

An Effective Way to Prevent the Aggregation of Nanoparticles Prepared by the Laser Ablation in Colloidal Solutions

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Abstract

One of the green processing for preparation metal nanoparticles is the laser removal system that offers a novel technique for nanoparticle nanofabrication. It is a simple method to produce metal nanoparticles without the use of chemicals. A silver plate and gold-silver alloy (99.99 purely) were prepared via pulsed laser (Nd: YAG, 1064 nm) ablation. Both solutions were made from deionized water of high purity. Different concentrations of PVA solutions were prepared (1- 2.5 %) Polymer (MW =18000) was used to prevent the aggregation of nanoparticles. The UV - Vis spectrophotometer and transmission electron microscopy (TEM) were used to determine the optical spectral characterization and morphological properties (refractive index, coefficient of extinction, a real dielectric constant, imaginary dielectric constant). We showed the prepared Ag-NPs and Ag-Au alloys such natural stabilizers change the surface of Au-NPs and their alloys in their chemical structure by way of a functional group. The peak intensity of Plasmon surface is directly related to particle density within solutions.

Keywords: New way, Quantum dot, colloidal solutions, laser ablation, Aqueous Solution, Polymer – Nanocollide composite.

Introduction

Laser ablation is the process of material removal from a surface by the action of laser-intense laser radiation. Laser ablation has attracted attention in many areas of technology and science and has been applied in several fields such as nanoparticles generation [1], pulsed laser deposition [2], laser surface cleaning, and microelectronic device fabrication [3]. The process of the localization of waves has been observed in many physical phenomena, such as for exactions in semiconductor nanostructures. During the last decade, manufacturing of nanoparticles by laser ablation of solids either in gas or in a vacuum was extensively explored. The pulsed laser ablation (PLA) technique has become a promising tool for the photonics, electronics, and medicine synthesis of Nano clusters. This gives nanoparticles the ability of chemically clean synthesis. Additionally, the cluster size distribution could also be controlled by carefully selecting the laser irradiation parameters and the media properties. In addition, PLA allows fast creation of nanoparticles from colloidal metals [4]. Over the years, a shift from existing chemical methods to liquid-phase laser ablation (LALP) to synthesizing nanoparticles (NPs) was observed mainly due to its environmentally friendly, contamination-free and non-hazardous nature. Gold nanoparticles (Au-NPs) have attracted particular interest among the various widely available NPs among scholars because of their broad

range of applications such as sensors [5], electronics [6], medical diagnoses [7], and therapeutic agent delivery [8]. In this regard it should be noted that the response of the NPs to the light interaction depends on the particle size [9]. A analysis of relevant literature clearly demonstrates differences in methods used to prepare Au-NPs, such as chemical methods [10, 11], sonochemical [12], microwave technique [13].

In Scientific and Industrial Fields, polymer composites incorporating bioaccumulation and polymer with plasmonic, conductivity, and catalysis properties attracted significant interest. Different devices have been used to distribute nanoparticles into polymer solutions, but the improvement of material quality is still limited due to the unnecessary dispersion of nanoparticles in a polymer com. Compared to traditional methods of synthesis for the preparation of composite polymers, pulsed liquid laser ablation (PLAL) is a special one-step technology due to its flexibility, high-rapidity and 'natural' reproducer [14]. The disadvantages of modern "nano-embedding" technics are the small digits of nanoparticulate materials ready-made, their cost and their purity. Because of its simplicity, high speed, and "green" products, pulsed laser ablation in liquid (PLAL) is a unique one-step technique compared to conventional synthesis methods for preparing polymer nanocomposites [15]. The process of integrating an inorganic nanoparticle in the matrix polymer would lead to the creation of a main shell compound inorganic-polymer. Dissolving the corresponding polymer in a monomer solution (i.e., PMMA in MMA) can stabilize nanoparticles in situ and prevent particle agglomeration by polymer paint [16]. These hybrid matrix-coupling agents may also prohibit variations in particles prevalence through the prototyping operation series like particle production in monomers, the eventual polymerisation, and the ultimate melting process for the creation of 3D polymer samples. Laser parameters to be used are also important for subsequent polymer composite efficiency, allocation of volume and mass load to NP. A direct representation is the big variation between PLAL-induced Ag-TPU composites prepared by 1,030 nm of fundamental laser wavelength and those produced through second harmonic wavelength (515 nm). Process time would result in a linear rise of ablation rate and a linear decrease of the hydrodynamic particles size under the former condition. Nonetheless, a progressive depletion of accumulated ablated mass occurs by using second harmonic wavelength due to the loss of excitation light. In addition, due to the high particles concentricity of colloids formed by fundamental laser wavelength, the peak intensity of the absorption spectrum is so higher.

Theory

Pulsed ultraviolet laser ablation of polymer surfaces [17–19], has been researched for over 20 years [20, 21], and continues to attract further attention, as it has become among the main methods for modern tech and manufacture. A thorough learning of the complicated mechanisms involving in the method of the laser-based material removal is the goal of the scientific community's activities due to its growing significance through both scientific and application areas. UV range wavelength (150 nm–350 nm) lead for a high absorption (coefficient of absorption $\gamma \sim 10^3 - 10^5 \text{ cm}^{-1}$, Table 1) for many polymers and so the fallen energy is stored only in the absorption duration only below the surface in the absorbing rate laboratories = $1/\gamma$ under $\sim 1 \mu\text{m}$. This ensures sufficiently low threshold fluences F_t (least energy density) above the ablation for nanosecond pulses is calculated in a proximately range $\sim 10 - 100 \text{ mJ/cm}^2$. Once the laser pulse is absorbed, if the absorbed fluence exceeds the threshold fluence $F > F_t$, the suddenly excited substance broaden quickly into the ablation liquid, a hot mixed of product gas, particles, fluid micro-droplets that are ejected to the material surface at high speed in an essentially normal direction. This method of direct material removal is successful in, for example, as described below, multipulse laser micro drilling. Additionally, as we have experimentally illustrated by periodic microbumps, during the

ablation pulse a lateral flux of fluid medium could be acquired due to the high pressure of the ablation surface. The cleanliness of the affects remaining on the surface is highly dependent on the state of the transitory heated 'liquid' and pressure level to recoil. Some polymers such as poly (ethylene terephthalate) (PET) that produce a thin transient low-viscosity liquid layer show a controlled lateral fluid expulsion by ablation (~1 J / cm²) to create a cumulating of polymer (micro bumps) outside of laser spot, at which pressure is less.

Experimental

PVA Poly(vinyl alcohol) Polymer (mw =18000) were obtained from Sigma-Aldrich. All samples were prepared from deionized water high pure. PVA In suitable containers solutions were prepared as stock solutions. PVA solutions were prepared with different concentrations (1% , 2.5%) . A silver plate and gold – silver alloy (99.99%) with dimensions (2 * 2 cm) and thickness (4 mm) was purchased from Shanghai Honest Chem. Co. Ltd. Laser ablation Was performed with a pulsed Nd : YAG laser Q-switch (wavelength 1064 nm, maximum energy 1000 mJ/pulse, frequency of 6 Hz). The laser beam was directed by a projector with a focal distance of 10 cm on a projector of gold or gold –silver alloy, which was mounted at the bottom of a 3mL glass vessel filled with aqueous PVA solutions (Figure 1). The liquid depth above the plate was roughly 13 mm. UV - Vis measurements were performed using an Aquarius (Cecil Company) spectrophotometer and room temperature range 200-1100 nm. The electron images of the nanoparticles in the solution were taken with a high-resolution transmission electron microscope (TEM Philips). A drop of a sample solution was mounted on a (carbon-coated) copper grid and left dry at room temperature.

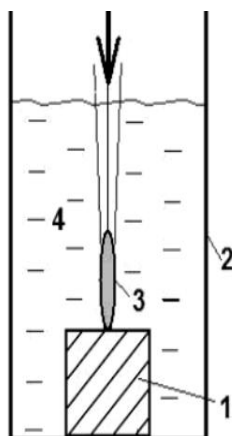


Fig .1, Practical setup: 1-silver target, 2- glass vessel, 3- plasma plume, 4 –aqueous solution.

The optical properties (refractive index , extinction coefficient ,real dielectric constant , imaginary dielectric constant)were calculated by using optical properties software.

Results and discussion

Through our practical experience in the preparation of colloidal nanoparticles, whether for metals or oxides, after a period of time, It suffers conglomerates. Therefore, we proposed using a new method to avoid or greatly reduce these conglomerates. So we suggested adding very few ratios of PVA polymer. As polymer is a material with large molecules possessing a property that surrounds impurities or metal atoms. This characteristic is generally characterized by polymer materials, especially dissolved in water. Therefore, we expect this research to play its role in preventing the clustering of nanoparticles. We divided the preparation procedure into two main groups, the first for

silver and the second for the silver-gold alloy. Two concentrations of PVA polymeric solutions were used (1 % and 2.5 %).

The prepared Ag-NPs and Ag-Au alloy had been stable for several months. These natural stabilizers modify the surface of Au-Nps and its alloys in their chemical structure by functional group. Figure (2) depicts UV-visible absorption spectra of the equipped samples in different concentrations after removal of the Ag plate and figure (3) represents UV-visible absorption spectra for Ag-Au alloy.

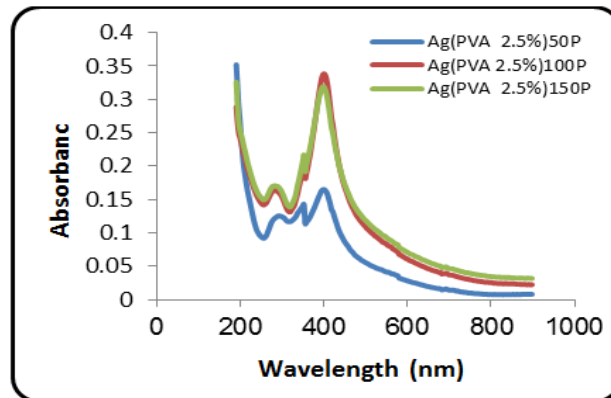


Fig. 2, depicts the UV-visible spectrum of absorption of Ag (PVA 2.5%) with specific pulses(50,100,150)

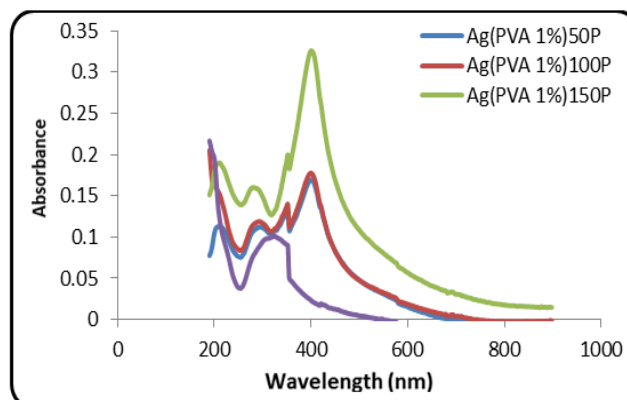


Fig. 3, represents UV-visible absorption spectra of Ag (PVA 1%) with different pulses (50,100,150)

Appearances of peaks around (391 nm) and (394 nm) for higher pulses for all samples are related to the presence of Ag-NPs in solutions. It is clear from the figure, the maximum wavelength (λ_{max}) shifted to higher wavelength (from 391–394 nm) by increasing pulses number

Of all samples, the occurrences of peaks around (391 nm) and (394 nm) of higher pulses are related to the presence of Ag-NPs in solutions. It is obvious from the figure that the overall wavelength (λ_{max}) shifted by rising the number of pulses to higher wavelength (from 391–394 nm). According to the Mie theory, this red change is related to the increase of the clustering cross-section and the growth of a large particle.

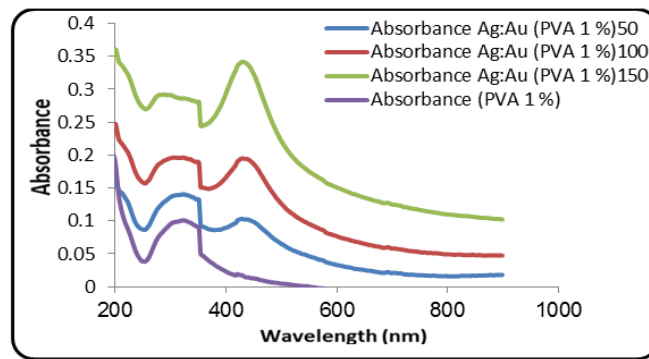


Fig. 4, represents UV-visible absorption spectra of Ag :Au (PVA 1%) with different pulses (50,100,150)

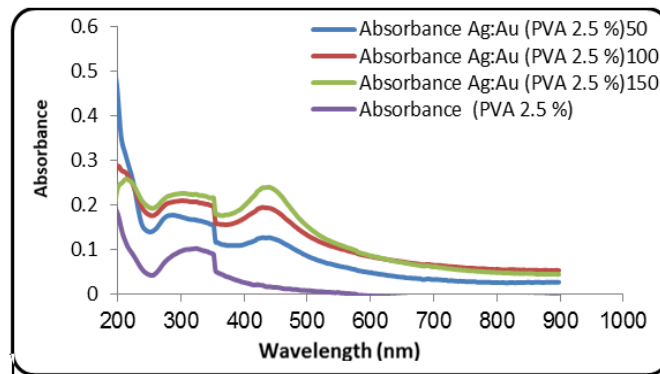


Fig.5, Represents Ag: Au (PVA 2.5%) UV-visible absorption spectrum with different pulses (50,100,150)

The same observation in the alloy(Ag: Au) solution (figure 4&5), The surface Plasmon peak strength is raised at around 421 nm, by increasing the number of pulses to 427 nm. At the other hand, in comparison with pure PVA solutions, the intensity is greatest. It can be seen that the use of higher pulses results in highest absorbance. The peak intensity of Plasmon surface is related directly to particle density inside solutions.

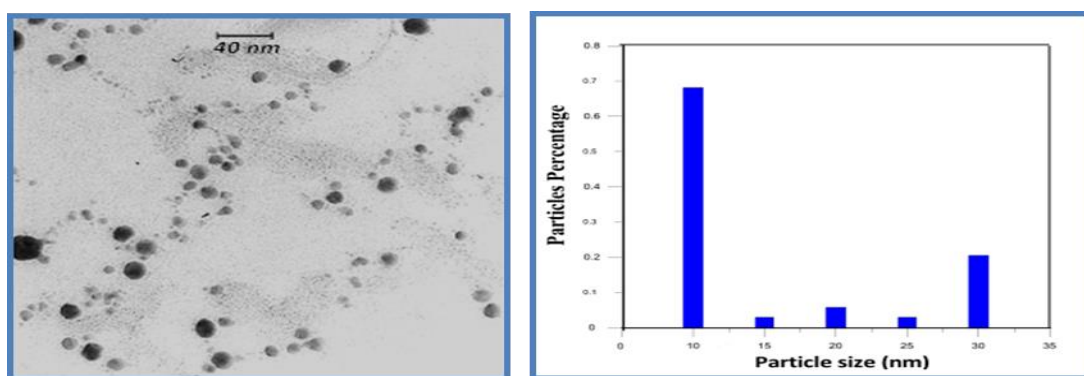


Fig. 6, TEM image and statistical distribution for the Au-Ag NP₅ solution in (PVA 1%)

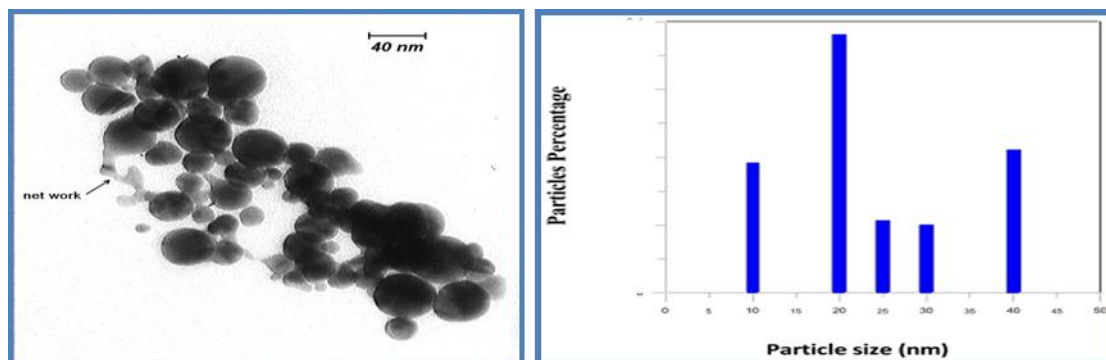


Fig. 7, TEM image and statistical distribution for the Au-Ag NPs solution in (PVA 2.5%)

TEM images Fig.(6 & 7) showed that PVA could be rather efficient reducers for these. However Au-Ag NPs nanoparticles covered with polymer do not have any chemical groups available on the surface, which emphatically convolutes an ensuing biomolecule immobilization step. A few materials, for example, PVA are likewise known to denature biomolecules or, at any rate, disable their natural movement with different concentrations (1-2.5 %). This implies the polymer plays a significant job in the precipitation of enormous particles.

Conclusions:

In this study, a new method was used as a different from previous methods. It was added very few ratios of PVA polymer. As polymer is a material with large molecules possessing a property that surrounds impurities or metal atoms. Where it was divided the preparation procedure into two main groups, the first for silver and the second for the silver-gold alloy. Two concentrations of PVA polymeric solutions were used (1 % and 2.5 %). The Ag-NPs and Ag-Au alloy were prepared stable for many months. These natural stabilizers modify the surface of Au-NPs and its alloys in their chemical structure by means of a functional group. Through the graphics and results that we got for both groups, Appearances of peaks around (391 nm) and (394 nm) for higher pulses are correlated with the presence of Ag-NPs in solutions for all samples. the max wavelength (λ_{max}) changed to higher wavelength (from 391–394 nm) by increasing the number of pulses. According to the Mie theory, this red change is related to the increase of the clustering cross-section and the formation of a large particle. The same observation in the alloy (Ag:Au) solution. The surface Plasmon peak strength is raised at around 421 nm, by increasing the number of pulses to 427 nm. At the other hand, the intensity is high compared to the pure PVA solutions. It can be seen that the use of higher pulses results in maximum absorbance. The peak intensity of Plasmon surface is directly related to particle density inside solutions.

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