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Silver Nanoparticles Synthesis, Properties, Applications and Future Perspectives: A Short Review

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Abstract: *Silver nanoparticles (Ag NPs) have gained significant interest due to their unique optical, antimicrobial, electrical, physical properties and their possible application. The change of energy level from continuous band to discrete band of Ag NPs with decrease in size of particles gives strong size dependent chemical and physical properties. Ag NPs show lower toxicity to human health while Ag NPs show higher toxicity to various micro-organisms. For this reason Ag NPs having scope for medical instruments, antimicrobial application, products for health care such as scaffolds, burn dressing, water purification, agriculture uses. Ag NPs can be synthesized by using various methods which is primarily classified into two type's namely physical process which includes laser ablation, condensation, evaporation etc. and chemical process which includes hydrazine, sodium borohydride, green synthesis etc. Among all these methods green synthesis is non-toxic, eco-friendly and cost effective. In this review paper different synthesis process especially green synthesis, properties, applications of silver nanoparticles and their recent advances are described. We also highlight the toxicity and compares Ag NPs with others nanoparticles.*
Keywords: *Ag NPs, Synthesis, Antibacterial Activity, Optical Properties, Applications, Toxicity.*

I. Introduction

The use of Ag NPs is rapidly increasing in current century because of their outstanding optical, microbial, electrical and chemical properties. Some of the uses of Ag NPs are in drug delivery, pathology, bioscience, detection of pathogens, catalysis, tumour detection, diagnostics, wound healing, antimicrobials etc. [1-3].

The properties of NPs depend on aspect ratio, crystal size, crystalline density and morphology [4-5]. Narrow sized and uniformly distributed nanoparticles possess higher chemical and physical properties due to their higher aspect ratio [6]. Ag NPs possess very high aspect ratio regardless of their synthesis process which determines surface related properties such as solubility and stability. High aspect ratio of Ag NPs is essential for different application e.g. catalysis, microbial resistance etc. One of the widely studied properties of Ag NPs is Surface Plasmon Resonance which is also found when aspect ratio is high. High ratio of surface area to volume ratio of Ag NPs exhibits microbial resistance and develops resistant strains [7]. Today researcher's main concerns are optical [8], catalytic [9] and microbial [10] properties. The change of energy level from continuous band to discrete band of Ag NPs with decrease in size of particles gives strong size dependent chemical and physical properties and sizes are dependent on various parameters [11-12].

To synthesize Ag NPs of different types and properties, various methods are used but always try to keep the size distribution as minimum as possible. Ag NPs can be synthesized with different shapes and sizes such as spheres, wires, rods and plates using various methods. Recently biosynthesis are widely used due to its lower toxicity and eco-friendly and cost effectiveness [13]. Biosynthesis which replacing chemical method of synthesis can be performed by fungi [14], bacteria [15], yeast [16-17] or plant extracts [18-20]. In biosynthesis Ag NPs synthesis occurs by reduction of silver salts. Metabolite from plant extracts acts as a reducing agent. The size, shape and morphology of Ag NPs depends on the tendency of reduction by the organic reducing agent.

This review paper covers the different synthesis process and their shortcomings of Ag NPs specially biosynthesis. Antimicrobial, physical and optical properties of Ag NPS are also analyzed. Various applications of silver nanoparticles and recent findings are described in the last part of the paper. Future recommendations are also suggested.

II. Synthesis

Ag NPs can be synthesized by using various methods which is primarily classified into two types namely physical process and chemical process. Physical process includes laser ablation, condensation, evaporation etc. and chemical process includes hydrazine, sodium borohydride, green synthesis etc. Most popular process green synthesis or bio synthesis, one physical process laser ablation and a chemical process borohydride method are described below-

2.1 Green Synthesis Method

Green synthesis of Ag NPs are divided into five types namely biological methods, polyccharide method, irradiation method, tollens methods and polyoxomerales methods. In biological method synthesis of Ag NPs occurs by the reduction of silver ion with the help of extracts of micro-organisms. Extracts of micro-organisms may also act as capping agents. Biosynthesis will be described later. Preparation of Ag NPs using polysaccharides and water as a capping agent is known as polyccharide method. Sometimes polyccharides act as both capping and reducing agent. Ag NPs are synthesized by using various irradiation methods such as formation of Ag NPs of various size and shape by laser irradiation of silver salt (aq.) and surfactant. Ag NPs can also be fabricated by tollens methods and polyoxomerales methods.

In biosynthesis process stable spherical Ag NPs with diameter 0.5 nm to 150 nm have been produced at various concentration of silver nitrate. For synthesis of Ag NPs various kinds of approaches using extract of plant is being used. A large number of plants are reported to synthesize Ag NPs are presented in table 1. These approaches have various advantages than physical, chemical and microbial synthesis because in this process there is no need to use of hazardous chemicals, wasteful purifications and high energy requirements. Basically green synthesis is the environmental friendly and cost effective alternative to physical and chemical methods.

Plant extract is the common reducing agent in green synthesis. Commonly silver ions get reduced in aqueous solution and produce different nanometer diameter of colloidal silver. In this crystallization route primarily Ag ions reduce to Ag atoms which then grow into oligomeric clusters. Finally these clusters assist to develop the colloidal Ag particles. Green synthesis process is shown in figure 1-

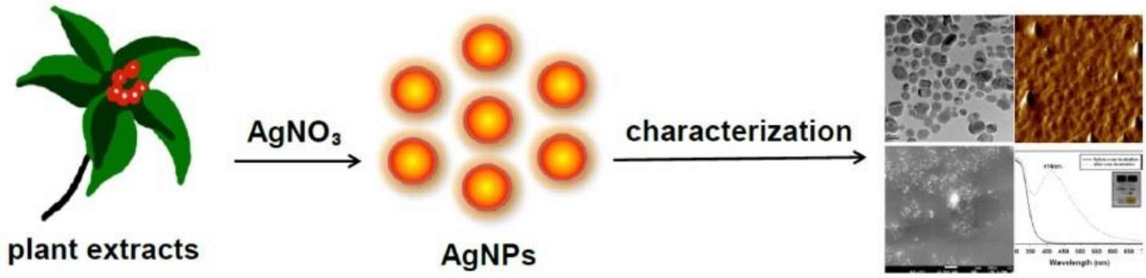

Figure 1: green synthesis process to synthesize Ag NPs [13].

Fabrication of Ag NPs follows three main principles, namely, solvent medium selection, picking environment friendly reducing agent and the choice of nontoxic substances to stabilize Ag NPs. Many researches used the synthesis of Ag NPs by using plant extracts. A vast collection of secondary metabolites is originated in plants which have redox capacity for biosynthesis of Ag NPs. So Ag NPs are formed from Ag+ ion by bio reduction with the help of plant metabolites. Green synthesis of silver nanoparticles by different researchers using plant extracts are represented in following table 1.

Table 1: Green synthesis of silver nanoparticles by different researchers using plant extracts.

Plant	Size, nm	shape	References
Calotropis procera	150–1000	Spherical	[21]
Eucalyptus hybrid	50–150	Spherical	[22]
Psoralea corylifolia	100–110	Spherical	[23]
Aloe Vera	50–350	Spherical, triangular	[24]
Alternanthera dentate	50–100	Spherical	[25]
Cinnamomum camphora	55–80	Spherical	[26]
Cinnamomum camphora	48–67	Spherical	[27]
Dioscorea bulbifera	35–60	triangles, pentagons, hexagons	[28]
Melia azedarach	78	Spherical	[29]
Nelumbo nucifera	25–80	Spherical, triangular	[30]
Rosa rugosa	30–60	Spherical	[31]
Tea extract Leaves	20–90	Spherical	[32]
Pogostemon benghalensis	>80	Spherical	[33]
Pistacia atlantica	10–50	Spherical	[34]
Centella asiatica	30–50	Spherical	[35]
Argyreia nervosa	20–50	Spherical	[36]
Portulaca oleracea	<60	Spherical	[37]
Swietenia mahogani	50	Spherical	[38]

Memecylon edule	20–50	Triangular, circular, hexagonal	[39]
Carica papaya	25–50	Spherical	[40]
Trachyspermum copticum	6–50	Spherical	[41]
Ziziphora tenuior	8–40	Spherical	[42]
Calotropis procera	19–45	Spherical	[43]
Datura metel	16–40	Quasilinear superstructures	[44]
Vitis vinifera	30–40	Spherical	[45]
Boswellia ovalifoliolata	30–40	Spherical	[46]
Coleus aromaticus	44	Spherical	[47]
Camelia sinensis	30–40	Spherical	[48]
Curcuma longa	31-40	spherical	[49]
Rhododedendron dauricam	25–40	spherical	[50]
Acorus calamus	31.83	Spherical	[51]
Cymbopogan citratus	32	Spherical	[52]
Premna herbacea	10–30	Spherical	[53]
Melia dubia	35	Spherical	[54]
Thevetia peruviana	10–30	Spherical	[55]
Garcinia mangostana	35	Spherical	[56]
Acalypha indica	20–30	Spherical	[57]
Citrus sinensis	10–35	Spherical	[58]
Chenopodium album	10–30	quasi-spherical	[59]
Boerhaavia diffusa	25	Spherical	[60]
Cocous nucifera	22	Spherical	[61]
Coccinia indica	10–20	Spherical	[62]
Vitex negundo	5 & 10–30	Spherical & FCC	[63]
Allium sativum	4–22	Spherical	[64]
Cinnamomum camphora	3.2–20	cubic hexagonal crystalline	[65]
Desmodium triflorum	5–20	Spherical	[18]
Eclipta prostrate	10–20	Spherical	[66]
Gelidiella acerosa	22	Spherical	[67]
Sesuvium portulacastrum	5–20	spherical	[68]
Swietenia mahogani	20	Spherical	[69]
Abutilon indicum	7–17	Spherical	[70]
Ficus carica	13	Spherical	[71]
Brassica rapa	16.4	Spherical	[72]
Citrus sinensis	10±1	spherical	[73]
Mucuna pruriens	6–17.7	spherical	[74]
Tanacetum vulgare	16	Spherical	[75]
Coleus amboinicus	8±0.8	spherical	[76]
Acalypha indica	0.5	spherical	[77]

2.2 Laser Ablation Method

Synthesis of Ag NPs with laser ablation method requires a minimum number of reagents, occasionally only pure solvent can be performed on bulk metal Ag sample either in liquid media [78-79] or in aerosols [80].

In this process a Silver target is immersed in aqueous solution in a vessel. A lesser pulse is stroked on immersed sample which results nanoparticle formation. It was possible to synthesize spherical Ag NP with logarithmically normal size distribution by Laser ablation [81]. He used Nd:YAG-laser and used acetonitrile as solvent & found average diameter of particles 2.2 nm – 3.9 nm. Earlier Ag NPs were produced by laser ablation in sodium dodecyl sulphate (aq.) solution. The number of the synthesized NPs was proportional to laser power. The average size of NP was increased with increasing the power of radiation and decreasing the concentration of surfactant. Laser irradiation is another process of synthesis of Ag NP [82]. This process aerosol of Ag micro-particles (1.2 μm) in nitrogen is irradiated by laser. Laser irradiation process consists of Ag NP nucleation, accumulation and growth. At first laser induced heating of silver micro-particles occurs and particles evaporate and finally ionize. Then the disintegration of micro particles starts and generating shock wave. Another shock wave from laser beam comes and colloids with this shock wave inside a particle. The collusion heats the micro-particles to its critical temperature and initiates catastrophic condensation of vapour (atomic). Finally local NP is formed in the area of shock wave at low pressure zone.

2.3 Borohydride Method

Reduction of salt of silver with Na Borohydride to synthesis Ag NP has become most extensively used method because of its higher reactivity than citrate and lower toxicity than hydrazine [83]. At first researchers synthesised Ag NP by using this method. He used solution of $AgNO_3$ and $NaBH_4$ having molar ratio 1:6 and cooled to zero degree centigrade temperature on active stirring. The diameter of synthesized silver particle was in the array of 1-10 nm and found a band of absorption spectrum at maximum wavelength of λ=400 nm. Later lots of publications on this method of synthesis by varying stabilizing media and varying molar ratio between

$AgNO_3$ and $NaBH_4$ have published. LaMer and Dinegar [84] states that during very fast period of time nucleation of colloid particles occurs then remains unaffected later. The growth mechanism of particles happens by reduction of silver ions on the surface of previously formed clusters. Later it was shown that cluster aggregate plays a fundamental role to form colloid particles [25-26]. The synthesis of spherical Ag NP in silver percolate ($AgClO_4$) and $NaBH_4$ solution was studied [27]. He found different colour in different stage of reduction. The colour of the solution was dark muddy green in 1st stage, changed to light yellow in 2nd stage and finally the solution again appeared dark in 3rd stage. He used various temperature and molar ratio between silver percolate ($AgClO_4$) and $NaBH_4$. He found characteristic absorption spectral band at wavelength of λ=200 nm in the early stage of all experiments. The characteristic absorption spectral band abruptly improved at wavelength of λ=390 nm and decreased at wavelength of λ=220 nm in 2nd stage. This phenomenon was described by growth in the size of Ag NP triggered by link of clusters into thicker aggregate (7-9 nm).

Elemental analysis of Ag+ ion content was carried out at various moment of growth to confirm the growth mechanism of Ag NP. It was found that Ag+ ion content was same at every cases and that means no Ag+ ion was lost. This experiment confirms that reduction of silver occurs first few seconds of the synthesis and made impossible of growth mechanism of particles happens by reduction of silver ions on the surface of previously formed clusters. Finally a stabilizer is bringing together with synthesis process to acquire long lasting stability and specific properties [85]. A considerable drawback of this method was the unfeasibility to achieve high concentration of Ag NP in final solutions made aggregate instable. A stabilising media laponite (A synthetic inorganic material) was used [86]. Cluster of Ag particle adsorbed on the surface of laponite and made their aggregation impossible

III. Properties

3.1 Antibacterial Activity of Ag NPs

Antibacterial effect against anaerobic and aerobic bacteria of Ag NPs is widely studied by different scientists and researchers. Small concentration of Ag NPs is harmless for human cell but deadly for majority of viruses and bacteria. Ag NPs reduce toxicity of cell without affecting the antibacterial efficacy [8] Nano particles show high Antibacterial activity because of their finely honed surface and they are small enough to penetrate through the membrane of cell to disturb the intracellular processes. Ag NPs show higher antibacterial effect because of their formation of free radicals on its surface [87]

Several mechanism of the inhibitory effect of Ag NPs on bacteria has been suggested. The high affinity of Ag NPs towards phosphorus and sulphur is the main fact of the antibacterial effect. A lot of sulphur-having proteins on cell membrane, Ag NPs react with sulphur-having amino acids outside or inside the cell membrane which destroys the cell viability of bacteria. It was also studied that Ag+ ions from the Ag NPs react with phosphorous resulting the stoppage of DNA replication or react with proteins containing sulphur, inhibits the enzyme functions. Generally Ag NPs diameter less than 10 nm attack the proteins of bacteria containing sulphur and leading to penetrability of the cell membrane and eventually death of bacteria [88]. Ag NPs having diameter less than 10 nm creates pores on the cell walls of bacteria which cause cell death by realising cytoplasmic content without altering extracellular and intracellular nucleic acids and proteins of bacterium [89]. Sondi [90] reported the changes of membrane structure of E. coli bacterium with interaction with Ag NPs which causes pores on its surface and ultimate death. Ag NPs with addition of antibiotics shows synergic effects against different micro-organism [91-92]. Modification of Ag Sulphadiazine with addition of dendrimers improves the efficacy of anti-bacteria [93]. Ag NPs also show anti-inflammatory properties [94].

Some researchers show that composites of polymer with lower amount of Ag NPs increases the antibacterial activity. One of the polymers is cationic chitosan. Composites of chitosan with Ag NPs have higher antibacterial effect than chitosan and Ag NPs. Positively charged matrix of chitosan is being captured by the negatively charged surface of the bacteria hence causes pores which leads to catastrophic disintegration of bacteria [95]. Antibacterial activity of Ag NPs depend on both size and shape [96]. It has shown that small particles have higher antibacterial activity than big particles because antibacterial activity largely depends on penetrating ability and surface to volume ratio of particles which smaller Ag NPs belongs [97]. A wide range of antibacterial activity of Ag NPs has been studied [98]. The highest antibacterial activity has been found against Streptococcus pyogenes, Staphylococcus aureus and Staphylococcus epidermidis and moderate sensitivity against Klebsiella pneumonia and Salmonella typhi [99].

3.2 Optical Properties of Ag NPs

Ag NPs has specific strong interaction on electromagnetic radiation. The first application of Ag NPs is to prepare pigments for fabrication ceramics and glass. Optical properties of Ag NPs depend on individual particles shape, size, and composition, their environment & presence and structure of adsorption layers [100].

The distinctive feature of spectrum of scattering and absorption of Ag NPs above 2 nm diameter is the appearance of a strong and wide-ranging band in the visible range or near -UV or -IR Ranges. This band is known as surface plasmon resonance (SPR). Silver shows the highest surface plasmon resonance band intensity than any other metals like copper and gold. Light strikes on the surface of Ag NPs and releasing conduction electrons which leads to SPR band [101]. If the diameter of Ag NPs is much less than the wavelength of incident light that leads to the formation of oscillating dipole. If dipole formation occurs near the surface then it is called the surface plasmon. If the particles are not spherical different orientations of Ag NPs with respect to incident wave is non-equivalent. For this reason cylindrical particles have two SPR band along and across its cylindrical axis. The negative and positive charge regions of dipole cause polarization which decreases the frequency and amplitude of the oscillation of dipole and shifts the band of SPR to long wavelength [102]. This effect increases with increasing the medium's dielectric permeability. Dielectric permeability of the medium has two part namely a real part and an imaginary part. Ag NPs has lowest imaginary part of dielectric permeability which lowers dissipation of electric field energy; hence it has highest efficiency of the SPR band of the Ag NPs.

The position and width of the SPR band depends on particle size and shape as dielectric permeability of Ag changes with the size of particle [103]. If the particle size becomes larger, possibility of formation of the quadruples and multipoles are increased hence additional band of SPR appears. A change in the shape of Ag NPs from spherical particles especially the arrival of sharp corners causes the shift of absorption peak to longer wavelengths. When the frequency of SPR band and frequency of the exciting radiation becomes equal, then plasmon field intensity reaches its peak as the probability of interaction of light and molecules through absorption, photoluminescence and scattering increases [104]. Raman scattering also increases with the presence of Ag NPs. Maximum increase in Raman scattering (105-1010 fold) was found in the presence of aggregates of Ag NPs [105].

IV. Applications

4.1 Medical Science Applications

Application of Ag NPs in medical can be divided into two types namely diagnostic and therapeutic uses. Lim et al found that Surface Enhanced Raman Spectroscopy (SERS) based on Ag NPs can be used in cancer detection in non-invasive way [106]. This process of cancer detection will be inevitable part of cancer detection in near future.

Now a days silver nanoparticle is widely used in medical science. It is used for wound dressing, scaffolds, eye treatment and dental hygiene [107] bone substitute biomaterials [108]. Exact mechanisms of wound healing have not yet known. Kwan et al [109] shows that after wood healing Ag NPs improves collagen alignment which results superior mechanical strength. Acticoat is most popular wound dressing. It is made of two layer of polyamide ester membranes coated with silver nanoparticle [110]. By Incorporating Silver Nanoparticles at surface antibacterial properties can be increased without affecting biocompatibility [107] and also provides superior cosmetic after wood healing and better efficacy. Silver contained materials are used for surgical meshes. Central venous catheters (CVC) contained silver nanoparticles are less infective in blood stream [111]. According to Sun et al. [112] human serum contains albumin stabilized silver nanoparticle which provides antiviral properties.

Recent studies of Ag NPs lead to utilization in some important applications such as diagnostic imaging, therapy, bio-sensing and cancer diagnosis. [113]. Ag NPs are considered to be used as drug delivery vehicles and cancer therapeutic agents. Interferon gamma and tumor necrosis can also be inhibited by Ag nano-particles [114]. Nano silver can be used for destroying unwanted cells due to its plasmonic nature. This operation can be done by absorbing light from target cell and then converting to thermal energy. The plasmonic nature of Nano silver can also be used to destroy unwanted cells. The cells can be conjugated to the target cells and then be used to absorb light and convert it to thermal energy; the thermal energy can lead to thermal ablation of the target cells [115].

Recently the outbreak of infectious diseases such as cholera (V. cholera), influenza (A/H5N1), diarrhea (E coli) etc. around the world has become a burden on public health and economics. Transmission of pathogens like bacteria, fungi, virus etc. causes outbreaks of such infectious diseases. Disinfectant products based on silver nanoparticles have been recommended for the cures of environments containing such pathogens [113].

4.2 Textile Applications

Nano materials are now commercially used in textile industries [116]. Nanoparticles are incorporated into fiber or coated on fiber. Silver nanoparticles are used in T shirt, sporting clothes, underwear, socks etc. [117].

4.3 Food Industry Applications

Silver nanoparticles are widely used in food industry reported by Cushen [118] mainly due to antibacterial actions and free of preservative. Small concentration of Ag NPs is harmless for human cell but deadly for majority of viruses and bacteria. For this reason it is extensively used in decontamination of food and water in day to day lifecycle and infection resistor in medicine. Nanoparticles are added into food packages. Sunriver industrial Nano silver fresh food bag is one of commercially available bag in which silver nanoparticles are added [119]. Ag NPs are widely used in consumer product namely soaps, food, plastics, pastes and textiles due to their anti-fungicidal and anti-bactericidal activities.

4.4 Optical Applications

Silver nano-particles also used in optical purposes. It is used in Solar cells, medical imaging, optical limiters, plasmonic devices etc.

4.5 Conductive Applications

LCDs, High intensity LEDs, touch screens, are using silver nanoparticles.

V. Toxicity And Challenges

Prime challenges of the upcoming decade would be the transition of lab treatment of Ag NPs to commercial application. A vast amount researchers and scientists around the world who are devoted to synthesis nanoparticles and studies their properties face challenges in their attempt to synthesize of these nanoparticles. If Ag NPs display a minor amount of toxicity to body, it would be fatal. Future investigations should be preparation of Ag NPs which aim at overcoming such kind of challenges and would be useful in designing effective drug delivery agent, diagnosing and treating fatal diseases besides ensuring higher safety and efficacy.

However aggregation and toxic nature of silver nanoparticles limits its uses in some application. Treatment of burn patients with ionic silver causes reactions of hyper-sensitivity. Some studies found that Ag NPs become harmful to specific cell lines. Toxicity and smaller Ag NPs are correlated [120]. Aggregation occurs because of their high surface energy. Ag NPs can also be easily contaminated or oxidized in air due to its high surface energy. This problem has overcome by incorporating Ag NPs into biodegradable polymer matrix like chitosan, alginate, gelatine etc.

VI. Comparison Of Ag Nps With Other Nps

A Silver shows the highest surface plasmon resonance band intensity than any other NPs like copper and gold. For having surface plasmon resonance effect both Ag NPs and Gold NPs are usually employed in optical detection. Since Ag NPs show sharper and stronger peaks of plasmon resonance than that of Gold NPs at the equal concentration of particles its efficiency of plasmon efficiency is higher. For this reason Ag NPs impart better sensitivity for applications like surface enhanced Raman scattering or localized surface plasmon resonance. Plasmon surface absorbance of gold NPs is in the wavelength range of 500 nm to 600 nm while most fluorophores emit above 500 nm. So quenching of some detectable fluorescence can occur when fluorescent dyes are adjacent to the surface of particle. This sort of fluorescence quenching is rarely occurred on the Ag NPs as surface absorbance of Ag NPs is mostly below than 500 nm. For this reason AG NPs have stronger fluorescent signal than gold NPs.

VII. Conclusion

Recent advances in Ag nanotechnology help us to design and synthesize Ag NPs. Biosynthesis is best of all other synthesis processes of Ag NPs because of their nontoxic nature. Their unique optical, physical, and antimicrobial properties would lead Ag NPs wide spread uses in medical and different sectors like would healing, food sanitation, drug delivery etc. Ag NPs can also be used by integration with other materials to improve their properties like plasmonic light traps. This properties are useful in fuels, solar cells, micro-electronics, medical imaging and waste management. Further desired properties can be obtained by preparing composite by using Ag NPs as reinforcement into polymer matrix. Aggregation and toxic nature of silver nanoparticles limit its uses in some application. Future investigations should be preparation of Ag NPs which aim at overcoming these kinds of challenges and would be useful in designing effective drug delivery agent, diagnosing and treating fatal diseases besides ensuring higher safety and efficacy.

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References

[1] M. G. Guzman, J. Dille, S. Godet, "Synthesis of Silver Nanoparticles by Chemical Reduction Method and Their Antibacterial Activity", World Acad Sci Eng Technol, vol. 43, pp. 357–364, 2008.

[2] D. J. Xiong, M. L. Chen, H. Li, "Synthesis of Para-Sulfonatocalix [4] Arene-Modified Silver Nanoparticles as Colorimetric Histidine Probes". Chem Commun, vol. 2008, pp. 880–882, 2008.

[3] S. Basu, S. Jana, S. Pande, T. Pal, "Interaction of DNA Bases With Silver NaNoparticles: Assembly Quantified Through SPRS and SERS", J Colloid Interface Sci, vol. 321, no. 2, 288-293, 2008.

[4] K. Anandan, V. Rajendran, "Morphological and Size Effects of Nio Nanoparticles via Solvothermal Process and Their Optical Properties", Mater. Sci. Semicond. Process. vol. 14, pp. 43-47, 2011.

[5] P. Laokul, V. Amornkitbamrung, S. Seraphin, S. Maensiri, S, "Characterization And Magnetic Properties Of Nanocrystalline $CuFe_2O_4$, $NiFe_2O_4$, $ZnFe_2O_4$ Powders Prepared By The Aloe Vera Extract Solution", Curr. Appl. Phys, vol. 11, pp. 101, 2011

[6] Y. Y. Mu, H. Liang, J. Hu, L. Jiang L. J. Wan, "Controllable Pt Nanoparticle Deposition on Carbon Nanotubes as an Anode Catalyst for Direct Methanol Fuel Cells". J. Phys. Chem. B, vol. 109, pp. 47, pp. 22212–22216, 2005.

[7] M. Rai, A. Yadav, A. Gade, ''Silver Nanoparticles As A New Generation of Antimicrobials'', Biotechnology Advances, vol. 27, pp. 76-83, 2009

[8] R. Karimzadeh, N. Mansour, "The Effect of Concentration on the Thermo-Optical Properties of Colloidal Silver Nanoparticles", Opt. Laser Technol., vol. 42, pp. 783, 2010.

[9] G. W. Yang, G. Y. Gao, C. Wang, C. L. Xu, H. L. Li, "Controllable Deposition of Ag Nanoparticles on Carbon Nanotubes as a Catalyst for Hydrazine Oxidation" Carbon, vol. 46, pp. 747, 2008.

[10] D. Mubarak-Ali, N. Thajuddin, K. Jeganathan, M. Gunasekaran, "Plant Extract Mediated Synthesis of Silver and Gold Nanoparticles and Its Antibacterial Activity against Clinically Isolated Pathogens", Colloids Surf. B Biointerfaces, vol. 85, pp. 360, 2011.

[11] M. A. Kostowskyj, D. W. Kirk, S. J. Thorpe, "Ag And Ag-Mn Nanowire Catalysts for Alkaline Fuel Cells", Int. J. Hydrogen Energ., vol. 35, pp. 5666, 2010.

[12] J. H. Lee, N. R. Kim, B. J. Kim, Y. C. Joo "Improved Mechanical Performance of Solution-Processed MWCNT/Ag Nanoparticle Composite Films With Oxygenpressure-Controlled Annealing", Carbon, vol. 50, pp. 98, 2012.

[13] Y. Park, New Paradigm Shift for the Green Synthesis of Antibacterial Silver Nanoparticles Utilizing Plant Extracts, Toxicological Research, vol. 30, pp. 169-178, 2014.

[14] M. Sastry, A. Ahmad, M. I Khan, R. Kumar, "Biosynthesis of Metal Nanoparticles Using Fungi and Actinomycete", Curr. Sci., vol. 85, pp. 162-170, 2009.

[15] N. Saifuddin, C. W. Wong, A. A. Nur, Yasumira, "Rapid Biosynthesis of Silver Nanoparticles Using Culture Supernatant of Bacteria with Microwave Irradiation", Journal of Chemistry, vol. 6, no. 1, pp. 61-70, 2009.

[16] M. Kowshik, W. Vogel, J. Urban, S. K. Kulkarni, K. M. Paknikar, "Microbial Synthesis of Semiconductor Pbs Nanocrystallites", Biotechnol. Bioeng. Adv. Mater., vol. 14, pp. 815-818, 2002.

[17] M. Kowshik, S. Ashtaputre, S. Kharrazi, W. Vogel, J. Urban, S. K. Kulkarni, K. M Paknikar, "Extracellular Synthesis of Silver Nanoparticles by A Silver- Tolerant Yeast Strain MKY3", Nanotechnology, vol. 14, pp. 95-100, 2003.

[18] N. Ahmad, S. Sharma, V. N. Singh, S. F. Shamsi, A. Fatma, B. R Mehta, "Biosynthesis of Silver Nanoparticles From Desmodium Triflorum: A Novel Approach Towards Weed Utilization" Biotechnology Research International, vol. 2011, pp. 1-8, 2010.

[19] D. Philip, "Green Synthesis Ofgold and Silver Nanoparticles Using Hibiscus Rosasinensis", Physica E: Low-dimensional Systems and Nanostructures vol. 42, no. 5, pp. 1417-1424, 2010.

[20] D. Philip, S. Unnib, A. Aromala, V. K. Vidhua, "Murraya Koenigiileaf-Assisted Rapid Green Synthesis of Silver and Gold Nanoparticles", Spectrochimica Acta Part A, vol. 78, pp. 899–904, 2011.

[21] S. A. Babu, H. G. Prabu, " Synthesis of AgNPs using the extract of Calotropis procera flower at room temperature", Mater Letter, vol. 65, pp. 1675–1677, 2011.

[22] M. Dubey , S. Bhadauria , B. Kushwah, " Green synthesis of nanosilver particles from extract of Eucalyptus hybrida (safeda) leaf", Dig J Nanomater Biostruct, vol. 4, pp. 537–543, 2009.

[23] D. Sunita, D. Tambhale, V. Parag, A. Adhyapak, "Facile green synthesis of silver nanoparticles using Psoralea corylifolia. Seed extract and their in-vitro antimicrobial activities" Int J Pharm Biol Sci, vol. 5, no. 1, pp. 457–67, 2014.

[24] S. P. Chandran, M. Chaudhary, R. Pasricha, A. Ahmad, M. Sastry, "Synthesis of gold nanotriangles and silver nanoparticles using Aloe vera plant extract", Biotechnol Prog, vol. 22, pp. 577–831, 2006.

[25] J. R. Nakkala, R. Mata, A. Kumar Gupta, S. R. Sadras, "Biological activities of green silver nanoparticles synthesized with Acorous calamusrhizome extract", Eur J Med Chem, vol. 85, pp. 784–94, 2014.

[26] J. L. Huang, Q. B. Li, D. H. Sun, Y. H. Lu, Y. B. Su, X. Yang, et al, " Biosynthesis of silver and gold nanoparticles by novel sundried Cinnamomum camphora leaf", Nanotechnology, 18. http://dx.doi.org/10.1088/0957-4484/18/10/105104, 2007.

[27] N. Kannan, K. Mukunthan, S. Balaji, " A comparative study of morphology, reactivity and stability of synthesized silver nanoparticles using Bacillus subtilis and Catharanthus roseus (L.)", G. Don. Colloids Surf B Biointerfaces, vol. 86, pp. 378–383, 2011.

[28] G. Rajakumar, A. Rahuman, " Larvicidal activity of synthesized silver nanoparticles using Eclipta prostrata leaf extract against filariasis and malaria vectors", Acta Trop, vol. 118,no. 3, pp. 196-203, doi: 10.1016/j.actatropica,2011.

[29] R. Sukirtha, K. M. Priyanka, J. J. Antony, S. Kamalakkannan, T. Ramar, G. Palani, "Cytotoxic effect of green synthesized silver nanoparticles using Melia azedarach against in vitro HeLa cell lines and lymphoma mice model", Process Biochem, vol. 47, pp. 273–279, 2011.

[30] T. Santhoshkumar, A. A. Rahuman, G. Rajakumar, S. Marimuthu, A. Bagavan, C. Jayaseelan, " Synthesis of silver nanoparticles using Nelumbo nucifera leaf extract and its larvicidal activity against malaria and filariasis vectors", Parasitol Res, vol. 108, pp. 693–702, 2011.

[31] S. P. Dubey , M. Lahtinen , M. Sillanpaa, "Green synthesis and characterizations of silver and gold nanoparticles using leaf extract of Rosa rugosa",Colloids Surf A, vol. 364, pp. 34–41, 2010.

[32] A. Nabikhan, K. Kandasamy, A. Raj, N. M. Alikunhi, " Synthesis of antimicrobial silver nanoparticles by callus and leaf extracts from saltmarsh plant, Sesuvium portulacastrumL", Colloids Surf B: Biointerfaces, vol. 79, pp. 488–93, 2010.

[33] S. J. Gogoi, "Green synthesis of silver nanoparticles from leaves extract of ethnomedicinal plantsPogostemon benghalensis (B) O", Ktz. Adv Appl Sci Res, vol. 4, no. 4, pp. 274–8, 2013.

[34] B. Sadeghi, A. Rostami, S. S. Momeni, " Facile green synthesis of silver nanoparticles using seed aqueous extract of Pistacia atlanticaand its antibacterial activity", Spectrochim Part A: Mol Biomol Spectrosc, vol. 134, pp. 326–32, 2015.

[35] A. Rout, P. K. Jena, U. K. Parida, B. K. Bindhani, "Green synthesis of silver nanoparticles using leaves extract of Centella asiatica L. For studies against human pathogens", Int J Pharm Biol Sci, vol. 4, no. 4, pp. 661–74, 2013.

[36] R. Thombre, F. Parekh, N. Patil, “Green synthesis of silver nanoparticles using seed extract of Argyreia nervosa”, Int J Pharm Biol Sci, vol. 5, no. 1, pp. 114–9, 2014.

[37] M. J. Firdhouse, P. Lalitha, “Green synthesis of silver nanoparticles using the aqueous extract ofPortulaca oleracea (L)”, Asian J Pharm Clin Res, vol. 6, no. 1, pp. 92–4, 2012.

[38] S. Mondal, N. Roy, R. A. Laskar, I. Sk, S. Basu, D. Mandal, “Biogenic synthesis of Ag, Au and bimetallic Au/Ag alloy nanoparticles using aqueous extract of mahogany (Swietenia mahogani JACQ) leaves”, Colloids Surf B Biointerfaces, vol. 82, pp. 497–504, 2011.

[39] T. Elavazhagan, K. D. Arunachalam, “Memecylon eduleleaf extract mediated green synthesis of silver and gold nanoparticles”, Int J Nanomed, vol. 6, pp. 1265–78, 2011.

[40] D. Jain, H. K. Daima, S. Kachhwaha, S. Kothari, ”Synthesis of plant-mediated silver nanoparticles using papaya fruit extract and evaluation of their antimicrobial activities”, Dig J Nanomater Biostruct, vol. 4, pp. 557–63, 2009.

[41] K. Vijayaraghavan , S. Nalini, N. U. Prakash , D. Madhankumar, “ One step green synthesis of silver nano/microparticles using extracts of Trachyspermum ammi and Papaver somniferum”, Colloids Surf B Biointerfaces, vol. 94, pp. 114–7, 2012.

[42] B. Ulug, M. HalukTurkdemir, A. Cicek, A. Mete, “Role of irradiation in the green synthesis of silver nanoparticles mediated by fig (Ficus carica) leaf extract”, Spectrochim Part A: Mol Biomol Spectrosc, vol. 135, pp. 153–61, 2015.

[43] M. Gondwal, G. J. N. Pant, “Biological evaluation and green synthesis of silver nanoparticles using aqueous extract of Calotropis procera”, Int J Pharm Biol Sci, vol. 4, no. 4, pp. 635–43, 2013.

[44] J. Kesharwani, K. Y. Yoon, J. Hwang, M. Rai, “Phytofabrication of silver nanoparticles by leaf extract of Daturametel: hypothetical mechanism involved in synthesis”, J Bionanosci, vol. 3, pp. 39–44, 2009.

[45] G. Gnanajobitha, K. Paulkumar, M. Vanaja, S. Rajeshkumar, C. Malarkodi, G. Annadurai, C. Kannan, “Fruit-mediated synthesis of silver nanoparticles using Vitis vinifera and evaluation of their antimicrobial efficacy”, vol. 3, no. 67, pp. 1–6, 2013.

[46] S. Ankanna, T. N. V. K. V. Prasad, E.K. Elumalai, N. Savithramma, “Production of biogenic Silver nanoparticles using Bosvellia ovalifoliolata stem bark”, Dig J Nanomater Bios, vol. 5, pp. 369–372, 2010.

[47] M. Vanaja, S. Rajeshkumar, K. Paulkumar, C. Gnanajobitha, C. Malarkodi, G. Annadurai, “ Phytosynthesis and characterization of silver nanoparticles using stem extract of Coleus aromaticus”, International Journal of Materials and Biomaterials Applications, vol. 3, no. 1, pp. 1-4, 2013.

[48] A. R. Vilchis-Nestor , V. Sánchez-Mendieta , M. A. CamachoLópez , R. M. Gómez-Espinosa, J. A. Alatorre, “ Solventless synthesis and optical properties of Au and Ag nanoparticles using Camellia sinensis extract”, Mater Lett., vol. 62, pp. 3103–5, 2008.

[49] M. Sathishkumar , K. Sneha, Y. S. Yun, “Immobolization of silver nanoparticles synthesized using Curcuma longa tuber powder and extract on cotton cloth for bactericidal activity”, Bioresource technology, vol. 101, pp. 7058-7965, 2010.

[50] A. K. Mittal, A. Kaler, U. C. Banerjee, “Free radical scavenging and antioxidant activity of silver nanoparticles synthesized from flower extract of Rhododendron dauricum”, Nano BioMed Eng, vol. 4, pp. 118–24, 2012.

[51] J. R. Nakkala, R. Mata, A. K. Gupta, S. R. Sadras, “Green synthesis and characterization of silver nanoparticles usingBoerhaavia diffusaplant extract and their antibacterial activity”, Indus CropProd”, vol. 52, pp. 562–6, 2014.

[52] S. A. Masurkar, P. R. Chaudhari, V. B. Shidore, S. P. Kamble, “Rapid biosynthesis of silver nanoparticles usingCymbopogan Citratus (Lemongrass) and its antimicrobial activity”, Nano-Micro Lett, vol. 3, no. 3, pp. 189–94, 2011.

[53] S. Kumar, R. M. Daimary, M. Swargiary, A. Brahma, S. Kumar, M. Singh, “ Biosynthesis of silver nanoparticles usingPremna herbaceaIeaf extract and evaluation of its antimicrobial activity against bacteria causing dysentery”, Int J Pharm Biol Sci, vol. 4, no. 4, pp. 378–84, 2013.

[54] V. Kathiravan, S. Ravi, S. A. kumar, “Synthesis of silver nanoparticles from Meliadubia leaf extract and their in vitro anticancer activity”, Spectrochim Acta Part A: Mol Biomol Spectrosc, vol. 130, pp. 116–21, 2014.

[55] N. N. Rupiasih, A. Aher, S. Gosavi, P. B. Vidyasagar, “Green synthesis of silver nanoparticles using latex extract of Thevetia peruviana: a novel approach towards poisonous plant utilization”, J Phys Conf Ser, vol. 423, pp. 1–8, 2013.

[56] R. Veerasamy, T. Z. Xin, S. Gunasagaran, T. F. W. Xiang, E. F. C. Yang, N. Jeyakumar, “Biosynthesis of silver nanoparticles using mangosteen leaf extract and evaluation of their antimicrobial activities”, J Saudi Chem Soc, vol. 15, pp. 113–20, 2010.

[57] C. Krishnaraj, E. Jagan, S. Rajasekar, P. Selvakumar, P. Kalaichelvan, N. Mohan, “Synthesis of silver nanoparticles usingAcalypha indicaleaf extracts and its antibacterial activity against water borne pathogens”, Colloids Surf B Biointerfaces, vol. 76, pp. 50–56, 2010.

[58] S. Kaviya, J. Santhanalakshmi, B. Viswanathan, J. Muthumary, K. Srinivasan, “ Biosynthesis of silver nanoparticles usingCitrus sinensispeel extract and its antibacterial activity”, Spectrochem Acta A Mol Biomol Spectrosc, vol. 79, pp. 594–8, 2011.

[59] A. D. Dwivedi, K. Gopal, “Biosynthesis of silver and gold nanoparticles using Chenopodium album leaf extract”, Colloids Surf A, vol. 369, pp. 27–33, 2010.

[60] Q. Suna, X. Cai, J. Li, M. Zheng, Z. Chenb, C. P. Yu, “ Green synthesis of silver nanoparticles using tea leaf extract and evaluation of their stability and antibacterial activity” , Colloid Surf A: Physicochem Eng Aspects, vol. 444, pp. 226–31, 2014.

[61] R. Mariselvam, A. J .A. Ranjitsingh, A. U. R. Nanthini, K. Kalirajan, C. Padmalatha, M. P. Selvakumar, “ Green synthesis of silver nanoparticles from the extract of the inflorescence of Cocos nucifera(Family: Arecaceae) for enhanced antibacterial activity”, Spectrochim Part A: Mol Biomol Spectrosc, vol. 129, pp. 537–41, 2014.

[62] A. S. Kumar, S. Ravi, V. Kathiravan, “Green synthesis of silver nanoparticles and their structural and optical properties”, Int J Curr Res, vol. 5, no. 10, pp. 3238–40, 2013.

[63] M. Zargar, A. A. Hamid, F. A. Bakar, M. N. Shamsudin, K. Shameli, F. Jahanshiri, “Green synthesis and antibacterial effect of silver nanoparticles using Vitexnegundo L”, Molecules, vol. 16, pp. 6667–76, 2011.

[64] A. Bankar, B. Joshi, A. R. Kumar, S. Zinjarde, “ Banana peel extract mediated novel route for the synthesis of silver nanoparticles”, Colloids Surf A, vol. 368, pp. 58–63, 2010.

[65] X. Yang , Q. Li , H. Wang , J. Huang , L. Lin , W. Wang, “Green synthesis of palladium nanoparticles using broth of Cinnamomum camphora leaf”, J Nanopart Res., vol. 12, pp. 1589–98, 2010.

[66] B. Ankamwar, C. Damle, A. Ahmad, M. Sastry, “Biosynthesis of gold and silver nanoparticles using Emblica officinalis fruit extract, their phase transfer and transmetallation in an organic solution”, J Nanosci Nanotechnol, vol. 5, pp. 1665–1671, 2005.

[67] M. Vivek, P. S. Kumar, S. Steffi, S. Sudha, “Biogenic silver nanoparticles by Gelidiella acerosa extract and their antifungal effects”, Avicenna J Med Biotechnol, vol. 3, pp. 143–8, 2011.

[68] A. Nabikhan, K. Kandasamy, A. Raj , N. M. Alikunhi, “Synthesis of antimicrobial silver nanoparticles by callus and leaf extracts from saltmarsh plant, Sesuvium portulacastrum L”, Colloids Surf B Biointerfaces, vol. 79, pp. 488–93, 2010.

[69] N. K. Mondal, A. Chowdhury, U. Dey, P. Mukhopadhya, S. Chatterjee, K. Das, J. K. Datta, “Green synthesis of silver nanoparticles and its application for mosquito control”, Asian Pac J Trop Dis, 4(Suppl 1):S204–S210, 2014.

[70] B. Sadeghi, F. Gholamhoseinpoor, " A study on the stability and green synthesis of silver nanoparticles using Ziziphora tenuior (Zt) extract at room temperature", Spectrochim Acta Part A: Mol Biomol Spectrosc, vol. 134, pp. 310–5, 2015.
[71] N. Geetha, T. S. Geetha, P. Manonmani, M. Thiyagarajan, "Green synthesis of silver nanoparticles using Cymbopogan Citratus (Dc) Stapf. Extract and its antibacterial activity", Aus J Basic Appl. Sci, vol. 8, no. 3, pp. 324–31, 2014.
[72] K. B. Narayanan, H. H. Park. "Antifungal activity of silver nanoparticles synthesized using turnip leaf extract (Brassica rapa L.) Against wood rotting pathogens", Eur J Plant Pathol vol. 140, pp. 185–92, 2014.
[73] S. Kaviya, J. Santhanalakshmi, B. Viswanathan , J. Muthumary, K. Srinivasan, "Biosynthesis of silver nanoparticles using Citrus sinensis peel extract and its antibacterial activity", Spectrochim Acta A Mol Biomol Spectrosc, vol. 79, pp. 594–598, 2001.
[74] S. Arulkumar, M. Sabesan, " Biosynthesis and characterization of gold nanoparticle using antiparkinsonian drug Mucuna pruriens plant extract", Int. J. Res. Pharm. Sci., vol. 1, pp. 417-420, 2010.
[75] S. P. Dubey, M. Lahtinen, M. Sillanpaa, "Tansy fruit mediated green synthesis of silver and gold nanoparticles", Process Biochem., vol. 45, pp. 1065–1071, doi:10.1016/j.procbio.2010.03.024, 2010b.
[76] D. Kumarasamyraja, N. S. jeganathan, "Green synthesis of silver nanoparticles using aqueous extract of acalypha indica and its antimicrobial activity", Int J Pharm Biol Sci, vol. 4, no. 3, pp. 469–76, 2013.
[77] V. Subramanian, "Green synthesis of silver nanoparticles using Coleus amboinicus lour, antioxitant activity and invitro cytotoxicity against Ehrlich's Ascite carcinoma, J Pharm Res., vol. 5, pp. 1268–72, 2012.
[78] A. Pyatenco, K. Shimokawa, M. Yamagichi, O. Nishimiura, M. Suzuki, "Synthesis of silver nanoparticles by laser ablation in pure water", Applied Physics A, vol. 79, num. 4-6, pp. 803-806, 2004.
[79] A. V. Simakin, V. V. Voronov, N. A. Kirichenko, G. A. Shafeev, "Nanoparticles produced by laser ablation of solids in liquid environment", Applied Physics A, vol. 79, num. 4-6, pp. 1127-1132, 2004.
[80] V. Amendola, S. Polizzi, M. M. Langmuir, "Free silver nanoparticles synthesized by laser ablation in organic solvents and their easy functionalization", American Chem-ical Society, vol. 23, num. 12, pp. 6766-6770, 2007.
[81] W. T. Nichols, J. W. Keto, D. E. Henneke, J. R. Brock, G. Malyavanatham, M. F. Becker, H. D. Glicksman, "Large-scale production of nanocrystals by laser ablation of microparti-cles in a flowing aerosol", Appl. Phys. Lett., vol. 78, pp. 1128-1130, 2001.
[82] W. T. Nichols, G. Malyavanatham, D. E. Henneke, J. R. Brock, M. F. Becker, J. W. Keto, H. D. Glicksman, "Gas and Pressure Dependence for the Mean Size of Nanoparticles Produced by Laser Ablation of Flowing Aerosols", J. Nanopart. Res., vol. 2, no. 2, pp. 141-145, 2000.
[83] D. D. Evanoff Jr, G. Chumanov,"Synthesis and Optical Properties of Silver Nanoparticles and Arrays", ChemPhysChem, vol. 6, pp. 1221 – 1231, 2005.
[84] V. K. LaMer, R. H. Dinegar, "Theory, Production and Mechanism of Formation of Monodispersed Hydrosols", J. Am. Chem. Soc., vol. 72, pp. 4847-4854, 1950.
[85] S. P. Gubin, N. A. Kataeva, "Coordination chemistry of nanoparticles", Russian Journal of Coordination Chemistry, vol. 32, pp. 883-893, 2006.
[86] J. Liu, J. B. Lee, D. H. Kim, Y. Kim, "Preparation of high concentration of silver colloidal nanoparticles in layered laponite sol, Colloids and Surfaces A: Physicochemical and Engi-neering Aspects", vol. 302, num. 1-3. , pp. 276-279, 2007.
[87] J. S. Kim, E. Kuk, K. N. Yu, J. H. Kim, S. J. Park, H. J. Lee, et al,"Antimicrobial effects of silver nanoparticles. Nanomedicine: Nanotechnology, Biology and Medicine", vol. 3, no. 1, pp. 95-101, 2007.
[88] Y. Matsumura, K. Yoshikata, S. Kunisaki, T. Tsuchido," Mode of bactericidal action of silver zeolite and its comparison with that of silver nitrate. Appl Environ Microbiol", vol. 69, pp. 4278-4281, 2003.
[89] J. R. Morones, J. L. Elechiguerra, A. Camacho, K. Holt, J. B. Kouri, M. J. Yacaman, "The bactericidal effect of silver nanoparticles" Nanotechnology, vol. 16, pp. 2346–2353, 2005.
[90] I. Sondi, B. Salopek-Sondi, "Silver nanoparticles as antimicrobial agent: A case study on E. coli as a model for Gramnegative bacteria", J Colloid Interface Sci, vol. 275, pp. 177–182, 2004.
[91] A. M. Fayaz, K. Balaji, M. Girilal, R. Yadav, P. T. Kalaichelvan, R. Venketesan, "Biogenic synthesis of silver nanoparticles and their synergistic effect with antibiotics: a study against gram-positive and gram-negative bacteria", Nanomedicine: Nanotechnology, Biology and Medicine, vol. 6, no. 1, pp. 103-109, 2010.
[92] M. A. Dar, A. Ingle, M. Rai, "Enhanced antimicrobial activity of silver nanoparticles synthesized by Cryphonectria sp. evaluated singly and in combination with antibiotics", Nanomedicine: Nanotechnology, Biology and Medicine, vol. 9, no. 1, pp. 105-110, 2013.
[93] S. J. Strydom, W. E. Rose, D. P. Otto, W. Liebenberg, M. M. de Villiers , "Poly (amidoamine) dendrimer-mediated synthesis and stabilization of silver sulfonamide nanoparticles with increased antibacterial activity", Nanomedicine: Nanotechnology, Biology and Medicine, vol. 9, no. 1, pp. 85-93, 2013.
[94] P. L. Nadworny, J. F. Wang, E. E. Tredget, R. E. Burrell, "Anti-inflammatory activity of nanocrystalline silver in a porcine contact dermatitis model", Nanomedicine: Nanotechnol-ogy, Biology and Medicine, 4 (3): 241-251, 2008.
[95] M. Banerjee, S. Mallick, A. Paul, A. Chattopadhyay, S. S. Ghosh, "Heightened Reactive Oxygen Species Generation in the Antimicrobial Activity of a Three Component Iodinat-ed Chitosan-Silver Nanoparticle Composite", Langmuir, vol. 26, pp. 5901–5908, 2010.
[96] S. Pal, Y. K. Tak, J. M. Song, "Does the antimicrobial activity of silver nanoparticles depend on the shape of the nanoparticle? Astudy of the gram-negative bacterium Escherichia coli", Appl Environ Microbiol, vol. 73, pp. 1712–1720, 2007.
[97] G. A. Martínez-Castañón, N. Niño-Martínez, F. Martínez-Gutierrez, J. R. Martínez-Mendoza, F. Ruiz, "Synthesis and antibacterial activity of silver nanoparticles with different sizes", J Nanoparticle Res, vol. 10, pp. 1343-1348, 2008.
[98] H. H. Lara, V. A. Nilda, L. C. I. Turrent, C. R. Padilla, "Bactericidal effect of silver nanoparticles against multidrug-resistant bacteria", World J Microbiol Biotechnol, vol. 26, pp. 615–621, 2010.
[99] A. Nanda, M. Saravanan, "Biosynthesis of silver nanoparticles from Staphylococcus aureus and its antimicrobial activity against MRSA and MRSE", Nanomedicine, vol. 5, pp. 452-456, 2009
[100] A. K. Popov, R. S. Tanke, J. Brummer, G. Taft, M. Loth, R. Langlois, A. Wruck, R. Schmitz, "Laser-stimulated synthesis of large fractal silver nanoaggregates", Nanotechnology, vol. 17, no. 8, pp. 1901, 2006.
[101] A. Moores, F. Goettmann, "The plasmon band in noble metal nanoparticles: an introduction to theory and applications", New J. Chem, vol. 30, pp. 1121, 2006.
[102] L. J. Sherry, S. H. Chang, G. C. Schatz, R. P. Van Duyne, "Localized surface plasmon resonance spectroscopy of single silver nanocubes", Nano Lett, vol. 5, pp. 2034, 2005.

[103] A. Henglein, “Physicochemical properties of small metal particles in solution: "microelectrode" reactions, chemisorption, composite metal particles, and the atom-to-metal transi-tion”, J. Phys. Chem., Vol. 97, pp. 5457-5471, 1993

[104] R. Jin, Y. C. Cao, E. Hao, G. S. MeÂtraux, G. C. Schatz, C. A. Mirkin, “Controlling anisotropic nanoparticle growth through plasmon excitation”, Nature (London), vol. 425, pp. 487, 2003.

[105] I. Khan, D. Cunningham, R. E. Littleford, D. Graham, W.E. Smith, D.W. McComb, “From micro to nano: analysis of surface-enhanced resonance Raman spectroscopy active sites via multiscale correlations”, Anal. Chem, vol. 78, pp. 224, 2006

[106] J. Lin, R. Chen, S. Feng, J. Pan, Y. Li, G. Chen, et al, “A novel blood plasma analysis technique combining membrane electrophoresis with silver nanoparticle-based SERS spec-troscopy for potential applications in noninvasive cancer detection”, Nanomedicine: Nanotechnology, Biology and Medicine, vol. 7, no. 5, pp. 655-663, 2011.

[107] H. Cao, X. Liu, F. Meng, P. K. Chu, “Silver nanoparticles-modified films versus biomedical device-associated infections”, Wiley Interdiscip. Rev. Nanomed. Nanobiotechnol, Vol. 2, pp. 670–684, 2010.

[108] N. Rescignano, I. Armentano, “Biopolymeric Nanoparticles with a Silver Core for Biomedical Application, Institute of Polymer Science and Technology”, pp. 301-318.

[109] K. H. L. Kwan, X. L. Liu, M. K. T. To, K. W. K. Yeung, C. M. Ho, K. K. Y. Wong, “Modulation of collagen alignment by silver nanoparticles results in better mechanical properties in wound healing”, Nanomedicine: Nanotechnology, Biology and Medicine , vol. 7, no. 4, pp. 497-504, 2011.

[110] M. Trop, M. Novak, S. Rodl, B. Hellbom, W. Kroell, W. Goessler, “Silver-coated dressing acticoat caused raised liver enzymes and argyria-like symptoms in burn patient”, J. Traum, vol. 60, pp. 648–652, 2006.

[111] K. K. Y. Wong, X. Liu, “Silver nanoparticles—the real silver bullet in clinical medicine” Med. Chem, Commun, vol. 1, pp. 125–131, 2010.

[112] R. W. Y. Sun, R. Chen, N. P. Y. Chung, C. M. Ho, C. L. S. Lin, C. M. Che, “Silver nanoparticles fabricated in hepes buffer exhibit cytoprotective activities toward HIV-1 infected cells” Chem. Commun, pp. 5059–5061, 2005.

[113] A. Majdalawieh, M. C. Kanan, O. E. Kadri, S. M. Kanan,” Recent advances in gold and silver nanoparticles: synthesis and applications”, J Nanosci Nanotechnol, vol. 14, no. 7, pp. 4757-4780, 2014.

[114] S. H. Shin, M. K. Ye, H. S. Kim, H. S. Kang, “The effects of nano-silver on the proliferation and cytokine expression by peripheral blood mononuclear cells” Int. Immunopharmacol, vol. 7, pp. 1813–1818, 2007.

[115] C. Loo, A. Lowery, N. Halas, J. West, R. Drezek, “Immunotargeted nanoshells for integrated cancer imaging and therapy”, Nano Lett, vol. 5, pp. 709–711, 2005.

[116] T. Walser, E. Demou, D. J. Lang, S. Hellweg, “Prospective environmental life cycle assessment of nanosilver t-shirts”, Environ. Sci. Technol, vol. 45, pp. 4570–4578, 2011.

[117] T. M. Benn, P. Westerhoff, “Nanoparticle silver released into water from commercially available sock fabrics. Environ” Sci. Technol, vol. 42, pp. 4133–4139, 2008.

[118] M. Cushen, J. Kerry, M. Morris, M. Cruz-Romero, E. Cummins, “Nanotechnologies in the food industry - recent developments, risks and regulation”, Trends Food Sci. Tech, vol. 24, pp. 30–46, 2012.

[119] Y. Huang, S. Chen, X. Bing, C. Gao, T. Wang,; B. Yuan, “Nanosilver migrated into food—Simulating solutions from commercially available food fresh containers. Packag” Technol. Sci, vol. 24, pp. 291–297, 2011.

[120] O. Brandt, M. Mildner, A. E. Egger, M. Groessl, U. Rix, M. Posch, et al. “Nanoscalic silver possesses broad-spectrum antimicrobial activities and exhibits fewer toxicological side effects than silver sulfadiazine” Nanomedicine: Nanotechnology, Biology and Medicine, vol. 8, no. 4, pp. 478-488, 2012.