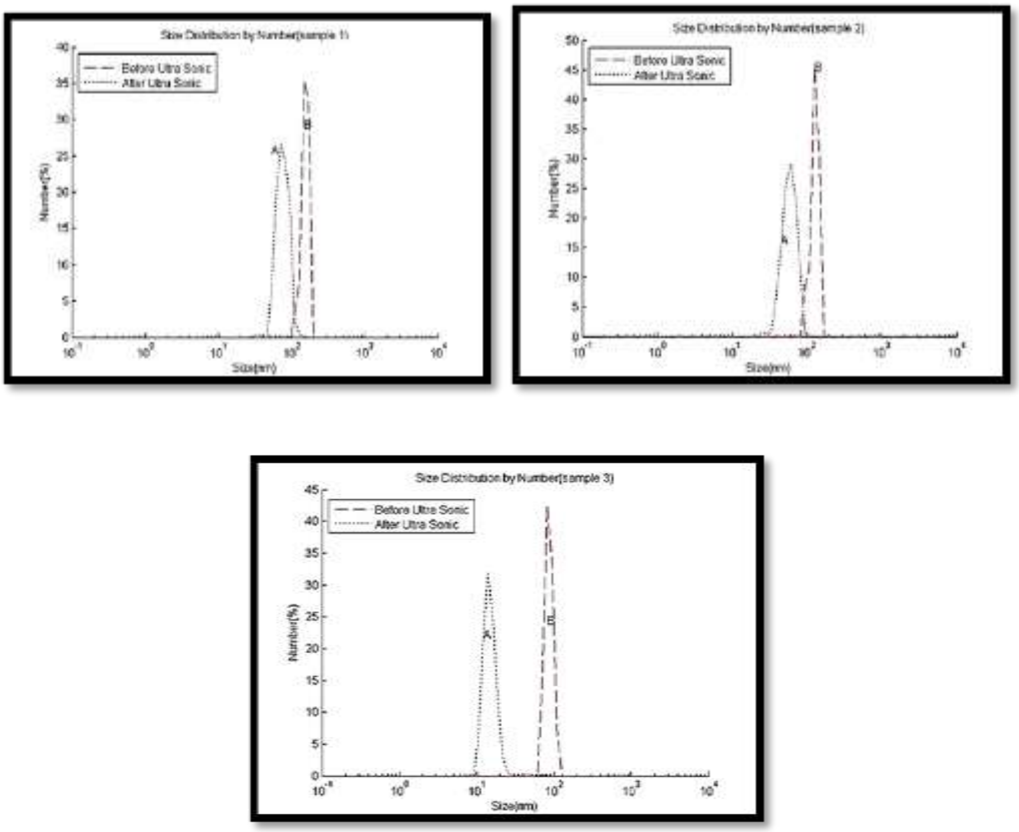

Fig.4 Hydrodynamic size distribution of Ag-NPs samples measured by (DLS).

Table 2: The peaks of hydrodynamic size distribution function of samples1-3

Sample name	Laser pulse repetition rates (kHz)	The peak before ultrasonic treatment (nm)	The peak after ultrasonic treatment (nm)
Sample 1	1	147.7	70.9
Sample 2	3	127.5	52.9
Sample 3	12	82.1	14.1

The hydrodynamic size distribution of all samples measured by (DLS) before and after ultrasonic treatments, are compared in figure 5. In the right figure, we can observe that the dispersion of nanoparticles in samples 1 and 2 are almost in the same particle sizes because the laser pulse repetition rates for these samples is not changing much. After increasing the laser pulse repetition rates to 12 kHz the peak occurred at lower size. By ultrasonic treatment of nanoparticles solution (right figure) the size and the dispersion of nanoparticles in solution decreases.

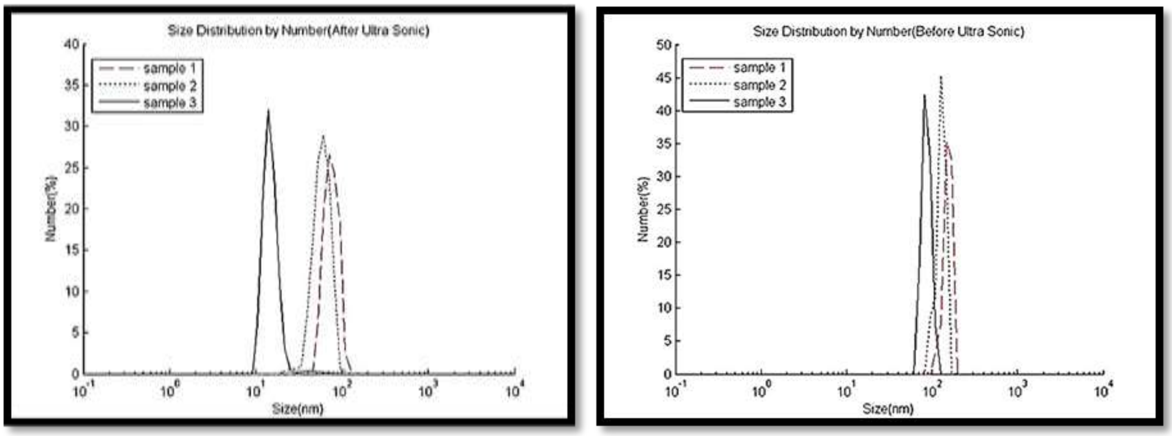

Fig.5 Ag-NPs, hydrodynamic size distribution of samples measured by (DLS) before and ultrasonic treatments.

4. CONCLUSION

The Ag-NPs successfully prepared by pulsed laser ablation of silver target in distilled water at different pulse repetition rates. The Ag-NPs prepared in this investigation are spherical in shape. UV-visible absorption spectra of all samples show the peaks around 400nm due to the phenomenon of surface Plasmon resonances. This wavelength shifted to lower wavelength by increasing of laser pulse repetition rates due to the decreasing of particle sizes. The uniform size distribution of nanoparticles in solution is observed after ultrasonic treatment.

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