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RESEARCH ARTICLE

UTILIZATION OF GOLD NANOPARTICLES IN PRODUCTION OF ANTIBACTERIAL COTTON FABRIC

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ABSTRACT

Current research was undertaken with manifold-objective: to establish the best condition and practice for preparation of stable suspension of gold nanoparticles of (AuNPS) through reduction (HauCl₄) with trisodium citrate; (b) to use state-of-art tools for characterization of AuNPs; (c) to create dialdehyde groups in the molecular structure of cotton Fabric in order to assume strong interaction between the latter and chitosan, d) to fabricate cotton-chitosan-gold nanocomposite (e) to characterize the latter fabric as well as its ability to function as antibacterial textile Mechanism of oxidation of cotton fabric by KIO₄ to create dialdehyde groups in the molecular structure of cotton in order to enhance interalia chemical interaction of cotton fabric with chitosan is reported along with best condition and practice for preparation of cotton fabric loaded with chitosan-gold nanocomposite. The use of world-class facilities, namely, AFM,TEM,UV-vis, Zeta potential, XRD, SEM shown that AuNPs are characterized by spherical shape, uniformly distributed as white dots on the fabric surface in case of cotton fabrics loaded with chitosan-gold nanocomposite and highly dispersed in gold colloids. AuNPs exhibit X-ray diffraction pattern which is well-known for gold crystals. Cotton fabric loaded with chitosan-gold nanocomposite displays antibacterial activity with the certainty that this activity is greater with G-ve than G+ve bacteria and with smaller than larger AuNPs size

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INTRODUCTION

Gold colloids are characterized by unique physical and chemical properties owing to their distinguished size and shape. The synthesis of gold nanoparticle (AuNPs) involves, as reported by number of researches teams, several synthetic procedures. Among these mention is made of the following Turkevich *et al.*, 1951 have reported a method in which hydrogen tetrachloroaurate (HAuCl₄) is reduced by sodium citrate in aqueous medium. Brust *et al.*, 1995 have prepared different ligand stabilized gold nanoparticles through reduction of HAuCl₄ in presence of a thiol. Warner and Weare (Warner *et al.*, 2000) have recently reported a synthetic method for synthesizing small water-soluble ligand, that is, stabilized gold nanoparticles based on ligand exchange reactions. Faraday in 1857 has introduced synthesis of colloidal metals in a two phase system, where reduction of an aqueous gold salt was effected with phosphorus in carbon disulphide to lead ultimately a colored aqueous solution of dispersed gold particles. Brust *et al.*, 1994 accentuated this method, through providing a one-step method for the synthesis of an unusual new metallic material of derivatised gold nanoparticles.

Recently, amino acids have been used as both the reducing agent and the nanoparticles capping agent (Selvakannan *et al.*, 2004) resulting in relatively stable AuNPs solution phase suspensions. Larger macromolecule such as dendrimers and polymeric system, have been employed as platforms to stabilize and reduce HAuCl₄ to nanoparticles as well (Kim *et al.*, 2005). Dendrimers can afford a unique degree of control over the formation of AuNPs through structurally reduced templating effects (Srivastava *et al.*, 2005). AuNPs have also been incorporated into polymers during nanoparticle synthesis, making use of a functionality contained in the polymer as a reducing and stabilizing agent for the resulting AuNPs (Bao *et al.*, 2003; Cho, 2005). Poly (ethylene oxide diamine has been used under mild conditions to reduce HAuCl₄ directly, yielding AuNPs produced within the polymer matrix (Chen, 2004). Direct AuNP incorporation into the polymer matrix did not provide a useful measure of control over AuNP size and the amine terminated PEO matrix method required heating since the polymer functioned also as the solvent. It has been also reported on the one-step synthesis of AuNPs in an amine-containing polyelectrolyte solutions, including poly (allylamine hydrochloride) (Sun *et al.*, 2004; Iwamoto *et al.*, 2003). In this instance elevated temperatures have been again used to facilitate the formation of AuNPs in a linear polyethyleneimine matrix. In addition to the chemical methods described above,

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there is physical methods which outline the synthesis of gold nanoparticles, for example UV (Wei and Qian, 2006), and gamma radiation (Pal et al., 2005; Doker et al., 2006). In a recent published research (Der et al., 2008), a method is described for production of gold nanoparticles in ethanol / water mix using the spark discharge system. Morphology and structure of many materials determine their optical and electrical as well as their catalytic behavior. Gold nanoparticles (AuNPs) exhibit an excellent biocompatibility with different kinds of biomolecules. AuNPs show promising applications owing to their structural, electronic, magnetic, optical and catalytic properties. These properties are very different from those of the corresponding bulk materials. Indeed, such properties possess a significant impact on many scientific fields, particularly in materials science and molecular biotechnology (Sugunan et al., 2005). Some applications are concerned with diagnostic and therapeutic treatment of diseases (Daniel et al., 2004), detection of pathogenic agents (Patil et al., 2005), drug delivery (Baptista et al., 2006) and biosensors (Georganopoulou et al., 2005) Opposite to simple metal particles or semiconductors, the properties of nanoparticle structure are characterized not only by the metallic cluster core but also by those of the organic molecules which constitute the surface layer that contributes to the cluster stabilization.

Gold colloids with special particles of about 5-20 nm particles appear as a deep red wine color with surface plasmon resonance absorption at about 550 nm. This absorption shifts and the color progressively changes through to a blue-grey color with increasing particle size till attaining 80-100nm. Gold is resistant to oxidation and the colors are stable towards UV light providing that there is no change in the particle size, shape or surrounding medium. Gold generally forms spherical nanoparticles. Nano gold is used in biological and biomedical applications (Han et al., 2007; Zhang et al., 2009). To-date gold nanoparticles (AuNPs) have been suspended in solution, physically deposited on surface (Li et al., 2004) Physical deposition of AuNPs at a surface is less than ideal owing to the weak forces that hold the nanoparticles to the surface. Chitosan, a naturally derived polymer, represents one of the most technologically important classes of bioactive materials with applications in different industrial (Pachero et al., 2010) and biomedical (Kardas et al., 2013) fields. By virtue of its excellent biocompatibility and biodegradability, chitosan is a very smart material for biomedical applications (Cárdenas et al., 2008). It is commercially obtained by deacetylation of chitin. Chitosan enjoys a unique structural and physicochemical characteristics that differ considerably from typical synthetic polymer (Nair et al., 2007). In recent years nanoparticles capped with chitosan have been widely synthesized (Huang et al., 2013). We undertake current work with manifold view (a) to synthesize stable suspensions of gold nanoparticles (AuNPs) using trisodiumcitrate as reducing agent b) to characterize AuNPs using world class facilities, c) to effect strong interaction between chitosan and cotton fabric through creation of dialdehyde groups in the molecular structure of cotton by oxidation of the latter with sodium periodate, d) to synthesize cotton-chitosan-gold nanocomposite, e) to characterize the cotton fabric containing chitosan-gold nanocomposite as well as the ability of this fabric to function as bactericide.

MATERIALS AND METHODS

Materials

Mill scoured and bleached cotton fabric was kindly supplied by Misr Company for Spinning and Weaving, Mehala El-Kubra, Egypt.

Chemicals

Hydrogen tetrachloroaurate trihydrate ($\text{HAuCl}_4 \cdot 3\text{H}_2\text{O}$), trisodium citrate, chitosan (low molecular weight) were purchased from Sigma Aldrich Co., all other chemicals were of laboratory grade.

Methodology

Preparation of gold nanoparticles (AuNPs)

In a 250 ml round flask, 1ml of the stock solution (0.1mg/10ml) was added to 100 ml of distilled water and heated until boiling under reflux. Then 1ml (170mg/1ml) of trisodiumcitrate solution was added dropwise to the boiling gold solution with stirring. The heating and stirring is continued for 15 minutes under reflux. A few minutes later, the color of the solution turned from pale yellow to deep red due to the formation of gold nanoparticles. Heating and stirring were continued for another 20 minutes. At this end heating was stopped while stirring was continued until the suspension was cooled down to ambient temperature.

Oxidation of cotton fabric with sodium periodate

Cotton fabric was immersed in a solution of sodium periodate in deionized water (400 ml) at a concentration of 1mg/ml. The solution was then stirred for 1hr at 60°C. The fabric was then washed with deionized water several times to remove the oxidant, then soaked in deionized water at ambient temperature (Ramadan et al., 2013). Thus oxidized material was used for the next reaction without drying.

Treatment of the oxidized cotton fabric with chitosan

A chitosan solution was prepared by stirring a dispersion of low molecular weight chitosan (2g) in 1% (W/V) aqueous acetic acid solution. The mentioned oxidized cotton fabric was immersed in chitosan solution with constant shaking for 2hrs at 60°C²⁹. The substrate so produced was washed with deionized water several times to yield cotton fabric loaded with chitosan.

Treatment of chitosan-loaded fabric with AuNPs

Treatment of cotton fabric loaded with chitosan with gold nanoparticles was carried out by soaking the chitosan-loaded fabric in gold nano particles suspension for 12 hrs to ensure uniform dispersion of gold nano particles in the chitosan matrix. At this end, the fabric was left to dry at ambient conditions. The cotton fabric loaded with chitosan-AuNPs was characterized by using SEM, EDX and XRD as described under sub-item 2.3

Morphological characterization of AuNPs

Characterization of gold nano particles suspension

-ZETA potential: Zeta potential and particle size distribution of the synthesized gold nano particles were analyzed by (Malvern Nano 2s90).

UV-vis spectra

Ultra violet-visible UV-vis spectra have been proved to be quite sensitive to the formation of gold nano particles (AuNPs) because AuNPs exhibit an intense absorption peak due to the surface Plasmon excitation. The latter describes the collective excitation of conduction electrons in a metal. Gold nanoparticles were recorded in spectrophotometer from 300 to 550 nm.

Transmission Electron Microscopy (TEM)

Particle shape and size were obtained using a JEOLJEM-1200. Specimens for TEM measurements were prepared by dissolving a drop of colloid solution on a 400 mesh copper grid by an amorphous carbon film and evaporating the solvent in air at room temperature.

Atomic force Microscopy (AFM)

The morphology of gold nano particles was investigated using an atomic force microscope (AFM) Wet-SPM (Scanning probe microscope-shimaolzu, Non contact mode).

Characterization of cotton fabric loaded with chitosan AuNPs-gold nanocomposite

Scanning Electron Microscopy (SEM)

Morphology of the cotton fabric loaded with chitosan-gold nanocomposite was investigated by scanning electron microscopy (SEM), Topcon-Microscope (ATB-55) was used to investigate morphological changes of the surface structure.

X-Ray Diffractometry (XRD)

XRD patterns of samples in question were recorded on a STOE STADI P transmission X-ray power Diffractometer system by monitoring the diffraction angle from 5 to 65 (2θ) using mono chromatizedcuka ($k=1.54051\text{\AA}$, radiation).

EDX Analysis

An elemental analysis of the particles was implemented by a SEM equipped with an energy dispersive X-ray spectrum (EDX), which can provide a rapid qualitative and quantitative analysis of the elemental composition.

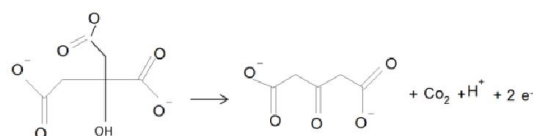
Antibacterial Activity

Agar diffusion test was used to assess the antibacterial activity of AuNPs-loaded cotton fabric (Gresham, 2001; Buchenska, 2001) Four test organisms were used G⁺ve bacteria (staphylococc aureus, Bacillus subtilis) and G⁻ve bacteria (Escherichia coli, Pseudomonas)

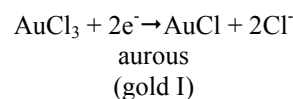
RESULTS AND DISCUSSION

Tentative Mechanism

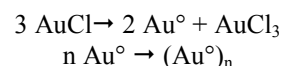
Herein we present research output pertaining to reduction of HAuCl₄ by trisodium citrate in order to synthesize and characterize gold nanoparticles along with their application to cotton bearing dialdehyde groups which permit strong interaction with chitosan. In this sense, the mechanism of citrate reduction of gold salt to form nanogold occurs in three steps (Xiaohui *et al.*, 2007) in which the citrate anions act as reducing agent to reduce Au³⁺ to Au⁰ and as stabilizing agent for stabilization of gold nanoparticles dispersion (Kumar *et al.*, 2004). Oxidation of citrate ions occurs to produce dicarboxyacetone:



Reduction of (gold III) salt to (gold I) salt occurs as shown under:



The gold atoms serve as nucleation sites for the growth of gold nanoparticles (Chiang *et al.*, 2005)



The further growth of the nanoparticles relies on the ratios of reactants, rate of stirring, rate of addition as well as type of reducing agent (Azzam, 2007). The ultimate AuNPs obtained acquire a negatively charged surface because of the deposition of citrate anions on the gold nanoparticles. This allows easy dispersion of the AuNPs in reaction media. The mechanism involved in preparation of cotton fabric loaded with chitosan-AuNPs composite, are shown in Figure 1.

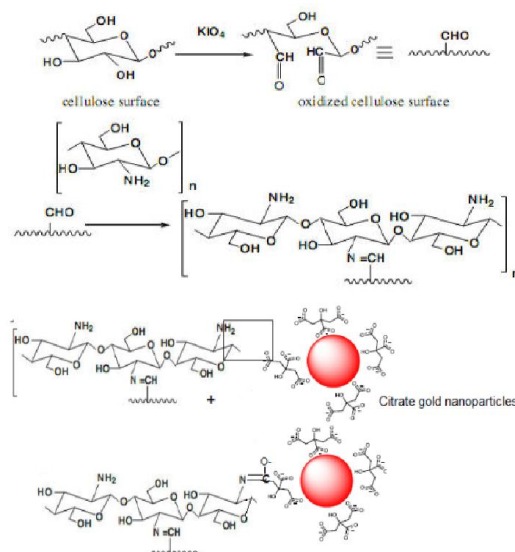


Figure 1. Preparation of dialdehyde cotton cellulose via reaction of the latter with KIO₄ followed by reaction with chitosan and ended by reaction with AuNPs, to yield cotton-chitosan-gold nanocomposite

Effect of reactant ratios on the size, shape and distribution of AuNPs

Transmission electron microscopy (TEM) is usually used to characterize the metallic nanoparticles with respect to size, shape and distribution of the nano-sized particles. Previous reports (Prasa *et al.*, 2010) have disclosed that the size of the nanoparticles prepared by the reduction of gold salt normally depends on the type and concentration of reducing agent as well as on the initial concentration of gold salt.

The type and concentration of reducing agent determine the rate of nucleation and the particle growth. Hence a slow reduction produces large particles, whereas fast reduction usually produces smaller particles. Preparation of gold nanoparticles using trisodium citrate as reducing agent is considered the best system for the production of AuNPs because of its reproducibility, simplicity and uniformity. Given below are the results of studying the effect of ratios of the reactants (Au:citrate ratios), on the size of AuNPs using TEM.

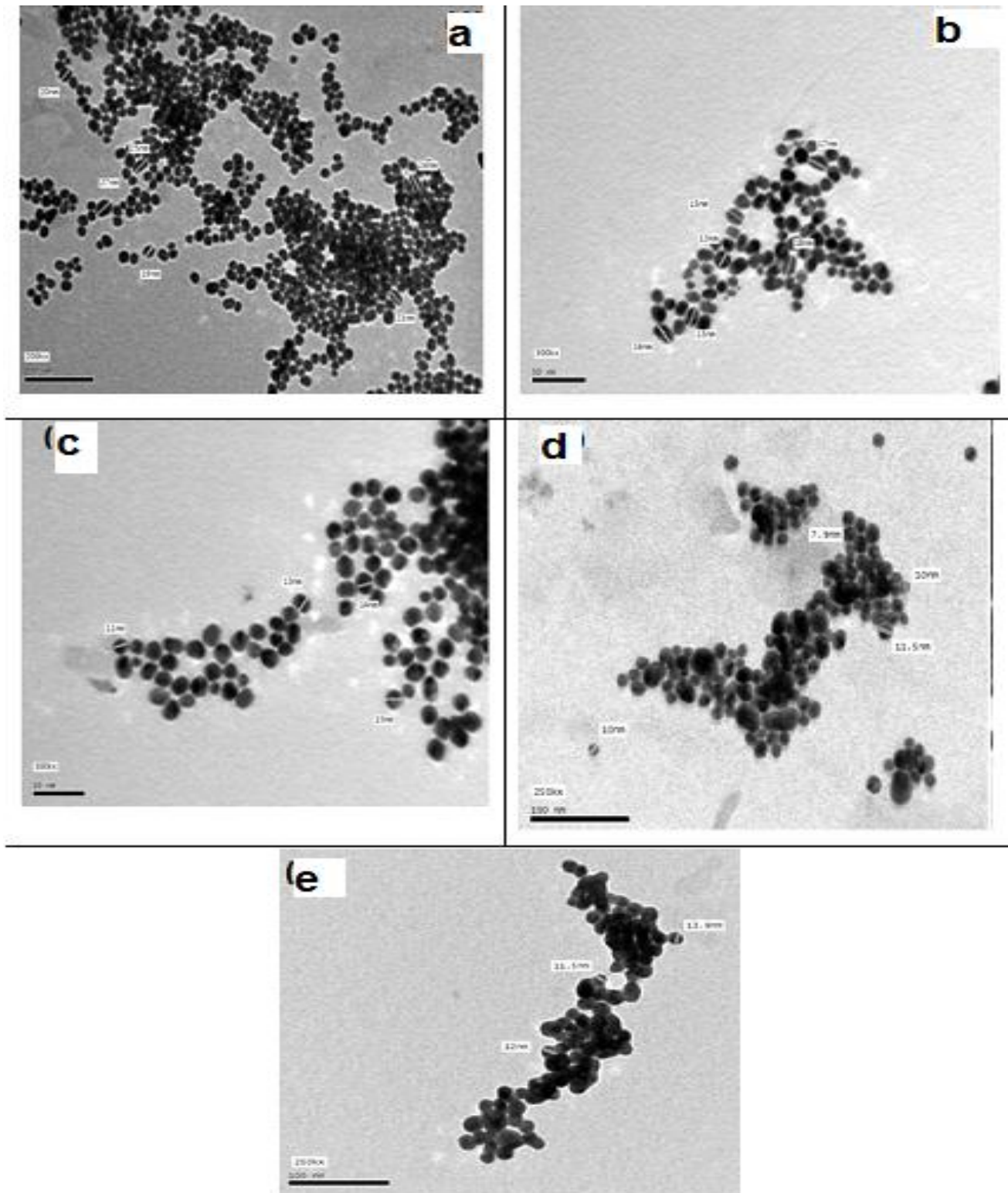


Figure 2(a-e). Transmission electron microscopy (TEM) images of AuNPs prepared using different ratios of gold salt solution /trisodium citrate

Table 1. Concentration of gold salt solution and its ratio with trisodium citrate

HAuCl ₄ . 3H ₂ O (ml)	Trisodium citrate 17% (ml)	Reactant Ratio Au:citrate (V:V)	Average particle size (nm)
0.25	0.75	1: 3	22
0.5	0.75	2: 3	16
0.75	0.75	3: 3	13
1	0.75	4: 4	9.5
1.5	0.75	6: 3	12

Condition used: (HAuCl₄. 3H₂O), (0.1mg/10ml H₂O); (citrate), (170mg/1ml H₂O), temp. (Reflux); Time; 15min, cooling for 15min with continues stirring.

Table 1 depicts that, when the reactants ratio is 1Au: 3 citrate the average size of AuNPs is 22 nm as can be seen from the TEM data (Fig. 2a). When the reactant ratio increases up to 4Au:3 citrate, the sizes of AuNPs decrease to an average value of 9.5 nm (Fig. 2 d).With further increase in Au: Citrate ratio up to 6: 3, the size of AuNPs is marginally larger as compared with those obtained using reactants ratio of 4:3 (Fig 2e). This is most probably due to the aggregation of gold nano particles at higher concentrations of gold. At any event, however, the size and size distribution of AuNPs are significantly affected by gold/citrate ratios. It is further noted that regardless of the reactants ratios within the range studied, the AuNPs are characterized by spherical shape with great tendency to form aggregation particularly when the lowest and highest ratios of Au: citrate were used.

UV-vis spectroscopy for characterization of the synthesized gold nanoparticles

UV-vis spectroscopy is one of the most important tools for characterization of nano-sized metal particles. The absorption behaviour arises from Surface Plasmon Resonance (SPR). SPR originates from coherent oscillations of electrons in the conduction band induced by the electromagnetic field (Hostetler *et al.*, 2008). Figure (3) shows the UV-vis spectra of the gold nanoparticles we have synthesized. Obviously, an absorption band is seen near 530nm. This absorption band is consistent with literature reports on AuNPs suspension and we assign this band as the plasmon resonance band (Sonnichsen *et al.*, 2000). The observed plasmon resonance displays maximum red-shifts. The AuNPS Plasmon resonance band is sensitive to both the size of the nanoparticles as well as to the dielectric response of the surrounding medium.

Atomic force microscopy: (AFM)

AFM measurement is an effective method which provides surface topography and phase images of nano-sized metal particles, by Tapping Mode Atomic Force Microscopy (TM-AFM) acquired images are obtained. The morphology, size distribution of nano gold particles in one dimension as well as in 3D dimensions and the mean radius of these nanoparticles were analyzed by (AFM).as may be realized from Figures 4,5 and 6

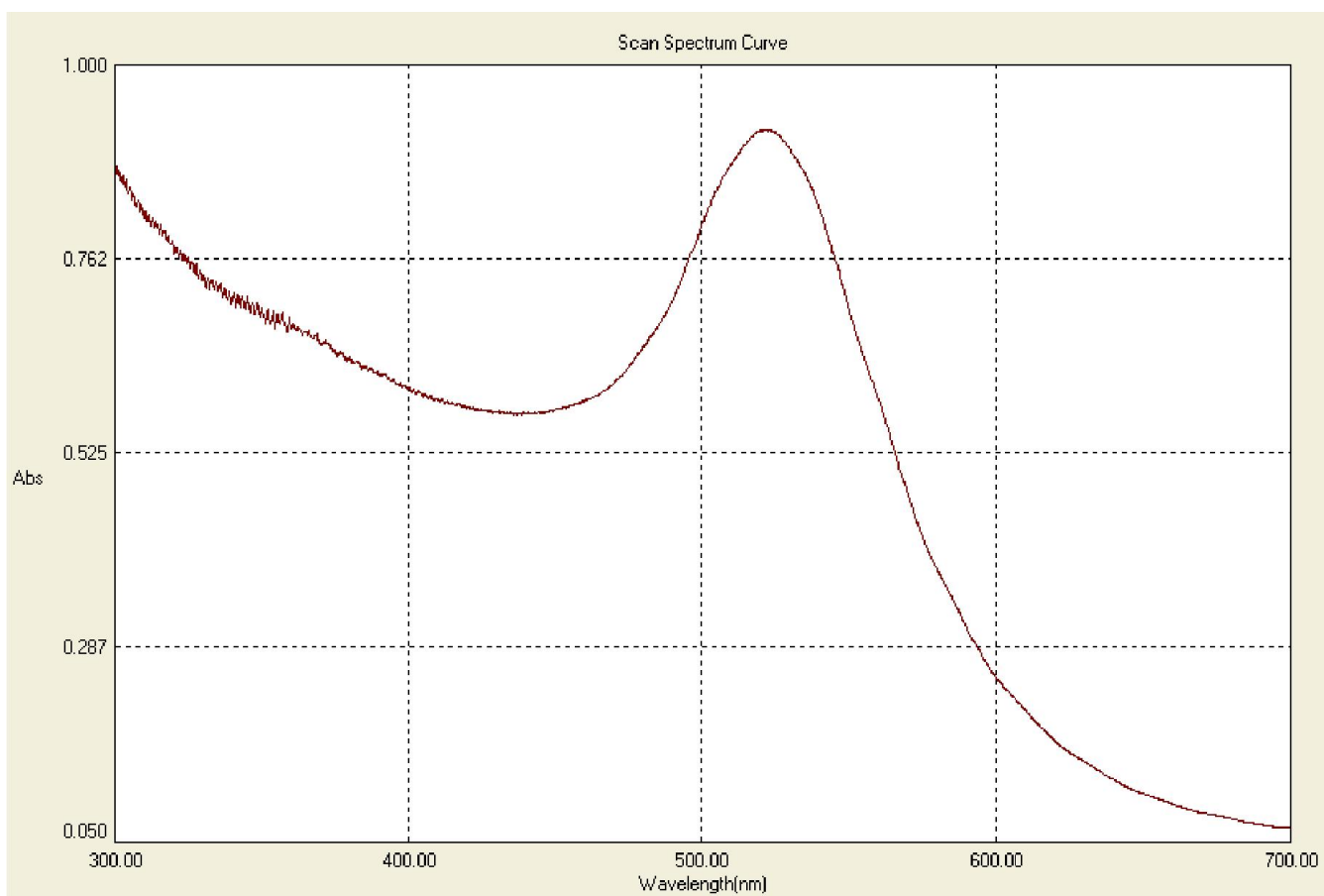


Figure 3. Ultraviolet-visible (UV-vis) spectra of Au nanoparticles prepared through reduction of HAuCl₄ by trisodium citrate

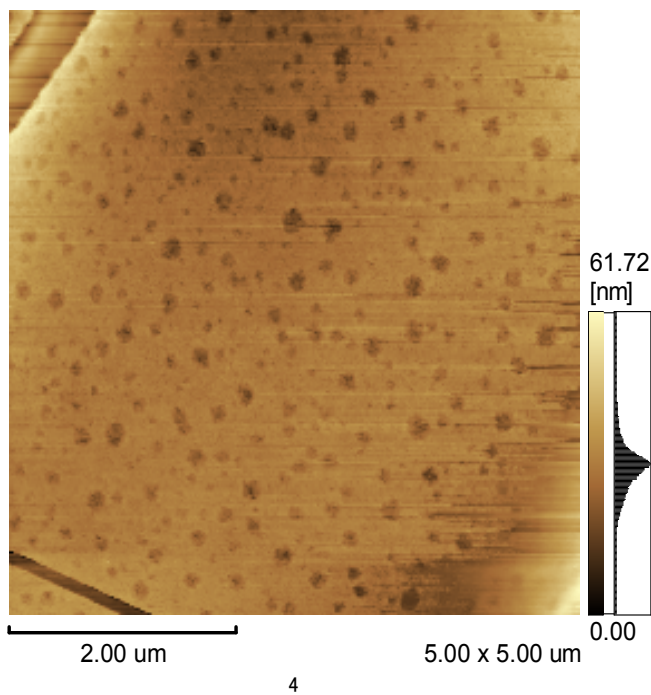


Figure 4. Surface topography image of gold nanoparticles suspension

Surface topography images are shown in Figure 4 in which the AFM image was taken from a much diluted suspension of AuNPs prepared by citrate. As is evident from figure 4 there are spherical nano-sized gold particles of nearly the same size. Indeed this finding agrees well with that concluded from TEM. Figure 5 shows the three dimensions image (3D) of AuNPs, while Figure 6 shows the relation between the number of the nanoparticles detected by AFM and their mean radius. As can be seen from figure 6 the gold nanoparticles exhibit almost the same spherical shape with nanoparticle size of the same radius whose assessment is in conformation with the homogeneity of the synthesized gold nanoparticles suspension.

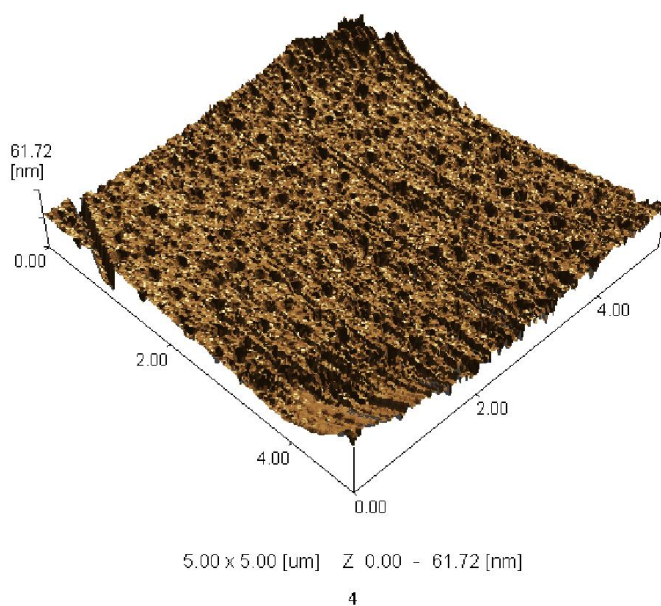


Figure 5. Three dimensional image (3D) of AuNPs

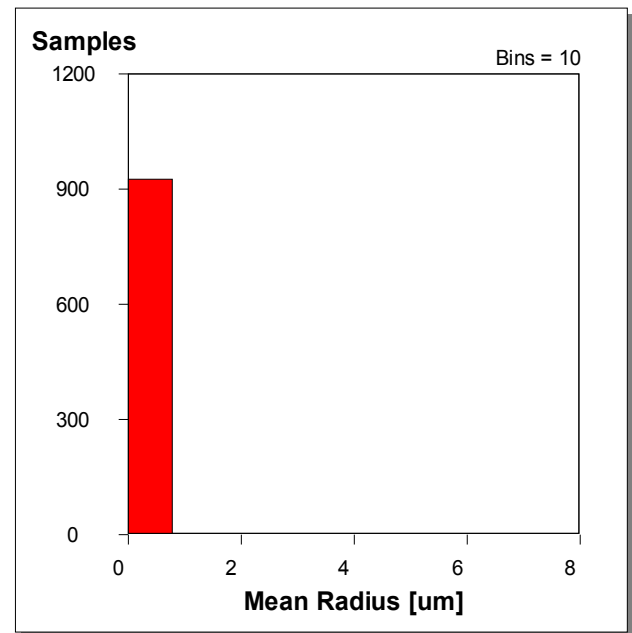


Figure 6. Relation between number of goldnanoparticles detected by AFM and their mean radius

Zeta potential and particle size distribution

Zeta potential is used to describe the basic zeta potential measurement principle behind the zeta sizer Nanodynamic light scattering. Zeta potential is also used to measure the hydrodynamic diameter and size distribution of the particles.

Figure 7a presents zeta potential distribution of gold colloid with a negative charge -54.4 mv, area percent of 62.9% and width of 7.49 mv which is sufficient to keep the particles from interacting with each other and therefore maintain a stable particle size of the sample. Results of figure 7b depict that the mean particle size of gold colloid is 15 nm which is almost agreeing with the TEM and AFM data.

Characterization of cotton fabric loaded with chitosan-goldnano composite

X-ray diffraction

Figure 8 shows the X-ray diffraction (XRD) pattern of cotton fabric loaded with chitosan-gold nanocomposite. Evidently, XRD peaks from atomic lattice of gold nanoparticles are seen and the peaks at 2θ 38.48, 44.54 are due to (111), (200) planes of face centered cubic (FCC) gold crystal. These peaks are perfectly matched with the joint committee on powder diffraction standard (JCPDS 04-0784) which is in conformation with face centered cubic (FCC) structure of gold crystals. The peak corresponding to (111) plane is more intense than the other planes, suggesting that the (111) plane is in the predominant orientation.

Scanning electronmicroscopy (SEM) and energy dispersive X-ray analysis EDX

The Scanning electron microscopy image of cotton fabric loaded with chitosan-gold nano composite is shown in Figure 9. It is clear that the gold nanoparticles have white dots dispersed evenly over the cotton fabric surface.

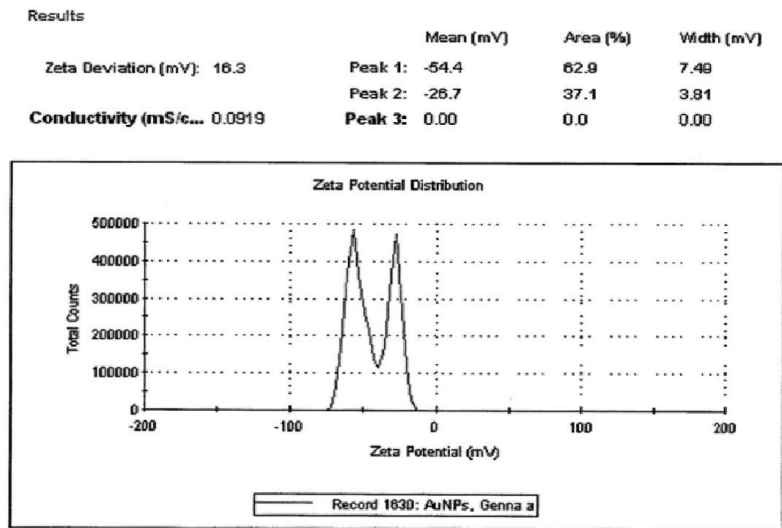


Figure 7a. Distribution of Zeta potential of gold nanoparticles

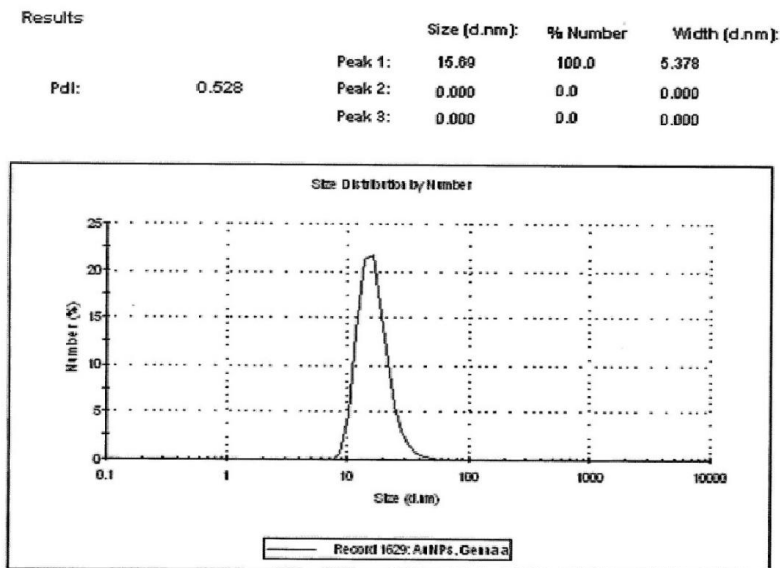


Figure 7b. Particle size distribution of gold nanoparticles

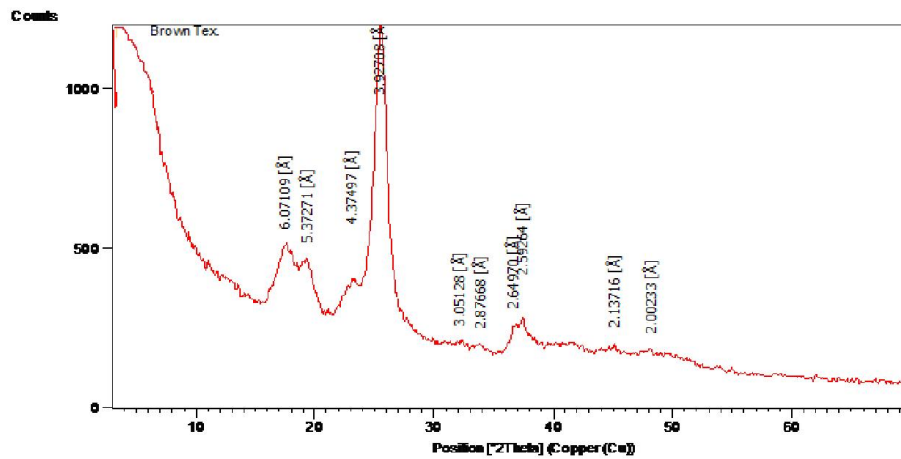


Figure 8. X-ray diffraction pattern of cotton fabric loaded with chitosan-gold nano composite

It is also seen Fig. 9 that AuNPs are spherical particles less than 50 nm which is the most common morphology. The nano gold particles are uniformly dispersed over the surface of the cotton fabric to give a purple colour. This is due to the very high extinction coefficient in the visible region from the surface plasmon resonance effect of the nano gold.

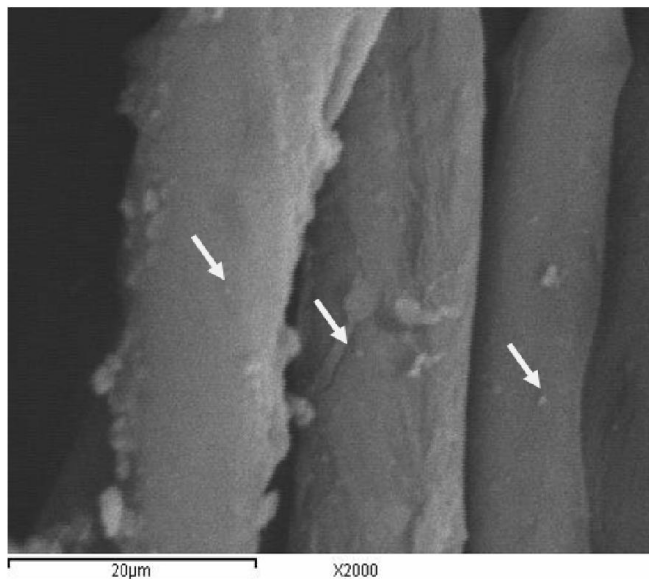


Figure 9. SEM image of cotton fabric loaded with chitosan – AuNPs composite

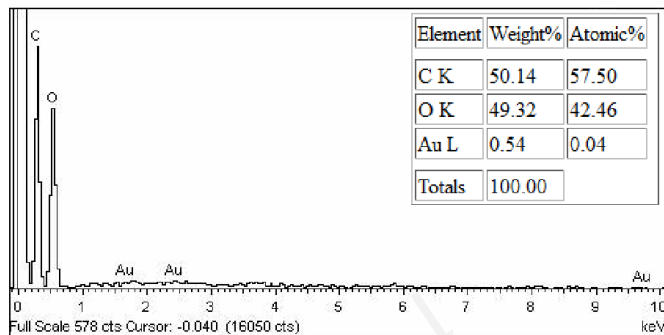


Figure 10. EDX analysis of cotton fabric loaded with chitosan – gold nano composite

On the other hand gold nanoparticles is confirmed by energy dispersive X-ray, EDX spectroscopy analysis as illustrated in figure 10. Based on this EDX analysis, it is concluded that the signals were coming from pure gold as shown in Fig. 10 in which EDX analysis confirm that the dispersed white dots over the fabric surface is Au.

Antibacterial activity (Diffusion Disc Method)

Table 2 shows the antibacterial activity of cotton fabric loaded with chitosan-AuNPs composite. It is clear that incorporation of AuNPs into cotton interacted with chitosan to form cotton. chitosan-gold nano composite, which acquires antibacterial activity against broad spectrum of bacteria such as G-ve bacteria (for example, Escherichia coli and Pseudomonas aeruginosa) and G+ve bacteria (which are exemplified by staphylococcus aureus, Bacillus subtilis).

Table 2. Antibacterial activity of cotton fabric loaded with chitosan-AuNPs composite

Samples	IZDmm				
	Particle size (nm)	G-ve		G+ve	
		Escherichia coli	Pseudo	Staph.	Bacillin
Blank cotton	-	0	0	0	0
Cotton fabric loaded with chitosan	-	6	7	0	6
Sample1	22	12	13	11	11
Sample 2	16	13	14	11	12
Sample 3	9.5	14	16	12	12

Where

Sample 1: was prepared using reactant ratio of 1 :1Au (1%) : 3 citrate (17%)

Sample 2; 2: 2 Au (1%): 3 citrate (17%)

Sample 3; 3: 4 Au (1%): 3 citrate (17%).

The bacterial effect is induced via the electrostatic attraction between negatively charged cell membrane of the bacteria and the positively charged AuNPs. A close examination of Table 2 would reveal that the best antibacterial activity, expressed as inhibition zone diameter (IZD), is obtained with cotton fabric loaded with chitosan- gold nano composite against (*Pseudomonas aeruginosa* G-ve bacteria which brings about an inhibition zone diameter of 16mm for cotton fabric sample containing AuNPs of the smallest nano-sized particles (i.e. 9.5 nm). The same holds true for G+ve bacteria but with the certainty that their IZD values are lower than those of G-ve bacteria. On the other hand, IZD for cotton sample loaded with chitosan- gold nano composite of larger size of AuNPs display lesser IZD when submitted to both G+ve and G-ve bacteria. In this instance inhibition zone diameter for G-ve and G+ve bacteria amounts to 6 mm and 7mm respectively for fabric samples loaded only with chitosan. It is as well to emphasize that smaller particle size of AuNPs can provide much more effective contact surface with bacteria, thus enhancing their antibacterial efficiency (Zhang *et al.*, 2008).

Hence, it could be concluded that the smaller the size of synthesized AuNPs the larger the surface area which interact with bacterial cells there by leading to increased antibacterial activity. Also as the nano gold is chemically bound to the fabric, it does not wash off and hence does not present any adverse environmental impacts.

Conclusion

A perusal at literature would signify the scarcity of published work pertaining to synthesis, characterization and utilization of gold nanoparticles (AuNPs) in textiles. With this in mind, we started our Endeavour by complaining briefly relevant literature available for such concern following this, our research was deigned to include innovative approach for preparation of AuNPs and world-class facilities for their characterization prior to their utilization in the of cotton finishing. The innovation involves; (1) oxidation of cotton fabric by KIO_4 to create disaldehyde groups in the molecular structure of cotton; (2) the so obtained oxidized cotton was reacted with chitosan through the newly created dialdehyde groups; (3) preparation of AuNPs as per the reduction of hydrogen tetrachloroaurate ($HAuCl_4$) with trisodium citrate;

(4) application of the as prepared AuNPs to the cotton fabric containing chitosan to yield cotton fabric loaded with chitosan-AuNPs composite i.e chitosan-gold nanocomposite; 5) Full characterization of both the AuNPs and fabric loaded with chitosan-gold nanocomposite and; (6) Determination of bactericidal properties of cotton fabric loaded with chitosan-gold nanocomposite.

Research output brought into focus the following findings (1) TEM images illustrate that gold-citrate ratio determines the size, shape and distribution of AuNPs. The AuNPs are characterized by spherical shape with great tendency to form aggregates particularly at lowest and highest Au:citrate ratios. Slow reduction produces large particles of nanosizes whereas fast reduction produces smaller nanosizes; (2) UV-vis spectroscopy of AuNPs in question exhibit absorption band near 530 nm which is the absorption band of gold according to literature; (3) Atomic force microscopy (AFM) provides surface topography and distribution of AuNPs in one dimension as well as in 3D dimension and the mean radius of AuNPs. The ultimate AuNPs obtained acquires negatively charged surface because of the deposition of citric anion on AuNPs in reaction media.

By and large the characterization of AuNPs using AFM are tallied with those brought about using TEM; (4) Zeta potential and particle size distribution results depict that the particle size of gold colloid is 15 nm which is almost agreeing with TEM and AFM examination; (5) X-ray diffraction patterns of cotton loaded with chitosan-gold nanocomposite is in full conformation with those known for gold crystals; (6) SEM shows that AuNPs appears as white dots dispersed evenly on the fabric surface; (7) EDX confirms that these dispersed white dots over the fabric surface is gold and; (8) Cotton fabric loaded with chitosan-gold nanocomposite display antibacterial activity with the certainty that this activity is greater with the certainly that this activity is greater with G-VE than G+ve bacteria and smaller than larger AuNPs size. In addition to the above, most appropriate conditions for synthesis of cotton fabric loaded with chitosan-gold nanocomposite with unprecedented properties along with mechanism involved in preparation of these fabrics are reported

REFERENCES

- Azzam, T. and Eisenberg, A. 2007. *Langmuir*, 23 2126-232
- Bao, C., M. Jin, *et al.*, 2003. Hyperbranched poly (amine-ester) templates for the synthesis of Au nanoparticles. *Mater. Chem. Phys.*, 82(3) 812-817.
- Baptista, P.V., Koizol-Montewka, M., 2006. Paluch-Oles J, Doria G., Franco R., *Clin. Chem.*, 52, 1433-1434.
- Brust, M., Fink, J., Bethell, D., Schiffrin, J., Kiely, C. J. 1995. *Chem. Soc. Chem. Commun.* 16 1655.
- Brust, M., Walker, M., Bethell, D., Schiffrin, D.J., Whyman, R. 1994. *Chem. Commun.* 7 801
- Buchenska, J. 2001. *J Biomater Sci Polym Edn* 12(2001)55-62
- Cárdenas, G., Anaya, P., von Plessing, C., Rojas, C., Sepúlveda, J. 2008. *J. Mater. Sci. Mater. Med.*, 19 (6) 2397-2405.
- Chen, S. J., and H. T. Chang, 2004. *Anal. Chem.*, 76(13), 3727-3734.
- Chiang, H., 2005. Hsu M, and Lai L "Journal of solid state
- Cho, J. and F. Caruso, 2005. *Chem. Mater.* 17(17) 4547-4553.
- Daniel, M., Astruc, D., 2004. *Chem. Rev.* 104, 293-346.
- Der Chi Tien, Kuo Hsiung Tseng, Chih Yu Liao, Jen-Chuen Huang and Tsiung Tshih Tsung 2008. Proceedings of the International MultiConference of Engineers and Computer Scientists 2008 Vol II IMECS 2008, 19-21 March, 2008, Hong Kong
- Doker, S., Celikbicak, O., Dogan, M., and Salih, B. 2006. *Microchemical Journal*, 84, pp. 80-87.
- Georganopoulou, D. G., Chang, L., Nam, J. M., Thaxton, C. S., Mufson, E. J., Klein, W. L., Mirkin, C. A. 2005. *Proc. Natl. Acad. Sci. U. S. A.* 102 (2005) 2273-2276.
- Gresham, B. J. 2001. In: Edwards JV, Vigo LT (eds) Bioactive fibers and polymers. American Chemical Society, Washington
- Han, G., Ghush, P., M. De, Rotello V.M. 2007. *NanoBiotechnology* 3, 40-45.
- Hostetler, M.J., J.E. Winglate, *et al.* 1998. *Langmuir* 14(1), 17-30.
- Huang, W., Wang, Y., Zhang, S., Huang, L., Hua, D., Zhu, X. 2013. *Macromolecules* 46 (3) 814-818.
- Iwamoto, M., Kuroda K., *et al.* 2003. *Eur. Phys. J. D: Atomic Mol. Opt. Phys.* 24(1-3) 365-367.
- Kardas, I., Struszczyk M., Kucharska M., Broek L.M., Dam J.G., Ciechańska D., in: P. Navard (Ed.), The European Polysaccharide Network of Excellence (EPNOE), Springer, Vienna, 2013, pp. 329-373.
- Kim, Y. G., Garcia-Martinez, J. C., *et al.* 2005. *Langmuir* 21(12) 5485-5491.
- Kumar, S., Gandhi, K. S., and Kumar, R. 46, 2007 3128-3136
- Li, C., Male, K. B., Hrapovic, S., Luong, J. H. T. 2005. *Chem. Commun.* 31, 3924-3926.
- Nair, L. S., Starnes, T., Ko, J. W. K., Laurencin C.T. 2007. *Biomacromolecules* 8 (12), 3779-3785.
- Pachero, E. A., Tiekink, E. R. T., Whitehouse, M. W. S. 2010 *CRC Press*, BocaRaton, pp 217-230
- Pal, K. Esumi, and Pal T. 2005. *J Colloid Interface Sci*, 288, 396-401,
- Patil S.D, Rhodes D.G., Burgess D.J., *AAPS J.* 7 E61-E77.
- Prasa, G. Sahoo *et al.* 2010. *Journal of Molecular Liquid*, 155, 91-95
- Ramadan, M., Samy, S., Abdelhady, M. and Hebeish, A. 2013. *RJTA* 17 (4).
- Selvakannan, P. R., Kumar, P. S., More, A. S., Shingte, R. D., Wadgaonkar, P. P., Sastry, M. 2004. 16(12) 966-971
- Sonnichsen, C., S. Geier, *et al.* 2000 *Appl. Phys. Lett.*, 77(19), 2949-2955.
- Srivastava, S., Frankamp, B. L., *et al.*, 2005. *Chem. Mater.* 17(3), 487-490.
- Sugunan, A., Thanachayanont, C., Dutta, J. Hilborn, J. G. 2005. *Sci. Technol. Adv. Mater.*, 335-340.
- Sun, X., S. Dong, *et al.*, 2004. *Polymer* 45(7), 2181-2184.
- Turkevich, J., Stevenson, P.C., Hillier, J. 1951. *Discuss. Faraday Soc.*, 11, 55.
- Warner, M. G., Reed, S. M., Hutchison, J. E. 2000. *Chem. Mater.* 12, 3316
- Wei, D. and Qian, W. 2006. "Journal of Nanoscience and Nanotechnology", 6, pp. 2508-14

Xiaohui Ji , Xiangning Song , Jun Li , Yubai Bai , Wensheng Yang , and Xiaogang Peng, 2007. *J. Am. Chem. Soc.*, 129 (45), pp 13939–13948

Zhang, Y., Peny, H., Huang, W., Zhau, Y., Yan , D. 2008. *J Colloid Interface Si* 325;371-376 (2008)

Zhang, Y., Zhang, K., Am, H. Ma, 2009. *J. Biomed. Sci.*, 1 115–125.
