Influence of Laser Wavelength and Solution Type on the Optical Absorbance of Colloidal AG Nanoparticles Synthesized by Laser Ablation

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Abstract

Silver colloidal nanoparticles were prepared by pulse Laser ablation of pure silver plate dipped in three deferent solutions deionized water (DI), distilled water (DW) and Polyvinylpyrrolidone (PVP) polymer. The ablation was performed by the Neodymium-doped Yttrium aluminum Garnet laser beam using two different wavelengths 1064 nm and 532 nm, energy of 650 mJ /pulse and 100 pulses number at room temperature. The impact of the wavelength of the laser beam and solution type on the surface Plasmon resonance bane (absorbance) and the surface morphology of the prepared Ag colloidal nanoparticles were investigated. The efficiency of the nanoparticle preparation process (PLA) was quantified in terms of the absorption spectra peaks. The optical density (absorbance) at (λmax) of Ag NPs which ablated by using Laser wavelength 1064 nm in all solution types was higher than its optical density (absorbance) which ablated using laser wavelength 532 nm. Also, the optical density (absorbance) of Silver nanoparticles which ablated in the PVP solution has a higher value than of those which ablated in DIW and DW solutions at both laser wavelengths 1064 nm and 532 nm. The images of the optical microscope (OM) and scanning electron microscope (SEM) of Silver nanoparticles ablated in DIW, DW and PVP polymer solutions showed that the nanoparticles have a spherical shape and the largest particle size in DW solution and the smallest particle size in PVP solution. As well as, Ag particle size ablated in the PVP solution was more uniformly distributed than those in DIW and DW solutions.

Key Words: Ag Colloidal Nanoparticles, PLAL, SPR Band, SEM.

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Introduction

The synthesis of silver nanoparticles (Ag NPs) has attracted great attention, due to its unrivaled optical, magnetic, catalytic and electronic properties which greatly distinct when compared to other bulk materials in addition to its function of their shape and size [1, 2]. The synthesis of colloidal nanomaterials in a liquid by Laser ablation technique is suitable for different types of nanoparticles in stable and metastable phased [1–3]. The investigation of the synthesis noble metal nanoparticles by laser ablation of metal targets in water (PLAL) has potential advantages in comparison with various chemical methods [4–7], especially in the biological applications. This preparation method is cost-effective, simple and the synthesized nanoparticles are contamination-free [8] which give permission to use in medical [9] and biological [10] applications.

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Colloidal nanoparticles have been prepared using a variety of different methods such as laser ablation in liquid [5], flame metal combustion [6], chemical, photo and electrochemical reduction [7, 8, 9], solvothermal electrolysis [10], green method, Microwave-induced, sonoelectrochemical, aerosol flow reactor, chemical fluid deposition, and spark discharge [11-13]. Among these methods, laser ablation in liquids has become well-known and common method in producing colloidal nanoparticles. So that it's a new method which was first used by Fojtik et al. in 1993 where it is a favorable method to controlled preparation creation of nanomaterials by fast reactive cooling of the ablated species at the plasma-liquid interface, with very high-quality nanoparticles and free from chemical materials [11,12]. In present work the impact of the laser wavelength and the solution type on the optical and morphological characteristics of Silver colloidal nanoparticles synthesized by laser ablation in liquid technique.

Experimental Details

Silver colloidal nanoparticles were prepared in this work by laser ablation method. Nd -YAG laser Q-switched system type HUAFEI have been used with the following parameters; 532 nm and 1064 nm wavelengths with pulse energy, pulse width, repetition rate and effective beam diameter of 650 mJ, 6 Hz, 10 ns and 5 mm respectively. To a obtain high laser effectiveness, a lens of 11 cm focal length was used. Metal plate of silver with high purity of (99.999) of Ag foil. The plate was polished and cleaned in ethanol and DW mixed solution and cutoff to small pieces of (0.7 × 0.7) cm to suite the experimental arrangements, then buffed by using emery paper, then rinsing in the solvents before the start of each experiment. The experimental framework for pulsed laser ablation of a metal target in aqueous solution illustrates in figure (1). The laser beam focused by lens above the target which immersed in the selected solution in a quartz vessel.

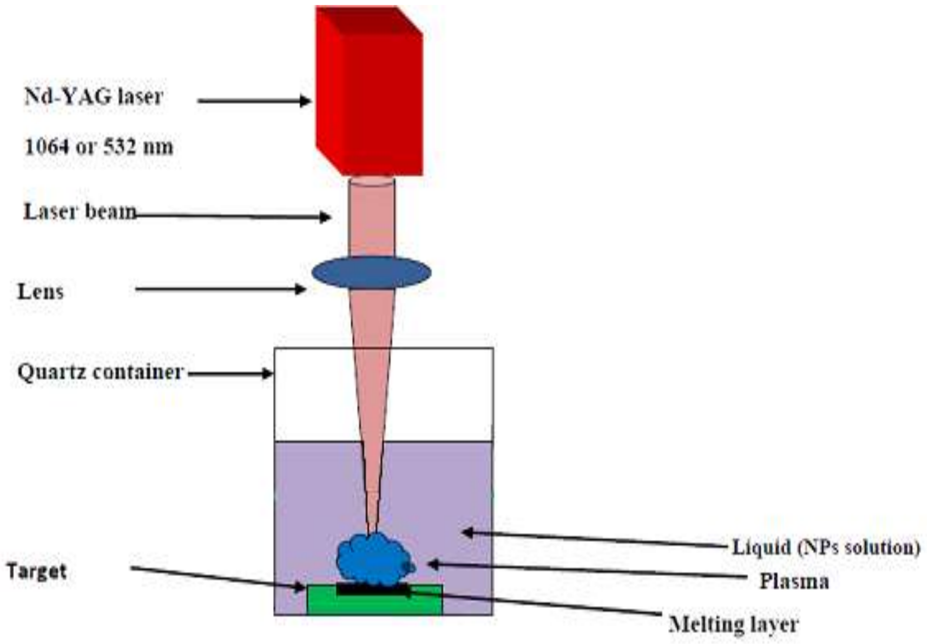


Figure 1. Experimental system for synthesis of colloidal nanoparticles by pulsed laser ablation in liquid (PLAL) technique

The preparation of colloidal Ag Nps in different solution types were achieved as follow: The silver plate was placed in 2ml of DI (deionized water), and ablated using100 Laser pulse, with Laser wave length 532 nm and 1064 nm and 650 mJ power. The same procedure was repeated using distilled water (DW) solution and 0.1 M of Polyvinylpyrrolidone (PVP) solution. Absorbance (SPR band) spectrum of colloidal Ag NPs were measured by using double beam Mega 2100 Sinco UV-Vis spectrophotometer. The surface morphology of the prepared samples was investigated by using an optical microscope (OM) type Olympic and scanning electron microscope

(SEM INSPECT- 550) at magnifications scale about (5 and10) µm.

Results and Discussion

The influence of laser wavelengths 1064 nm, 532 nm and the solution type on the optical density (absorbance and SPR band) and the surface of Ag colloidal nanoparticles prepared by laser ablation in liquid were investigated. The Ag colloidal nanoparticles were synthesized at laser energy, pulse width, repetition rate and laser pulses number of 650 mJ, 10 ns, 6 Hz and 100 pulses at room temperature. Figures 2,3 and 4 shows the optical density (SPR band, absorbance) of Ag colloidal NPs synthesized in DIW, DW and PVP solutions respectively with laser wavelengths (1064 and 532) nm. The figures reveal that the optical density (absorbance, SPR band) of Ag nanoparticles synthesized at laser wavelength 1064 nm was higher than that was synthesized at laser wavelength 532 nm for all types of liquids. The increase of the Laser wavelength leads to an increase in optical density, so in the wavelength1064 nm, the absorbance increased in each type of solution. Also, it can note that the optical density of Ag colloidal nanoparticles synthesized in the PVP solution was approximately (0.82) higher than of it in DIW (0.55) and in DW (0.44). This difference values of SPR band (absorbance) is an evidence of an increase in density of nanoparticles inside each liquid, that's mean that the SPR band influenced by the type of solution and the laser wavelength. This can be attributed to the effect of the laser beam which acts to uproot the number of nanoparticles in each pulse, so the density of the nanoparticles increased and vice versa. On the other hand, it can be noted that the optical density peaks of Silver NPs in DIW was at 404 nm for 1064 Laser wavelength related to Ag nanoparticles SPR band and shifted towards higher wavelength at 413 nm for laser wavelength 532 nm. The same behavior was observed for the DW and PVP solutions were the absorption beaks were shifted from 400 nm to 412 nm and to 407 nm for DW and PVP solutions respectively SPR phenomenon to taken place, the particle size should be smaller than the incident photon wavelength and the optical density of the absorbance peak depend on the quantity of the nanoparticles [13]. The shift in the SPR band (absorption) wavelength peak depends on the size of the nanoparticle where if the size of the nanoparticles increment, their SPR band wavelength will be red-shifted to higher values and vice-versa [14] as clearly shown in the figs. 2,3 and 4.

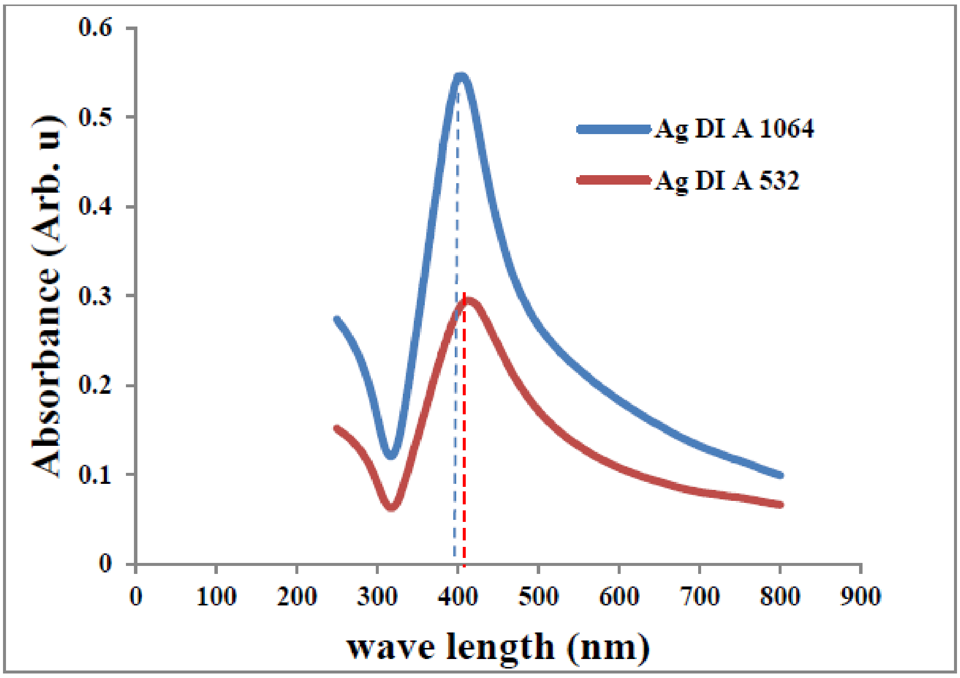


Figure 2. The SPR band wavelength and the variation of absorbance vs. the icedent wavelength of Ag nanoparticles prepared in DIW at laser wavelengths (1064 and 532) nm

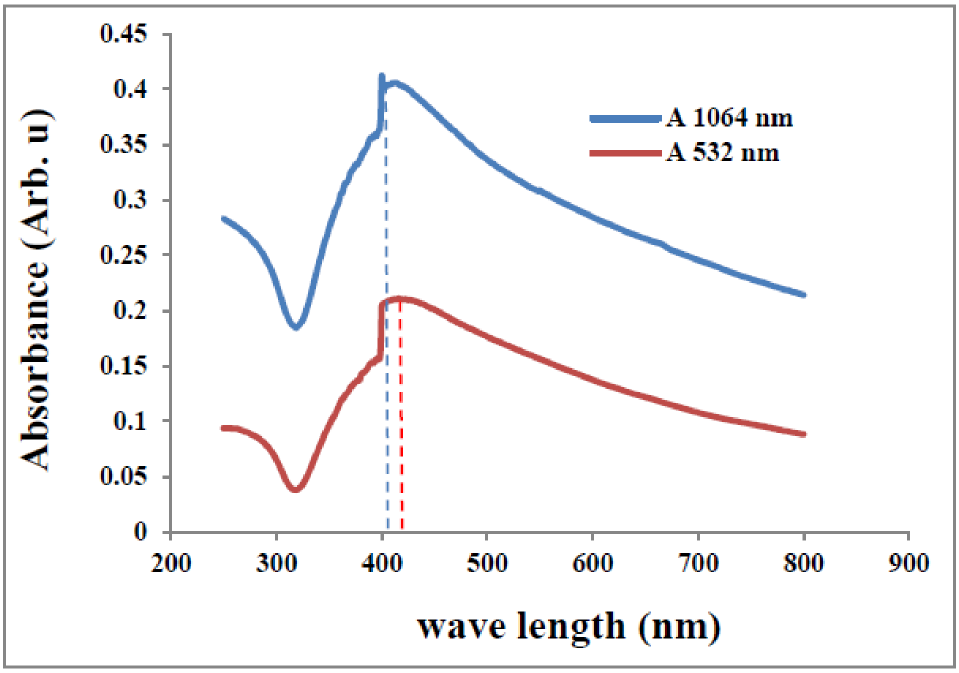


Figure 3. The SPR band wavelength and the variation of absorbance vs. the icedent wavelength of Ag nanoparticles prepared in DW at laser wavelengths (1064 and 532) nm.

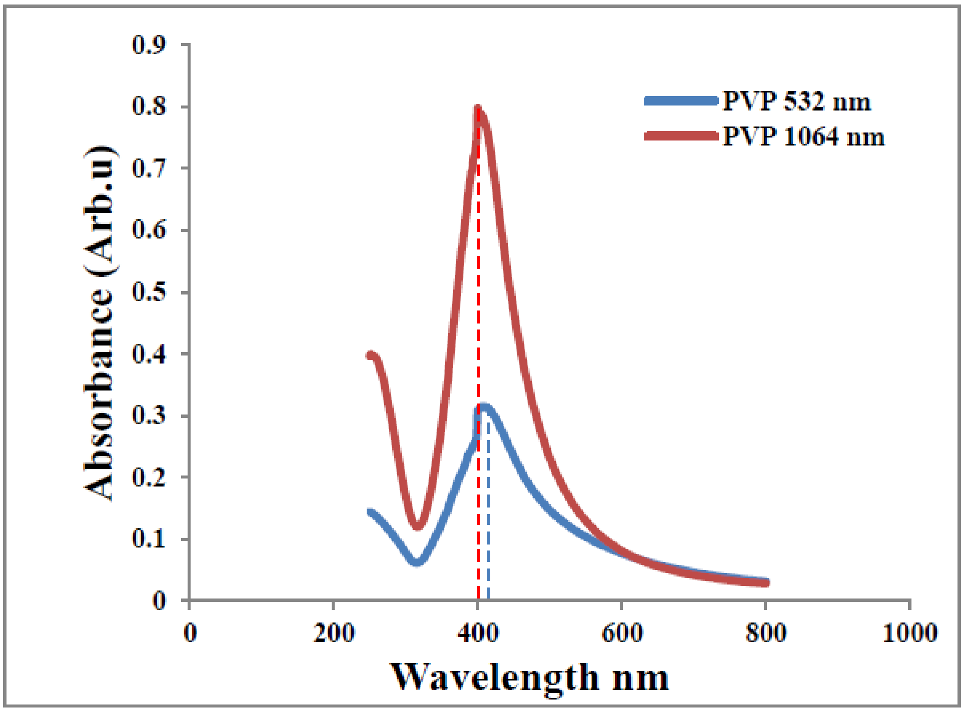


Figure 4. The SPR band wavelength and the variation of absorbance vs. the icedent wavelength of Ag nanoparticles prepared in PVP at laser wavelengths (1064 and 532) nm.

The effect of a liquid type of DIW, DW and PVP on the SPR band of pulsed laser ablation of Ag NPs at laser wavelengths 1064 nm and 532 nm were studied as shown in figures 5 and 6 for respectively. From the figures, the SPR band and the optical density was strongly depended on the type of the liquid medium, where the optical density was higher for PVP solution than of DIW and DW solutions. The peak positions were kept around 400 nm and slightly increased for DIW to longer wavelengths, which can be attributed to the increment of the particle size. The ablation process was done using a PVP solution showed a higher optical density in comparison with that of DIW and

DW solutions. The ablation using the DW solution has the lowest optical density, which indicated lower ablation performance in this solution. This behavior attributed to the ionic nature of the distilled water, where the ions may work as a barrier in the laser path, which may decrease the laser energy that contacts the target [15, 16].

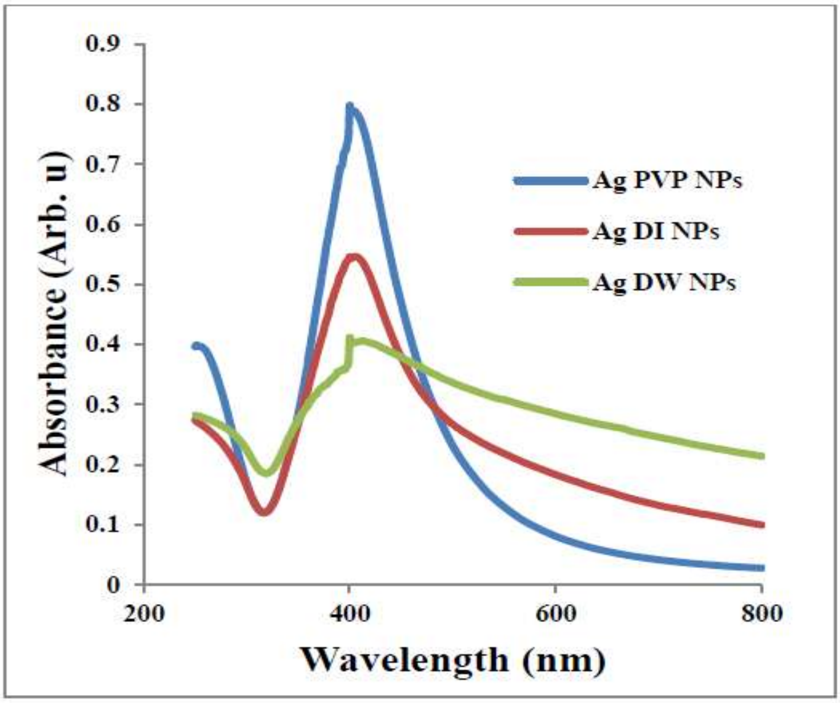


Figure 5. SPR band (optical density) of colliodal Ag nanoparticles ablated in PVP, DIW and DW solutions using Laser wavelength 1064 nm

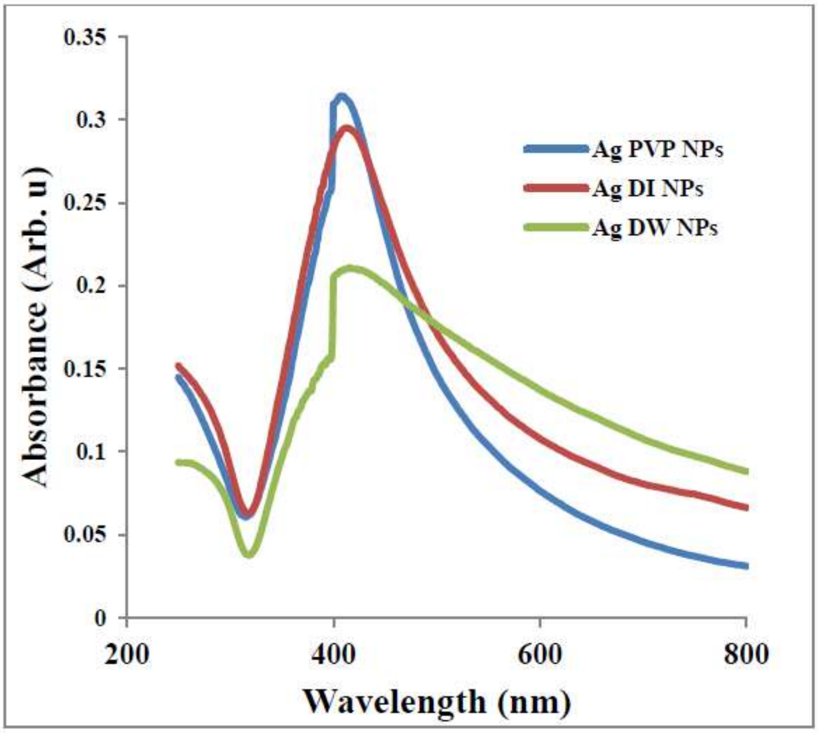
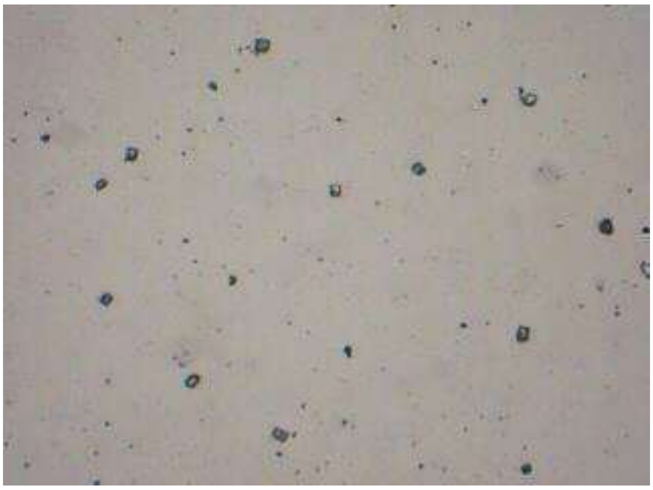


Figure 6. SPR band (optical density) of colliodal Ag nanoparticles ablated in PVP, DIW and DW solutions using Laser wavelength 532 nm

The optical and scanning electron microscope images of Ag nanoparticles ablated using PVP, DIW and DW solutions at 1064 nm and 532 nm Laser wavelengths are shown in figures 7, 8 and 9. where a and b of the figures shows the optical microscope images for 532 and 1064 nm laser wavelength, while c of the figures represent the SEM images for the Ag NPs with laser wavelength 1064 nm. It can be seen from the figures that the synthesized Ag nanoparticles are spherical in shape and the particle size in about 8 -100 nm, which uniformly distributed with low aggregation around the surface. The SEM image of Ag NPs in PVP solution show the better uniformly distribution with lower particle size and lower aggregation regions than that of prepared in DIW and DW where the polymer molecule capping Ag nanoparticles and then be less aggregation regions. The particle size was decreases with the increase of the solution density, where the PVP solution has the highest density and highest viscosity. This may be demonstrated by the interaction between the PVP molecules and Ag nanoparticles produced from the laser ablation. These results were in good agreement with the literatures [15, 16 and 17].



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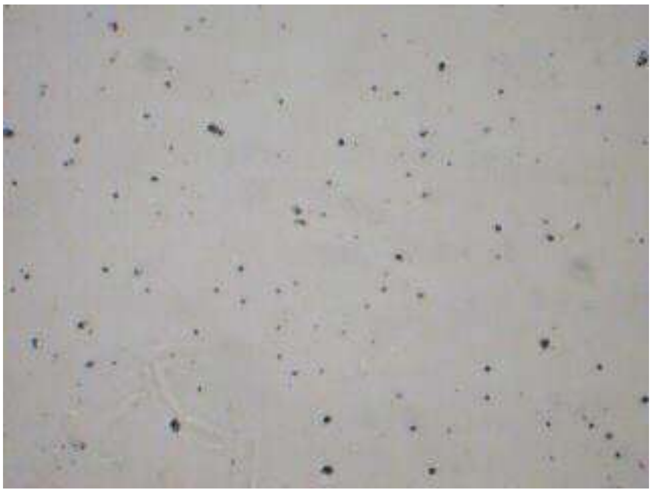

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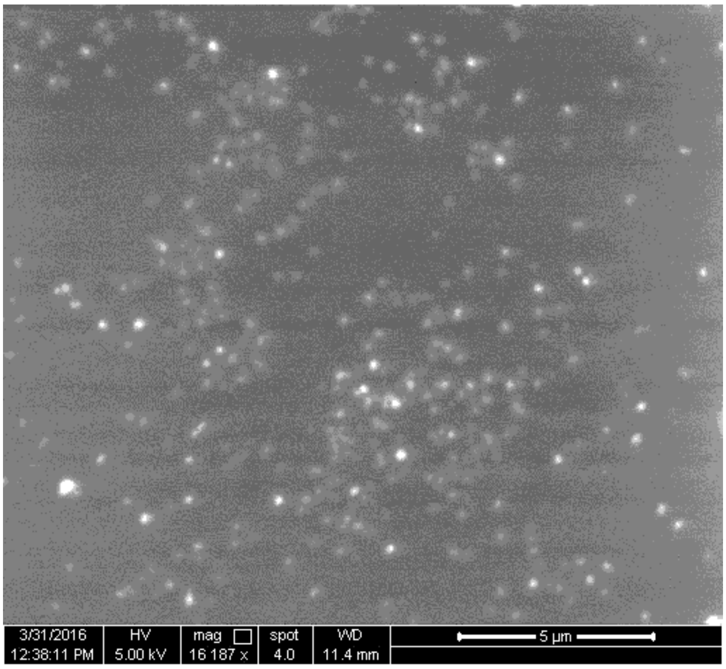

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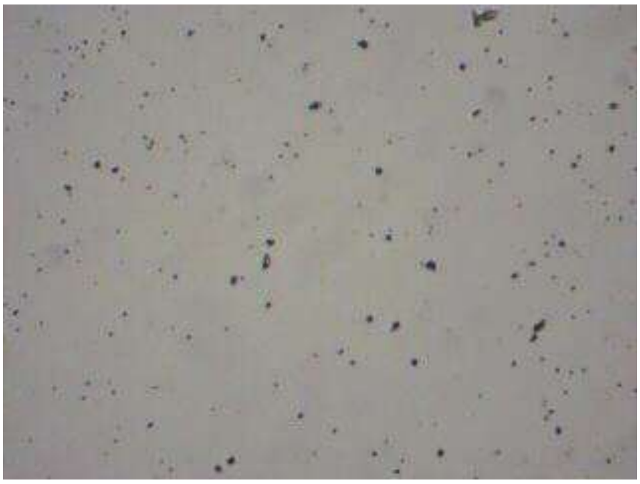
Figure 7. Optical microscope images of Ag NPs in DIW with laser wavelength a: (532 nm), b: (1064 nm) and c: SEM image in DIW and (1064 nm) wavelength.

a



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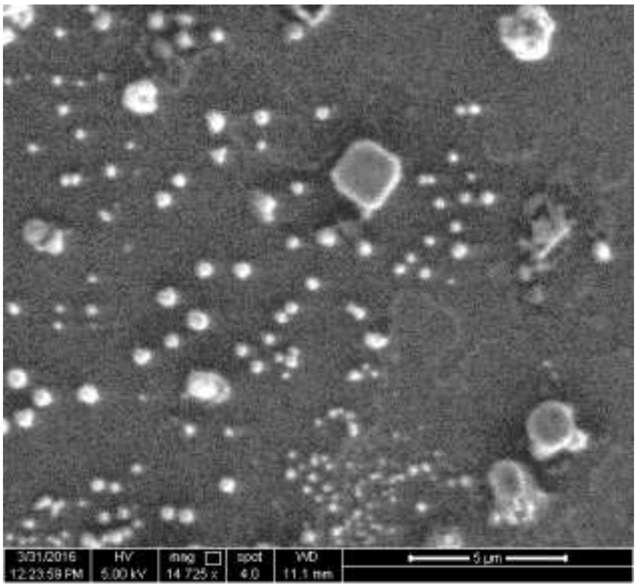

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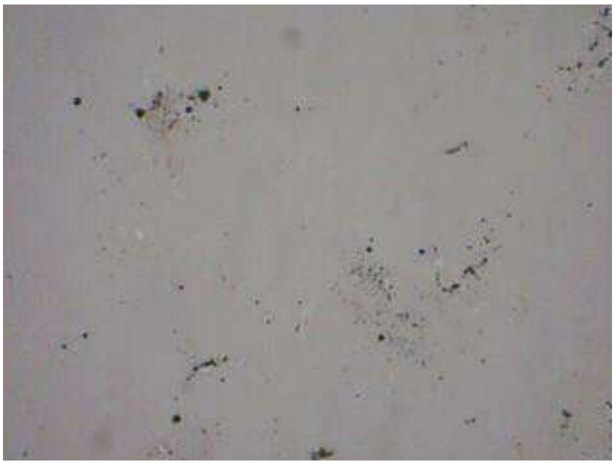
Figure 8. Optical microscope images of Ag NPs in DW with laser wavelength a: (532 nm), b: (1064 nm) and c: SEM image of Ag NPs in DW and (1064 nm) wavelength



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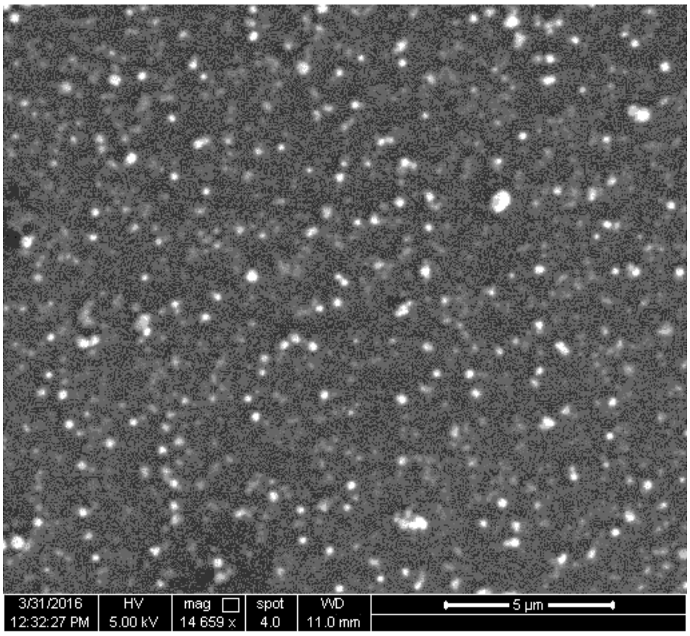

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Figure 9. Optical microscope images of Ag NPs in PVP with laser wavelength a: (532 nm), b: (1064 nm) and c: SEM image in PVP and (1064 nm) wavelength.

Conclusions

- This study provides an easy, simple, fast and one-step way for the synthesis of pure colloidal silver nanoparticles with less aggregation.
- The PVP is good solution for synthesis of silver nanoparticles (Ag NPs).
- The absorption spectrum in a solution of silver nanoparticles quasi-symmetrically around the (400-420) nm wavelength, the Ag NPs shape are quasi-spherical, are pale yellow color, the particle size about 8-100 nm.

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