Review Article

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AN OVERVIEW OF SILVER NANOPARTICLES

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ABSTRACT

During the past few years, silver nanoparticles became one amongst the foremost investigated and explored technology derived nanostructures, given the fact that nano silver primarily based materials established to possess attention-grabbing, challenging, and inspiring characteristics appropriate for numerous applications. Generation after generation, the postulates come back forth regarding properties of silver for the traditional Greeks cook from silver pots and the recent saying “born with silver spoon in his mouth” so show that ingestion with a silver spoon was renowned as uncontaminated. Silver has an excessive amount of contemporary industrial uses and is considered as a store of wealth. Silver nanoparticles are unit one amongst the foremost very important and interesting nano materials among many metals like nanoparticles. they need been urban as a complicated unit within the field of nanotechnology. This review predominately focused on advantages and synthesis of silver nanoparticles using physical, chemical, and biological ways. However, physical, and chemical methods are harmful and expensive however the biological technique is easy, rapid, non- noxious and eco-friendly. It additionally explains regarding mechanism of action, numerous characterization techniques as well as UV- Visible Spectroscopy, Localized Surface Plasmon Resonance (LSPR), X-ray Diffraction (XRD), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Fourier Transform Infrared (FTIR) spectroscopy, X- ray Photoelectron Spectroscopy (XPS), Dynamic Light Scattering (DLS), Zeta Potential and finally concluded with numerous applications.

Keywords: Silver nanoparticles, synthesis, mechanism, characterization techniques, numerous applications.

INTRODUCTION

Nanoparticles have mesmerized a massive attention of the scientific world thanks to their giant expanse to volume magnitude relation and high reactivity with unrivalled properties. Nano derives from Greek word “nanos” which implies dwarf or very little. Nanoparticles starting from one to 100 nm are in trend today thanks to its size – relying optical, thermal, electrical, and biological properties.

Metal nanoparticles exhibit novel and size- connected physicochemical properties considerably completely different from their bulk counterpart[1]. The distinctive properties of metal nanoparticles are associate degree envoy of their potential uses in medicine, catalysis, optics, cosmetics, renewable energies, inks, electronics, medical imaging, environmental correction, and medicine devices[2-6]. Different types of metal nanoparticles like copper, zinc, titanium, magnesium, gold, and silver. Among that silver nanoparticles are of explicit interest thanks to its outstanding antimicrobial effectivity against bacterium, virus, and different eukaryotic organisms. They're conjointly most well liked thanks to their distinctive physical, chemical, and biological properties compared to their macro-scaled counterparts.

Over 23% of all products based on nanotechnology, diagnostic and therapeutic programs infused with silver nanoparticles and are well known for their antiviral, antifungal, antibacterial agents applied to canvas and added to cosmetic products as antiseptic to overcome skin issues.

Advantages of Silver Nanoparticles

- High scale production of silver nanoparticles is feasible.
- To get powder formulation silver nanoparticles can be lyophilized and freeze dried.
- Silver nanoparticles possess long term stability.
- Controlled drug delivery of silver nanoparticles can be attained.[7]

PHYSICAL METHODS

Physical ways use physical energies turn out to supply to provide the silver nanoparticles with slender size distribution and conjointly produce an outsized amount of silver nanoparticles during a single method. These ways can offer silver nanoparticle powder.[8]

Evaporation- Condensation Method

In this methodology, the argentiferous (silver- organic) supply is unbroken within the boat with the warmth centre during a tube chamber. Centre heat is comfortable to evaporate the non- silver particles that get eliminated with the carrier gas forgoing the silver nanoparticles. The additional the temperature of the chamber, the additional the concentration of silver nanoparticles shaped. however, this methodology takes a reasonably giant time to achieve stabilised temperature.[9]

Laser Ablation Method

In this methodology, argentiferous or silver plate is scattered during a liquid medium and light with a light beam. Light beam was absorbed by the metal plate and forms a hot plasma that contains silver nanoparticles of most concentration. The liquid medium lowers down the temperature and cools the locality that initiates the formation of silver nanoparticles. the character of silver nanoparticles shaped, and the ablation potency depends upon several factors like the wavelength of the optical device moving the argentiferous target, the period of optical device pulses, the optical device fluency, the ablation period of your time and the effective liquid medium with or while not presence of surfactants.[10]

CHEMICAL METHOD

Chemical Reduction of Silver Nanoparticles

The most unremarkably used methodology for the synthesis of silver nanoparticles is chemical reduction by reducing inorganic and organic agents. The various reducing agents are usually sodium citrate, sodium borohydride, ascorbate, elemental hydrogen, polyol process, Tollens reagent, N, N-dimethylformamide (DMF), and poly (ethylene glycol) - block copolymers used to reduce silver ions in aqueous or non-aqueous solutions. These reducing agents reduce the silver ions and lead to the formation of silver and metal, which is then converted into oligomeric clusters. These clusters eventually lead to the formation of metallic colloidal silver particles[11-13]. It is important to use protective materials to stabilize the dispersing nanoparticles during the preparation of metal nanoparticles and to prevent them from being deposited or bound in nanoparticle environments, avoiding their agglomeration.[14]

Polymeric chemicals such as poly vinylpyrrolidone, polyethylene glycol, poly methacrylic acid, poly methyl methacrylate have been reported to be effective protective agents for stabilizing nanoparticles.

Photochemical Method

This methodology utilizes light (mainly ultraviolet light) to convert resolution of mixture silver nanoparticles to stable formulation with totally different sizes and shapes. During this methodology, the precursor supply could be a silver sol that gets photochemically reduced to create the silver nanoparticles within the presence of compound stabilizers like PVP, PMMA, and PMAA. The expansion of the nanoparticles shaped by this methodology is controlled by choosing the concentration of stabilizers and type of light source.[8,9]

Tollens Method

In this methodology, the Ag $(NH_3)^{2+}$ (Tollens reagent) is reduced by saccharides within the presence of ammonia that yields silver nanoparticle films among the scale vary of 20–50 nm and silver nanoparticles of assorted sizes. The pH is usually between 11.5 and 13.0. pH conjointly influences the particle size as at low pH the scale of nanoparticles is comparatively tiny. By reducing the pH, the polydispersity of silver nanoparticles is earned.[10]

Irradiation Method

Silver nanoparticles is synthesized by employing a type of irradiation ways. Laser irradiation of an aqueous solution of silver salt and surfactant can produce silver nanoparticles in a well outlined form and size distribution.[15]

BIOLOGICAL SYNTHESIS

Generally, chemical, or physical methodology is employed to arrange the metal nanoparticles. However, the chemicals employed in physical and chemical ways are usually expensive, harmful, and flammable however the biogenic ways are economical, energy saver and having environmentally benign protocols technique for inexperienced synthesis of silver nanoparticles from totally different microorganisms like yeast, fungi, and bacterium, etc and plant tissues like leaves, fruit, latex, peel, flower, root, stem, etc as shown in (Figure 1). Phytochemicals like lipids, proteins, polyphenols, radical acids, saponins, amino acids, polysaccharides, amino polyose, enzymes, etc gift in plants are used as reducing and capping agent. the utilization of agro waste and micro-organisms materials not solely reduces the value of synthesis however conjointly minimizes the necessity of using venturous chemicals and stimulates “green synthesis” means for synthesizing nanoparticles.[16,17]

This methodology of synthesis is incredibly straightforward, less time demand and energy as compared to the physical and chemical ways with predictable mechanisms. The opposite benefits of biological ways are the supply of an enormous array of biological resources, a faded time demand, high density, stability, and the ready-to-soluble as ready nanoparticles in water. Therefore, biogenic synthesis of metal nanoparticles unwraps up mammoth opportunities for the utilization of perishable materials.

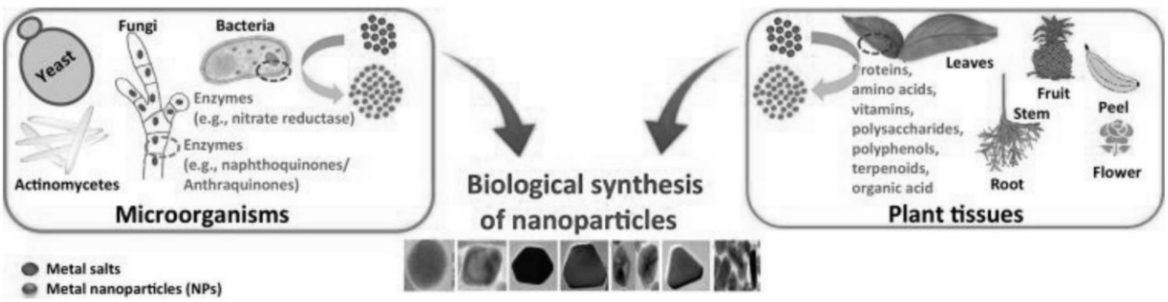

Figure 1: Biogenic synthesis of metal nanoparticle of various shape and size using microorganisms and plant tissues extracts[18]

Mechanism of action

The exact mechanism of action of silver on the microbes remains not famous however the possible mechanism of action of silver ions and silver nanoparticles are projected in keeping with the morphological and structural changes found within the bacterial cells.

Mechanism of Action of Silver Nanoparticles

The silver nanoparticles exhibit an effective antimicrobial property due to their extremely large surface area, providing better contact with microorganisms. Nanoparticles attach to the cell membrane and pierce the inside of bacteria. Bacterial membranes contain sulphur-containing proteins and silver nanoparticles combine with these cellular proteins as well as phosphorus-containing DNA-like substances. When silver nanoparticles enter a bacterial cell, they form a base of cells in the centre of the bacterium where the bacteria meet, protecting the DNA from the silver ions. Nanoparticles effectively attack the respiratory chain, cell division eventually leading to cell death. Nanoparticles release silver ions from bacterial cells, which increase their bactericidal activity.

CHARACTERIZATION TECHNIQUES FOR ANALYSIS OF SILVER NANOPARTICLES

UV- Visible Spectroscopy

UV- Visible spectroscopic analysis is an unusually useful and solid methodology for essential drawing of integrated nanoparticles that is likewise accustomed screen the union and soundness of silver nanoparticles. Silver nanoparticles have a singular optical property that makes them powerfully connect with explicit wavelengths of light. UV-Vis spectroscopic analysis is speedy, easy, basic, sensitive, specific for varied sorts of nanoparticles, simply want a brief amount of your time for estimation associated eventually an adjustment isn't needed for molecule drawing of mixture suspensions. In silver nanoparticles, the physical phenomenon band and valence band lies terribly on the point of one another within which electrons move swimmingly. These free electrons offer ascent to a surface plasmon reverberation (SPR) retention band, prevalence owing to combination swaying of electrons of silver nanoparticles in reverberation with the light wave.

Localized Surface Plasmon Resonance (LSPR)

LSPR could be a logical, additive spatial oscillation of the conduction electrons in a metal nanoparticle, that might be directly excited by near-visible light. The localized surface plasmon resonance condition is outlined by several factors, which has electronic properties of the nanoparticle, the form and size of the particle, dielectric environment, temperature etc. minor changes within the native dielectric environment leads to the misfunctioning of LSPR. The frequency of LSPR spectral peak is sensitive to the nanostructure surroundings through the native index of refraction. As a result, the shifts of LSPR frequency are extensively used as a way for the detection of molecular interaction on the point of the surface of the nanoparticle.[19-23]

X-ray Diffraction (XRD)

The XRD illustrates the crystalline structure of nanoparticles. When the x-ray reflects on the sample (crystal structure), it shows different distinct patterns. Various physicochemical features of the sample can be predicted from these patterns. The x-ray pattern is compared to a standard or sample pattern, from which impurities can be simply detected. There's interplanar spacing within the diffraction patterns that is additionally known as d values; these d values are matched with commonplace silver values.

The average crystalline size of nanoparticles can be calculated by using Debye-Scherrer formula:

$$D = \frac{k}{bcosq}$$

where D is that the average crystalline size of the nanoparticles, k is that the geometric factor (0.9), λ is that the wavelength of X-ray source, and b is that the angular fullwidth at half maximum (FWHM) of the XRD peak at the diffraction angle. By using this formula, the average size of the silver nanoparticles can be calculated.[24,25]

Scanning Electron Microscopy (SEM)

It is a high- resolution technique accustomed find whole morphology and surface characteristics of the nanoparticles. It's terribly economical methodology to see totally different particle sizes, size distributions and nanomaterial shapes. During this technique whole sample is analysed by scanning with a focussed fine beam of electrons and magnetic attraction lenses to get pictures of abundant high resolution. Surface morphology of the sample is set by the assistance of secondary electrons emitted from the sample surface.

Transmission Electron Microscopy (TEM)

TEM is a quantitative methodology for determination of particles, particle size, size distribution and surface morphology. During this technique, determination relies upon the ratio of distance between the objective lens and image plane. Transmission microscopy techniques will offer direct imaging, optical phenomenon and spectroscopical data, chemical composition either at the same time or in a very serial manner of the specimen with sub – nm spatial resolution.

In this technique sample was ready by drop-casting a dispersion of silver nanoparticles on carbon coated copper grids were allowed to dry at temperature. the benefits of TEM over SEM are that it's higher spatial resolution and analytical measurements can even done by this system. The key disadvantages are high vacuum, skinny sample sections and sample preparation is time overwhelming method.[26]

Fourier Transform Infrared (FTIR) Spectroscopy

In this methodology, the functional group of silver nanoparticles is recognized. The transition objective of silver nanoparticles may be found at 490 nm and signalling of OH close to 3499 cm.[24,27]

The advantages of FTIR spectrometers over dispersive ones are speedy information assortment, robust signal, giant signal- to-noise magnitude relation and fewer sample heat- up.

X- ray Photoelectron Spectroscopy (XPS)

XPS is a quantitative spectroscopical surface chemical analysis technique, that is employed to estimate empirical formulae[28-31]. It's additionally referred to as electron spectroscopy for chemical analysis (ESCA)[30]. XPS plays eccentric role in giving entrance to qualitative, quantitative, or semi- quantitative and evolution data regarding the sensor surface. X- ray irradiation of the nanomaterial results in the emission of electrons and therefore the measurement of K.E. and number of electrons escaping from the surface of nanomaterials provides XPS spectra.[28-31]

Dynamic Light Scattering (DLS)

Dynamic light scattering is a methodology that depends on the interaction of light with particles. Among the techniques for the characterization of nanoparticles, the foremost ordinarily used is DLS. DLS measures the light scattered from a laser that passes through a colloid, and largely depends on Rayleigh scattering from the suspended nanoparticles. To test the toxicity of any nanomaterial, its characterization in answer is important. Therefore, DLS is principally accustomed confirm particle size and size distributions in liquid or physiological solution. The dimensions obtained from DLS is typically larger than TEM, which can ensue to the influence of Brownian motion. DLS is a non-destructive methodology accustomed acquire the common diameter of nanoparticles distributed in liquids. It has the special advantage of examining an oversized number of particles concurrently; but it's variety of sample-specific limitations.[32,33]

Zeta Potential

Surface zeta potentials were measured by using the laser zeta meter. A zeta potential was accustomed confirm the surface potential of the silver nanoparticles. The criteria of stability of nanoparticles are measured once the values of zeta potential ranged from above +30 mV to not up to -30 mV.[34]

APPLICATIONS OF SILVER NANOPARTICLES

- Silver nanoparticles has received monumental attention of researchers thanks to their thanks to their budding applications in most fields. In the current context, they have attracted people's interest because of their unique physical, chemical, and biological properties compared to their larger counterparts.
- Silver nanoparticles exhibit broad spectrum of anti-bactericidal, antiviral, anti- inflammatory, anti-tumour and anti-oxidative properties beside biological and chemical sensing, imaging drug carrier and diagnosis of HIV/ AIDS/ cancer.
- Silver technology, rising as an aggressive technology within the field of orthopaedics thanks to its antimicrobial properties. Therefore, silver nanoparticles will be employed in orthopaedical applications like trauma implants, bone cement and hydroxyapatite coatings to forestall film formation. The formation of the biofilm is that the major supply of the morbidity in orthopaedical surgery. The promising results with *in vitro* and *in vivo* studies of the employment of silver nanoparticles during this field to scale back the chance of infection in a good and biocompatible manner.[35]
- Silver nanoparticles have numerous uses in areas such as food additives, food packaging and active food ingredients. To safeguard food from dust, gases, light, germs, moisture nanocomposite low density polyethylene film containing silver and zinc oxide nanoparticles in packaging, can be safe, cheap, easy to dispose of and reused.
- Nano silver product like beauty soap hair shampoo and conditioner, body formulation, sanitizer, toothbrush, facial mask sheets, skin care line, make-upline, wet wipes, disinfectant spray, and detergent etc., are influenced by our way of life at a good extent.[36]
- Silver nanoparticles can also be incorporated into the production of dental adhesives or oral care gels. Silver nanoparticles with particle size less than 15 nm and a concentration of 0.004% W / W show high efficiency to prevent bacterial growth causing unpleasant odours and tooth cavities.
- Silver was used for hundreds of years in oral care and gained worldwide attention in 19th century, being a significant part in dental amalgams used for tooth restoration. Silver nanoparticles also are employed in numerous fields of dentistry like dental prostheses, restorative, endodontic dentistry and implantology.
- Silver nanoparticles and silver ion carriers represent an important strategy for delaying wound healing processes, as diabetic wounds can be associated with many secondary diseases. Silver nanoparticles will facilitate diabetic patients in early wound-healing stages however providing minor scars.[37]
- Nano silver-based compounds and materials proven promising potential towards the event of unconventional and performance-enhanced therapy of eye connected infectious conditions.
- Silver nanoparticles coated nylon fibres employed in creating of floor coverings that helps to secure them against dangerous odours and growth of microorganisms.
- Duran *et al.* prepared silver nanoparticles using *Fusarium oxysporum* and studied its antibacterial effect when applied to cotton fabrics against *Staphylococcus aureus*. They suggest that garments containing silver nanoparticles are sterile and are employed in hospitals to prevent infection by pathogenic bacteria such as *Staphylococcus aureus*.[38]
- Silver nanoparticles are employed in optical purposes. It is employed in solar cells, medical imaging, optical limiters and plasmonic devices etc.
- Silver nanoparticles also are employed in LCDs, High intensity LEDs and touch screens.
- The Nano materials are commercially employed in textile industries by incorporating into fibre or coated with fibre, as an example silver nanoparticle are employed in T shirt, sporting garments, undergarments, socks etc.[39]

Anticancer Applications of Silver Nanoparticles

- Silver nanoparticles will be with success used as novel nanostructured platforms for diagnostics and treatment of various cancers.
- Lim *et al* found that Surface Enhanced Raman spectrometry (SERS) supported silver nanoparticles will be employed in cancer detection in non- invasive approach.[40]
- In recent years, nanoparticles have attracted a lot of attention in cancer medicine thanks to their special physical and chemical properties, which provides rise to a new field of antitumor — cancer nanomedicine.[41,42]

OTHER APPLICATIONS

Pharmaceutics and Medicine

- Treatment of inflammatory bowel disease, disease of the skin and eczema
- Genetic detection of viruses
- Catheter coverage of cerebrospinal fluid canals
- Coating of implants for joint replacement
- Covering of the central venous catheter for monitoring
- Implantable material using clay-layers with starchy stable silver nanoparticles.

Dentistry

- Polyethylene tubes stuffed with protein sponge embedded with silver nanoparticle dispersion.
- Silver- loaded silicon oxide nano-composite resin filler (dental resin composite).

CONCLUSION

Recent advances in silver nanotechnology help us to design and synthesize silver nanoparticles. Various physiological, chemical, and biological processes are designed to synthesize silver nanoparticles. Biological ways using plant extracts have benefits over different ways thanks to their systems are single step in nature, setting friendly (green chemistry), value effective, safe, compatibility for pharmaceutical applications, no want for (hazardous chemicals, air mass, energy, power) and easily scaled up for large–scale synthesis. More than 100 biological sources to produce silver nanoparticles have been reported over the past decade by numerous authors. Biological agents for synthesizing silver nanoparticles cover chemicals produced naturally in plants. several plants have become probable sources for reducing and stabilising agents for inexperienced synthesis of silver nanoparticles. Silver nanoparticles have shown nice attention thanks to their uncommon physical, chemical, electronic, catalytic, magnetic, anti- bacterial and biological activities.

REFERENCES

1. Ju-Nam Y, Lead JR. Manufactured nanoparticles: An overview of their chemistry, interactions, and potential environmental implications. Science of the total environment 2008; 400(1): 396-414.
2. McConnell WP, Novak JP, Brousseau LC, Fuierer RR, Tenent RC, Feldheim DL. Electronic and optical properties of chemically modified metal nanoparticles and molecularly bridged nanoparticle arrays. The Journal of Physical Chemistry B 2000; 104(38): 8925-8930.
3. De M, Ghosh PS, Rotello VM. Applications of nanoparticles in biology. Advanced Materials 2008; 20(22): 4225-4241.
4. Lu AH, Salabas EE, Schüth F. Magnetic nanoparticles: Synthesis, protection, functionalization, and application. Angewandte Chemie International Edition 2007; 46(8): 1222-1244.
5. Ghosh Chaudhuri R, Paria S. Core/shell nanoparticles: Classes, properties, synthesis mechanisms, characterization, and applications. Chemical Reviews 2011; 112(4): 2373-2433.
6. Monteiro DR, Gorup LF, Takamiya AS, Ruvollo-Filho AC, de Camargo ER, Barbosa DB. The growing importance of materials that prevent microbial adhesion: Antimicrobial effect of medical devices containing silver. International Journal of Antimicrobial Agents 2009; 34(2): 103-110.
7. Alaqad K, Saleh TA. Gold and silver nanoparticles: Synthesis methods, characterization routes and applications toward drugs. Journal of Environmental and Analytical Toxicology 2016; 6(4): 1-10.
8. Haider A, Kang IK. Preparation of silver nanoparticles and their industrial and biomedical applications: A comprehensive review. Advances in Materials Science and Engineering 2015; 2015: 1-16.
9. Zhang S, Tang Y, Vlahovic B. A review on preparation and application of silver nanofibres. Nanoscale Research Letters 2016; 11(80): 1-8.
10. Iravani S, Korbekandi H, Mirmohammadi SV, Zolfaghari B. Synthesis of silver nanoparticles: chemical, physical, and biological methods. Research in Pharmaceutical Sciences 2014; 9(6): 385-406.
11. Wiley B, Sun Y, Mayers B, Xi Y. Shape-controlled synthesis of metal nanostructures: the case of silver. Chem Eur J 2005; 11(2): 454–463.
12. Evanoff, Chumanov G. Size-controlled synthesis of nanoparticles. 2. measurement of extinction, scattering, and absorption cross sections. J Phys Chem B 2004; 108(37): 13957–13962.
13. Merga G, Wilson R, Lynn G, Milosavljevic B, Meisel D. Redox Catalysis on "naked" silver nanoparticles. J Phys Chem C 2007; 111(33): 12220–12206.
14. Oliveira M, Ugarte D, Zanchet D, Zarbin A. Influence of synthetic parameters on the size, structure, and stability of dodecanethiol-stabilized silver nanoparticles. J Colloid Interface Sci 2005; 292(2): 429–435.
15. Abid JP, Wark AW, Brevet PF, Girault HH. Preparation of silver nanoparticles in solution from a silver salt by laser irradiation. Chem Commun 2002; (7): 792–793.
16. Chouhan N, Ameta R, Meena RK. Biogenic silver nanoparticles from *Trachyspermum ammi* (Ajwain) seeds extract for catalytic reduction of p-nitrophenol to p-aminophenol more than $NaBH_4$. Journal of Molecular Liquids 2017; 230: 74-84.
17. Roy N, Gaur A, Jain A, Bhattacharya S, Rani V. Green synthesis of silver nanoparticles: An approach to overcome toxicity. Environmental Toxicology and Pharmacology 2013; 36(3): 807-812.
18. Neelu Chouhan. Silver Nanoparticles: Synthesis, Characterization and Applications. Chapter- 2. Intechopen; 2018. p. 1-39.
19. Sönnichsen C., Reinhard B.M., Liphardt J., Alivisatos A.P. A molecular ruler based on plasmon coupling of single gold and silver nanoparticles. Nat. Biotechnol 2005; 23(6): 741–745.
20. Sannomiya T., Hafner C., Voros J. *In situ* sensing of single binding events by localized surface plasmon resonance. Nano Lett 2008; 8(10): 3450–3455.
21. Li C., Wu C., Zheng J.S., Lai J.P., Zhang C.L., Zhao Y.B. LSPR sensing of molecular biothiols based on noncoupled gold nanorods. Langmuir 2010; 26(11): 9130–9135.
22. Zijlstra P., Paulo P.M., Orrit M. Optical detection of single non-absorbing molecules using the surface plasmon resonance of a gold nanorod. Nat. Nanotechnol 2012; 7(6): 379–382.
23. Lis D., Cecchet F. Localized surface plasmon resonances in nanostructures to enhance nonlinear vibrational spectroscopies: Towards an astonishing molecular sensitivity. Beilstein J. Nanotechnol 2014; 5: 2275–2292.
24. Tran QH, Nguyen VQ, Le A. Silver nanoparticles: Synthesis, properties, toxicology, applications, and perspectives. Advances in Natural Sciences: Nanoscience and Nanotechnology 2013; 4: 1-21.
25. Jyoti K, Baunthiyal M, Singh A. Characterization of silver nanoparticles synthesized using *Urtica dioica* Linn. Leaves and their synergistic effects with antibiotics. Journal of Radiation Research and Applied Sciences 2016; 9(3): 217-27.
26. Tarek A El-Desouky, Hala A.M. Ammar. Honey mediated silver nanoparticles and their inhibitory effect on aflatoxins and ochratoxin A. Journal of Applied Pharmaceutical Science June 2016; 6(06): 083-090.
27. Zhang X, Liu Z, Shen W, Gurunathan S. Silver nanoparticles: Synthesis, characterization, properties, applications, and therapeutic approaches. International Journal of Molecular Sciences 2016; 17(9): 1-34.
28. Joshi M., Bhattacharyya A. Characterization techniques for nanotechnology applications in textiles. Indian Journal of Fibre and Textile Research 2008; 33(3): 304–317.
29. Acosta E.J., Gonzalez S.O., Simanek E.E. Synthesis, characterization, and application of melamine-based dendrimers supported on silica gel. Journal of Polymer Science Part A: Polymer Chemistry 2005; 43(1): 168–177.
30. Demathieu C., Chehimi M.M., Lipskier J.F., Caminade A.M., Majoral J.P. Characterization of dendrimers by X-ray photoelectron spectroscopy. Applied Spectroscopy 1999; 53(10): 1277–1281.
31. Manna A., Imae T., Aoi K., Okada M., Yogo T. Synthesis of dendrimer-passivated noble metal nanoparticles in a polar medium: Comparison of size between silver and gold particles. Chem. Mater 2001; 13(5): 1674–1681.
32. Kou T., Jin C., Zhang C., Sun J., Zhang Z. Nanoporous core-shell $Cu@Cu_2O$ nanocomposites with superior photocatalytic properties towards the degradation of methyl orange. RSC Advances 2012; 2: 12636–12643.
33. Lange, H. Comparative test of methods to determine particle size and particle size distribution in the submicron range. Part. Part. Syst. Charact 1995; 12(3): 148–157.
34. E. Akman, B. Genc Oztoprak, M. Gunes, E. Kacar, A. Demir, Effect of Femtosecond Ti: Sapphire Laser

Wavelengths on Plasmonic Behaviour and Size Evolution of Silver Nanoparticles. Photonics and Nanostructures-Fundamental Applications 2011; 9: 276–286.
35. Brennan SA, Ní Fhoghlú C, Devitt BM, O'Mahony FJ, Brabazon D, Walsh A. Silver nanoparticles and their orthopaedic applications. Bone & Joint Journal 2015; 97-B (5): 582-589.
36. Rai M, Birla S, Ingle A, *et al*. Nano silver: An inorganic nanoparticle with myriad potential applications. Nanotechnology Reviews 2014; 3(3): 281-309.
37. Mishra M., Kumar H., Tripathi K. Diabetic delayed wound healing and the role of silver nanoparticles. Dig. J. Nanomater. Bios 2008; 3(2): 49–54.
38. Duran N, Marcato PD, Souza GD, Alves OL, Esposito E. Antibacterial effect of silver nanoparticles produced by fungal process on textile fabrics and their effluent treatment. Journal of Biomedical Nanotechnology 2007; 3: 203-208.
39. Benn T. M., Westerhoff P. Nanoparticle silver released into water from commercially available sock fabrics. Environ. Sci. Technol 2008; 42(11): 4133-4139.
40. J. Lin, R. Chen. S. Feng, J. pan, Y Li. G Chen, *et al*. A novel blood plasma technique combining membrane electrophoresis with silver nanoparticle- based SERS spectroscopy for potential applications in non-invasive cancer detection. Nanomedicine: Nanotechnology, Biology and Medicine 2011; 7(5): 655-663.
41. Shi J, Kantoff PW, Wooster R, Farokhzad OC. Cancer nanomedicine: progress, challenges, and opportunities. Nat Rev Cancer 2017; 17(1): 20-37.
42. da Silva PB, Machado RTA, Pironi AM, Alves RC, de Araújo PR, Dragalzew AC, *et al*. Recent Advances in the Use of Metallic Nanoparticles with Antitumoral Action-Review. Curr Med Chem; 2019. p. 2108-2146.

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