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Research Article

Investigation of the Effect of Chemical and Physical Parameters on Preparation, Production Efficiency and Aspect Ratio of Gold Nanorods in Seed-Mediated Growth Method

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Abstract

In the present paper, gold nanorods were synthesized with a modified seed-mediated growth method. This method, in terms of adjusting and controlling the aspect ratio to reach optimum optical properties and special applications reasonable, is a flexible method. Thus, in this research work, a comprehensive study has been carried out on the effect of chemical and physical parameters of the preparation method, procedures for preparation and environmental conditions on the preparation and properties of the synthesized gold nanorods. Characterization on the structural properties of synthesized gold nanorods using the UV-vis, FTIR and XRD spectrometries were performed. Investigate and measure of the UV-Visible absorption spectra, provides an explanation present for the formation and a mechanism for controlling the growth of gold nanorods. Results showed that the gold nanorods were formed only at a sufficient concentration of CTAB stabilizer, besides silver nitrate as a controller of the aspect ratio of gold nanorods was used, but the presence of high concentrations of them reduces the nanorods production efficiency. Moreover, changes in the gold salt concentration indicate that gold nanorods with high aspect ratios were formed in growth solution. Usage of the high volumes of the seed solution causes more growth in the nanorods and the effect of increasing the ageing time of seed solution was associated with increasing the production efficiency at the same conditions. Finally, the study of the environmental parameters showed that optimum temperature and pH for the synthesis of the gold nanorods are 25-30°C and 2-3, respectively.

Keywords: Gold nanorods; Seed-mediated growth method; Surface plasmon fluctuations; Aspect ratio; Production efficiency; Hexadecyltrimethylammonium bromide.

Introduction

Nowadays, production of nanoparticles with controlled shape, many scientists attention at nanotechnology field attracted. The gold nanorods with single shape have optimum optical properties those results in the local surface plasmon resonance at the longitudinal dimensions of gold nanorods. Fluctuations high sensitivity this nanoparticle than that slight changes at surrounding environmental, it has turned into a good choice in a variety of medical and biological fields such as sensors [1], medical imaging [2-4], diagnosis and treatment of disease [5, 6] and drug delivery and gene transfer [7, 8]. Preparation of gold nanorods with high efficiency and uniform shape control for use those in the various research fields, study topic of many scientists in the last years.

The traditional method used for the preparation of gold nanorods is the seed-mediated growth method that by El-Sayed et al. [13] and Morfi et al. [14] were presented, due to simplicity, high-efficiency production, uniform shape control, and simple surface modification those have been developed. Morfi et al. prepared gold nanorods by the seed-mediated growth method at the absence of silver ions. At the absence of silver ions, gold nanorods solution prepared including combined of gold rods and spheres. Finally, pure nanorods were achieved by using centrifuge. This seed-mediated growth three steps method provides nanorods with aspect ratios of 10 to 25 [14]. In the seed-

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mediated growth method that developed by El-Sayed et al., the aspect ratio of gold nanorods was controlled with the value change of silver nitrate and nanorods produced had an aspect ratio less than 10 and high efficiency of 90% [13].

In the last years, many studies of researchers on the preparation of gold nanorods with seed-mediated growth method in the presence the silver nitrate with high production efficiencies and shape uniform have been focused and nanorods production efficiency by using this method reaches more than of 99%. Many researchers in their studies investigated and studied the seed-mediated growth method and they achieved valuable results [15-35]. Jana et al. reported the growth of gold nanorods with the length of 12 nanometers by citrate stabilizer from the seed-mediated growth method with operations changes at factors and condition or reducing the gold salt [17]. They showed that with control of parameters such as reduction factors scale to growth solutions can be avoided of additional nucleation [18]. In fact, gold nanorods prepared by this method had a smaller aspect ratio (3.6-2) than the gold nanorods prepared by seed-mediated growth traditional methods with the help of silver. Reducing light dissipation and the same proportion of increasing the absorption value of these smaller nanorods, they have turned into the very efficiency factors to optothermal treatment [20, 21].

Optical properties of gold nanorods and their local surface plasmon resonance strongly depended on the aspect ratio of nanorods. From longitudinal localized surface plasmon resonance absorption peak of gold nanorods, the comprehensive information from produced gold nanorods can be achieved. Draine and Flatau by using the discrete dipole approximation, accurate relation between the wavelength of longitudinal localized surface plasmon resonance peak and aspect ratio of gold nanorods were established (eq. 1) [22]. Where at this relation by setting the wavelength of longitudinal localized surface plasmon resonance peak, the aspect ratio of nanorods was calculated.

$$AR = (\text{Peak Position (nm)}/99.3) \quad (1)$$

In the present research work, we prepared rod-shaped gold nanoparticles by modified seed-mediated growth method in the presence of the silver nitrate with purity, uniformity, quality and high production efficiency. As mentioned, the seed-mediated growth method in the presence of the silver, in terms of setting and controlling of the aspect ratio for reach optimum optical properties and special applications reasonable, is a flexible method. Therefore, in the second stage at this research work, we examined a comprehensive study of the effect of chemical and physical parameters of the preparation method steps and environmental conditions on the preparation and properties of the gold nanorods produced. Studied parameters including are temperature, pH, concentrations of reactive material (gold salt, silver nitrate, CTAB), the volume used and ageing time of seed solution. Effects of each these parameters investigated and examined on the preparation, aspect ratio and optical properties of gold nanorods.

Materials and methods

For performing this research, tetrachloroauric acid ($HAuCl_4$, $3H_2O$, 99.95%), ascorbic acid (99%), cetyltrimethylammonium bromide (CTAB, 99%), sodium borohydride ($NaBH_4$, 99%) and silver nitrate was purchased from Merck company. For the preparation of all aqueous solutions as well as a wash of test dishes ware used the deionized water. To investigate the particle crystallography structure produced was used the XRD device, X' pert Pro MPD model. By using the spectrometer, MagnaIR 550 model in order to study the surface properties was executed the FT-IR analyze. Also, to determine other properties of gold nanostructure produced such as aspect ratio, nanoparticles purity, shape and morphology of nanostructure was used the UV-Visible spectroscopy, UV-1800 model and transmission electron microscope, FEI model.

Preparation of gold nanorods

Gold nanorods were prepared by the modified seed-mediated growth method in the presence of the silver nitrate [10,17]. Seed-mediated growth method involves two steps; the first step is a preparation of gold nanoparticle seeds where was known as the seed solution and the second step is growth its seeds and preparation of gold nanorods. At this method, the aspect ratio of gold nanorods simply by changing the preparation parameters such as seed solution value, silver nitrate solution value and so on can be adjusted.

Seed solution

At first, 5 ml of cetyltrimethylammonium bromide (0.2 M) were combined with 0.5 ml of gold salt solution (0.005 M), then to stirring solution, was added 0.6 ml sodium borohydride solution (0.01 M) that leading formation one brownish yellow solution. The resulting solution was retained for two hours in the room temperature (25-degree centigrade).

Growth solution

Growth solution was prepared from 5 ml of cetyltrimethylammonium bromide (0.2 M), 0.2 ml of silver nitrate solution (0.004 M) and 1 ml of gold salt solution (0.005 M). After slow stirring, ascorbic acid was added to the reaction dish. Ascorbic acid as one poor reduction factors has changed the colour of growth solution from dark yellow to colourless. At the final stage, the seed solution prepared in the previous stage was added to the growth solution. The stirring solution colour gradually changed and the pH of reaction environmental was measured with pH paper.

Study the effect of chemical and physical parameters on the preparation and properties of gold nanorods

As been mentioned in the previous sections, seed-mediated growth preparation method in the presence of the silver nitrate showed the excellent regulation ability of aspect ratio that was efficient for the optimization of optical properties. In this research work to investigate the effect of chemical and physical parameters changes of the seed-mediated growth preparation method in the presence of the silver nitrate on the preparation and properties of gold nanorods was examined. For this purpose, at the first, silver nitrate solutions (with concentrations of 0.003, 0.004, 0.005 and 0.007 M), cetyltrimethylammonium bromide (with concentrations of 0.04, 0.08, 0.1 and 0.2 M) and gold salt (with concentrations of 0.0001, 0.005 and 0.01 M) were prepared. Then each solution prepared of reactant material was used separately in the preparation work method of gold nanorods. Then for study, the effect each of concentrations changes from nanostructure solutions prepared, sampling was executed. In addition, the effect of concentrations change of the participant material in a reaction in order to study of temperature effect, formation setups of gold nanorods in the aqueous batch with temperatures of 25, 35, 60 and 90-degree centigrade were executed. Also by changing the value of ascorbic acid consumed in the growth setup for this method, gold nanostructures in a reaction environmental were formed with a pH=2, 4, 8,10. Reaction environmental pH has been measured by using the pH paper. In this case, the effect of reaction environmental pH also was studied. Also in order to study the effect of seed solution on the preparation of gold nanorods, two parameters were examined: volume of seed solution added and ageing time of seed solution. Volume parameter by adding 5, 12 and 30 microliter of seed solution were studied separately to growth solutions prepared according to the preparation method of section (2-2). In effect test of time ageing, to seed solution prepared in the first phase of the seed-mediated growth method was divided into the three equal values. Then, the first seed solution immediately after the preparation, others after two hours retaining in the temperature room and finally third seed solution after five hours retaining in the temperature room was added to seed solutions prepared according to preparation method. In order to study the effect of chemical and physical parameters of the test, samples taken of UV-Visible spectra from solutions was recorded immediately after the preparation.

Results and discussion

Gold nanorods by seed-mediated growth method in the presence of silver ions and based on stabilizer of cetyltrimethylammonium bromide (CTAB) were prepared. In this method, at the first, seed solution by reducing tetrachloroauric acid ($HAuCl4$) with a reduction factor of sodium borohydride in an aqueous solution of CTAB was prepared. At next setup, growth solution by adding ascorbic acid as a poor reduction factor to reduce gold (III) to gold (I), to an aqueous solution of CTAB and gold salt solution and silver nitrate was prepared. Presence of gold nanoparticles in the growth solution where was prepared as seed solution at first setup, it can be accelerated the reduction gold (I) to gold (0) at nanorods surface in the presence of ascorbic acid. This leads to adding of gold ions to gold nanoparticles surface and causes growth nanorods. The role of CTAB is the formation and stabilization of the nanostructure form.

Based on studied executed, the primitive and best method for confirming the formation of gold rods nanostructure is studying a surface plasmon fluctuations this nanostructure where has been recorded with UV-Visible absorption spectra. Figure 1 shows the UV-Visible absorption spectra of gold nanorods stabilized with CTAB. Based on the polarizability of descending light, electrons resonance of metal conduction layer can occur in the two directions along the length and width of nanorods [12]. For this reason, in the UV-Visible absorption spectra of gold nanorods prepared, two absorptions have been appeared in the visible area (520 nanometers) and near of infrared (780 nanometers). From absorption band resulting from a longitudinal localized surface plasmon resonance can be achieved to comprehensive information of gold nanorods prepared. According the linear relation between the peak location and aspect ratio of nanorod (eq. 1) and with regarding to wavelength of a longitudinal localized surface plasmon resonance of nanorods (figure 1), the aspect ratio of gold nanorods prepared by seed-mediated growth method in the presence of silver nitrate and stabilized with CTAB was obtained of 3/2. As seen in the graph of figure 1, gold nanorods as compared with nanoparticles of the gold sphere, have two localized surface plasmon resonances. In the lateral localized surface plasmon resonance at a wavelength of 520 nanometers and longitudinal localized surface plasmon resonance at a wavelength of 780 nanometers has been seen. The sharpness of absorption peak resulting from a longitudinal localized surface plasmon resonance shows the being unicast of gold nanorods sample and low intensity of absorption peak resulting from longitudinal localized surface plasmon resonance shows the small value of sphere nanoparticle existing in the sample.

Surface properties of gold nanorods by using the FITR spectrometry were determined. Absorption spectra FITR of gold nanorods has been shown in Figure 2. In gold nanorods that prepared by the seed-mediated growth method in presence of silver nitrate, has been used CTAB as a surface capping ligand. In fact, the surface of gold nanorods was covered with two layers of CTAB molecules where produced a strong positive charge and avoiding from the accumulation of synthesized nanorods and providing high form stability. As seen in figure 2, a wide peak in the area of 3445 cm^{-1} resulting from stretching fluctuations of hydroxyl groups. Also, absorption in 2852-2920 cm^{-1} of FITR spectra was related to the C-H group and absorption in 1479 cm^{-1} was related to methyl group [N(CH3)3] in CTAB [1, 25]. The results were indicated that the surface of synthesized gold nanorods, entirely covered and stabilized with CTAB.

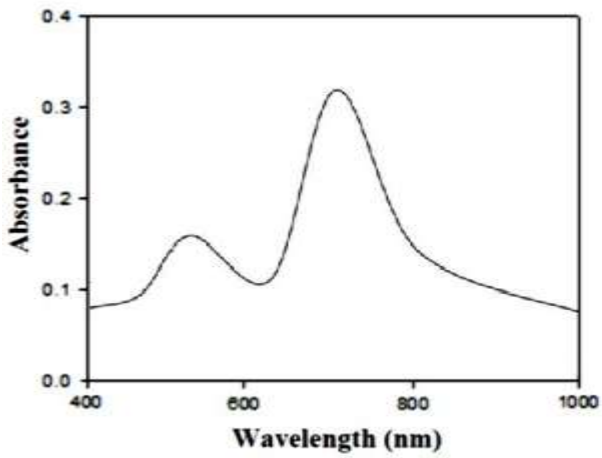

Figure 1. UV-Visible spectra of synthesized gold nanorods by seed-mediated growth method, in presence of silver nitrate and CTAB stabilizer

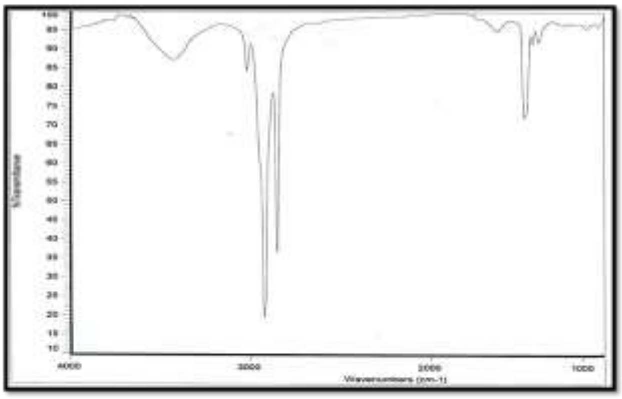

Figure 2. FTIR spectra of synthesized gold nanorods by seed-mediated growth method, in presence of silver nitrate and CTAB stabilizer

XRD spectroscopy was used for characterization of the synthesized gold nanorods structure where has been shown in figure 3. Based on the pattern of x-ray diffraction, gold nanorods have a face-centred cubic structure (fcc). The peaks for this spectrum at 3864.61 ,°44 ,°°, and 67.61°, are the reflections lines of plates (111), (200), (220) and (311) respectively where was correspondence with gold diffraction standard [1, 26, 27]. Also, long and explicit peaks resulting in plates reflections of gold nanorods in this spectrum show the purity of nanoparticles prepared and product crystalline nature.

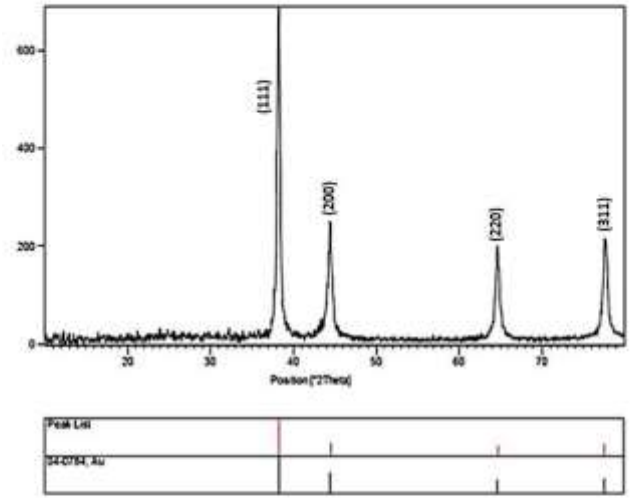

Figure 3. X-ray diffraction pattern of synthesized gold nanorods by seed-mediated growth method, in presence of silver nitrate and CTAB stabilizer.

To determine the morphology, size, purity, and quality of making rods nanostructure prepared from gold salt was used the transmission electron microscope. Figure 4 shows the image of the transmission electron microscope of gold nanorods prepared. Totally, 112 particles were analyzed. From figure 4, can be concluded that the nanoparticle had a uniform rods structure, also in these methods, production efficiency of gold nanorods is very high because the number of gold sphere nanoparticle was achieved to less. Based on the scale band of transmission electron microscope images, average width and length of nanostructures have been obtained 27.2 nanometers and 8.7 nanometers respectively. According to UV-Visible absorption spectra and wavelength of longitudinal localized surface plasmon resonance of gold nanorods prepared (figure 1) and transmission electron microscope pictures (figure 4), width to length ratio of gold nanorods prepared with the seed-mediated growth method in the presence of silver nitrate, have been estimated of 3 to 1.

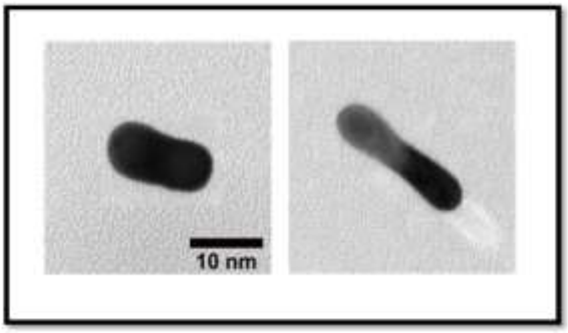

Figure 4. TEM images of synthesized gold nanorods by seed-mediated growth method, in presence of silver nitrate and CTAB stabilizer

The optical properties of gold nanorods strongly depend on their aspect ratio (width to length ratio). The seed-mediated growth preparation method in the presence of silver nitrate, in addition to high production efficiency and uniformity on shape and size of gold nanorods prepared, showed the excellent adjustability of aspect ratio. The effect of gold salt concentration in the reactive dish was studied by using the UV-Visible spectroscopy (figure 5). It's observed that in the low concentrations of gold salt, gold nanorods are not formation. The gold nanorods were formed from 0.1 Ms of gold salt solution and concentrations increase leads to increases in the production efficiency of gold nanorods. The interaction of gold ions and CTAB leads to the formation of metal- complex micelle (Au-CTAB). According to the measurements performed, for the formation of gold nanorods, the maximum volume mixing ratio of gold ions to CTAB is 200:1. In the formation of gold rods nanostructure, volume ratio more than this value leads to non-control growth of nanoparticle and formation of irregular nanostructures. When the concentrations of CTAB more than of concentrations critical of micelle and volume ratio of gold ion to stabilizer more than of 10:1, leads to dissolving of gold ions in the CTAB and form a strong complex. Also, whatever this ratio increases to 200:1, the mechanism of nanorods growth based on zipping bilayer of CTAB, leads to increasing the gold ions to growing surfaces and enhance the length of gold nanorods [28, 29].

The effect of silver nitrate by changing their concentration value, based on UV-Visible absorption spectra were investigated (figure 6). As seen in the figure, with the increasing concentration effect of silver nitrate, absorption spectra contain red convection where shows the decrease aspect ratio of gold nanorods. The role of silver ions (even in the very low values), growth control of gold nanorods in the intended aspect ratio, but enhance the concentrations of silver nitrate leads to more sediment of gold ions on the gold nanorods surface and as a result increases their aspect ratio [30-32].

To investigating the effect of CTAB, gold nanorods by using different concentrations of CTAB as a cation surfactant were prepared. The role of CTAB information of gold nanorods includes three setups: (a) Decreasing the affinity of very high of gold salt and formation a strong complex with CTAB where leads to delaying of the reduction process; (b) Protect from gold ions (III) by retaining them to inside the micelle; (c) The growth of nanorods accrues due to preferential superficial absorption of CTAB on their surface. The UV-Visible absorption spectra recorded from the stabilizer concentration effect of CTAB (figure 7), shows that the using of stabilizer low concentrations of CTAB leads to the formation of gold sphere nanoparticle. From 0.2 Ms concentration of CTAB solution, the nanorods formed and increasing the concentrations value leads to produce of gold nanorods with high efficiency. Therefore, in the seed-mediated growth method for preparation of gold nanorods, 0.2 Ms can be considered as cation surfactant critical concentration of CTAB, wherein more quantities of its, gold nanorods were formed [9-11].

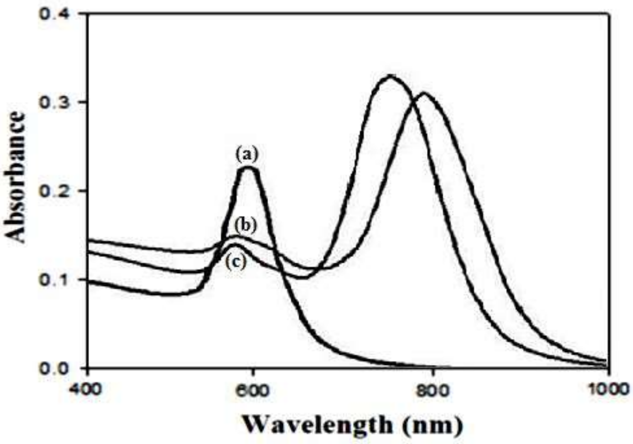

Figure 5. UV-Visible spectra of synthesized gold nanorods with various concentrations of gold salt: (a) 0.001 M; (b) 0.005 M; (c) 0.01 M

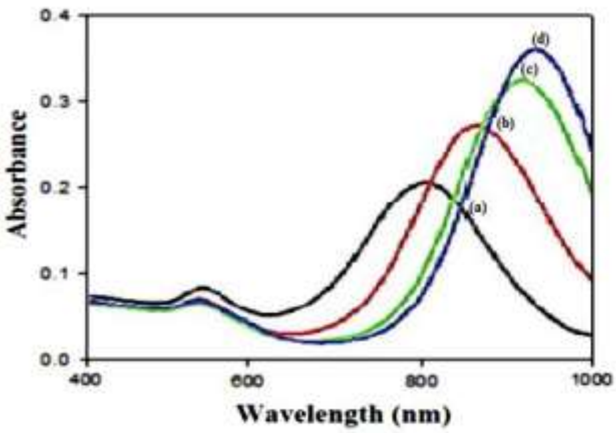

Figure 6. UV-Visible spectra of synthesized gold nanorods with various concentrations of silver nitrate: (a) 0.003 M; (b) 0.004 M; (c) 0.005 M; (d) 0.007 M

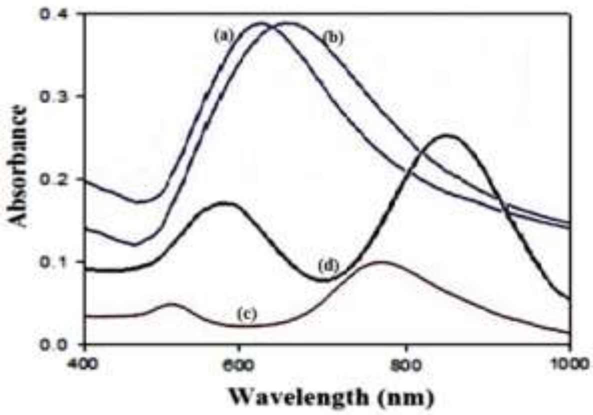

Figure 7. UV-Visible spectra of synthesized gold nanorods with various concentrations of CTAB stabilizer: (a) 0.008 M; (b) 0.004 M; (c) 0.1 M; (d) 0.2 M

The reaction temperature performs sufficient roles to determine the size and distribution of particle size [35]. A sufficient reaction temperature leads to produce of nanocrystalline with narrow particle size distribution. In such temperatures, nucleosynthesis and growth steps in the preparation of nanoparticle occur separately, in a way that growth steps begin after formations of cores. The UV-Visible absorption spectra of samples prepared from gold nanorods in aqueous batch with different temperatures were recorded and have been shown in figure 8. As shown in the absorption spectra, due to temperature increase, spectra intensity of longitudinal localized surface plasmon resonance were decreased. Also, the largest aspect ratio of gold nanorods with a spectral wavelength of 780 nanometers longitudinal localized surface plasmon resonance in the 25°C was formed. This ratio based on linear eq. (1), was measured of 3/2. By surveying the spectra picks of the samples of longitudinal localized surface plasmon resonance in the UV-Visible absorption spectra (figure 8), has been specified that in the effect of temperature increase, a significant change occurs in the morphology of gold rods nanoparticle. From properties obtained samples absorption spectra can be cited the reduce of aspect ratio of gold nanorods with the effect of temperature increase, so that in temperature of 90 degrees centigrade, nanorods with the lowest aspect ratio (length of width ratio of 1/2) were formed and in this temperature, due to increase concentration of gold nanospheres compared to the nanorods prepared, production efficiency of nanorods and purity value strongly have been decreased [28,35].

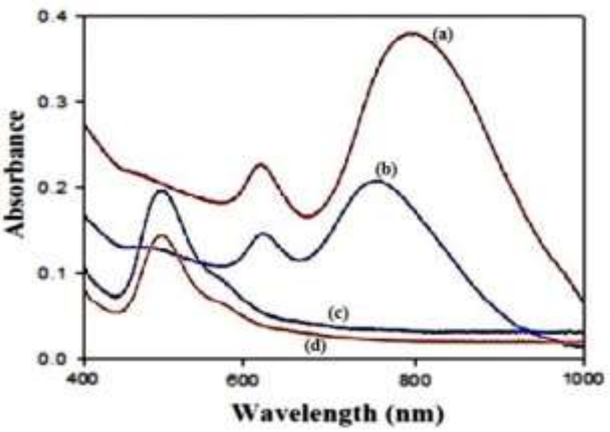

Figure 8. UV-Visible spectra of synthesized gold nanorods at different temperature: (a) 25 °C; (b) 35 °C; (c) 60 °C; (d) 90 °C

The difference between morphology and optical properties depending to the size of gold nanorods in increasing temperature of 25 to 90 degrees centigrade can be explained according to two basic properties related to limitation of the colloid reaction at different temperatures. The first of basic properties were related to the molecular driven and oscillations thermal that leads to large molecular irregularities (increase entropy). The second aspect is the critical micelle concentration of CTAB, the cationic surfactant in different temperatures. As respects in the effect of increasing temperature, the critical concentration of micelles increasing and irregularities thermal also occurs in the reaction material, the aspect ratio of gold nanorods at high temperatures is decreasing [35]. The optimum temperature for preparation of gold nanorods by seed-mediated growth method according to the obtained results in this section is 25°C.

The UV-Visible absorption spectra of gold nanorods prepared were recorded in different pH of growth solutions (figure 9). In the very acidic pH, spectra peaks of transverse and longitudinal localized surface plasmon resonance of gold rods nanostructure have appeared at the absorption spectra. If growth environmental pH was increased, spectrums showed just one peak in the range of 500 to 600 nanometers that was evidenced by the formation of gold sphere nanoparticle. As have been shown in figure 9, at pH greater than 4, absorption pick of longitudinal localized surface plasmon resonance does not appear. Base on observations, desired limit of pH, for preparation of gold nanorods is in the range between of 2 to 3. Nevertheless, in pH equals 4, blue convection has existed in the longitudinal localized surface plasmon resonance which shows reduce of aspect ratio and skinny morphology of gold nanorods.

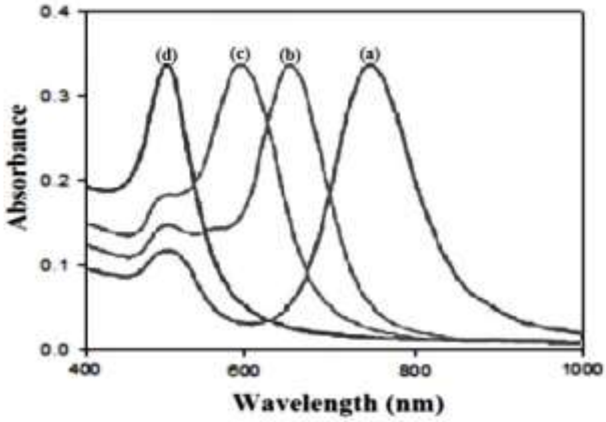

Figure 9. UV-Visible spectra of synthesized gold nanorods at different pH: (a) pH=2; (b) pH=4; (c) pH=8; (d) pH=10

In the very acidic pH, the potential of reducing poor ascorbic acid leads to a slower reduce of gold (III) to gold (I). When seed solution was added to this solution, reduction of gold (III) to gold (I) has occurred which leads to preferential deposition these atoms on the seed nanoparticle surface. In addition, in the very acidic pH, due to increasing the concentrations of hydrogen ions in the growth solution, repulsion between gold nanorods was increased which causes to the growth of gold nanorods and result is the increase in their aspect ratio. In fact, understanding the pattern and change performance in the size and morphology of gold nanorods prepared by the seed-mediated growth method with the change of reactive environmental pH needs to an accurate understanding of the formation process mechanism according to comprehensive information of papers and references, it has [30,31]. Based on studies, nanorods which with the seed-mediated growth method and in the presence of silver auxiliary ions have prepared, have four lateral surfaces and two surfaces in the peaks. As regards that the energy level of lateral surfaces is higher than of peaks surface, sequential layers absorption of CTAB has occurred on the lateral surfaces. That this issue is preventing of interaction gold ions with the lateral surface of nanorods covered from CTAB. In addition, when the silver nitrate was added to the solution in a very acidic pH, bromide silver was absorbed on the lateral surface of gold nanorods selectively. Therefore, the compressed layer of CTAB and bromide silver on the lateral surface of gold nanorods for the growth of rods nanoparticle, gold atoms deposition was guided in the surface of the peak of nanorod which causes to the formation of higher nanorods. According to growth mechanism considered, in the growth solution with alkali character, bromide ion with hydroxyl ions and/or ascorbate ions for abortion are replacing on the surface of the micelle and smaller micelles from CTAB were formed. In finally, the repulse of CTAB molecules from the surface of gold nanorod causes to grow in the two directions of rod nanoparticle and the aspect ratio of nanostructures formed was reduced [30-32]. Thus, it can be anticipated that in pH under 2, length of gold nanorod was increased and abortion peak resulting from longitudinal localized surface plasmon resonance appears in the higher wavelength (about 900-1100 nanometers) [30,31]. Figure 10 shows the growth mechanism schematic of gold nanorods in different pH [32].

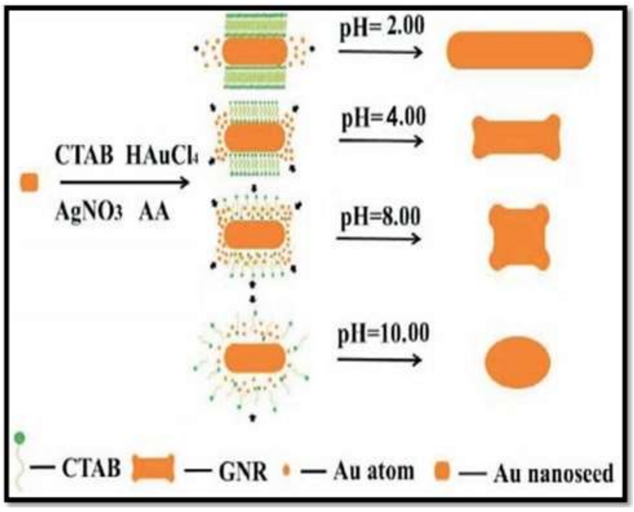

Figure 10. Schematic of gold nanorods growth mechanism at Different pH [32]

The volume effect of seed solution to the growth of rods was studied. As a result, it can be said that by changing the amount volume of seed solution applied in the growth solution in the seed-mediated growth method and in the presence of the fixed concentration of the silver ions, can be adjusted the aspect ratio of nanorods produced. Figure 11 shows the result recorded from this experiment. As seen in the figure, red convection in absorption spectra of nanorods produced a representative increase in their aspect ratio. If the amount volume used from seed solution in the growth solution was increased, more seeds for growth and convert structure rod to gold nanoparticle exist in the reaction environment. Nevertheless, the growth of these seeds directly to the amount of salt gold existing also depends on the reaction environment. Therefore, a concentration of gold nanorods by increasing the volume amount of seed solution does not change significantly. As a result, the growth of seeds and nanostructures rod was constrained and nanorods formed in a constant diameter are taller. The result shown in figure 11 proves this Hypothesis that by increasing the volume of seed solution, was increased the aspect ratio of gold nanorods [38,39].

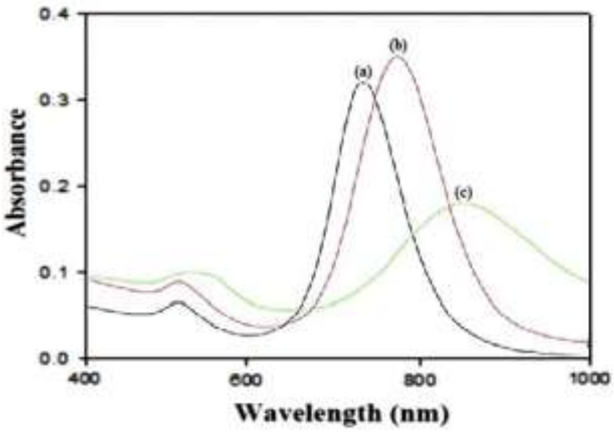

Figure 11. UV-Visible spectra of synthesized gold nanorods by adding different volumes of seed solution: (a) 5 µl; (b) 12 µl; (c) 30 µl

The ageing time of seed solution is also one of the major parameters for control the size and distribution of the final product. In this paper, the effect of ageing time of solution prepared in the first steps of seed-mediated growth method as a seed solution in a different time on the preparation and purity of gold nanorods was studied and investigated and the result has been shown in figure 12. By using the new seed solution prepared, can be obtained the smaller gold nanorods. But in this way, production efficiency of gold nanorods was decreased, because salt gold existing in the growth solution, in this case, a considerable amount produce the sphere nanoparticle which can be seen in figure 12. When the seed solution was added to the growth solution, immediately began reducing the salt gold and with deposition of gold atoms on the surface of the seed, produces the gold nanocrystal which leads to a change specified in the colour solution. Whatever the ageing time of seed solution increases, actually the sufficient time for growth of gold nanoparticle in the seed solution was increased and a larger seed was obtained which by adding them to growth solution, larger nanorods with more aspect ratio was formed. For this reason, selection a sufficient time foraging seed solution to achieve the optimum production from reaction efficiency and aspect ratio of the particle is necessary. Also, by increasing the ageing time of seed solution, morphology and size of nanorods produced, become more uniform [36,37].

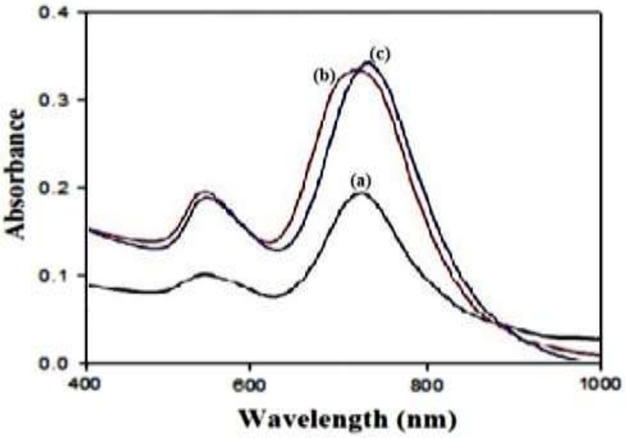

Figure 12. UV-Visible spectra of synthesized gold nanorods by adding seed solution with different ageing time periods: (a) fresh seed solution; (b) ageing of seed solution for 2 hr; (c) ageing of seed solution for 5 hr

Conclusions

SGLT2 inhibitors are a class of anti-diabetic agents that act on the proximal tubule of the kidneys. They increase the urinary glucose excretion by inhibiting the sodium-glucose cotransporter, thus reducing the amount of glucose in the blood circulation. As for now, there are three drugs approved by FDA from this class: canagliflozin, dapagliflozin, and empagliflozin. SGLT2 inhibitors have benefits such as weight loss, no hypoglycemic effects, and as it acts on kidneys there are no harmful effects on the pancreas. These beneficial effects are not seen with other class of drugs such as biguanides and sulphonylureas. The main side effects of SGLT2 inhibitors are urinary tract infections, genital infection, diabetic ketoacidosis.

Conflicts of interest

The authors declare no conflict of interest.

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