A Review on Synthesis Silver Nano-Particles

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Abstract

Nanotechnology could be a very important field of modern research dealing with design, synthesis, and manipulation of particle structures ranging from approximately 1-100 nm. Silver nanoparticles are the topics of researchers because of their distinctive properties (e.g., size and shape depending optical, antimicrobial, and electrical properties). A variety of preparation techniques have been reported for the synthesis of nanoparticles such as physical, chemical and biological synthetic methods. Nowadays, there is a growing need to develop clean, reliable and environment friendly processes, that they do not use toxic chemicals within the synthesis protocols. Green synthesis approaches include mixed-valence polyoxo metalates, polysaccharides, Tollens, biological, and irradiation method which have advantages over conventional methods involving chemical agents associated with environmental toxicity. This manuscript presents an overview of silver nanoparticle synthesis by using physical, chemical, and biological approach.

Keywords
Nanoparticle, Synthesis, Silver nanoparticle, Mechanism.

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Introduction

Nanotechnology could be a quickly increasing field and has been probably utilized in a large assortment of economic product worldwide. Over the last few years, the engineering and scientific communities have been visualizing remarkable progress in the field of nanoscience and technology (Jha et al., 2014). Nanotechnology deals with small structures and materials with dimensions ranging from a few nanometers to less than 100 nanometers (Sharma and Bhargava, 2013).

The use of the term "nanotechnology" was developed to include a complete range of technologies: material sciences, where the designs of new materials for wide-ranging applications were related; to electronics, where memories, computers, components and semiconductors are related; to biotechnology, where new drug delivery and diagnostics systems are concerned (Bhatt, 2003). Some microorganisms, together with microorganism, yeast, and filament-like fungi play a crucial role within their mediation of poisonous metals through the reduction of the metal ions; thus, these microorganisms may well be used as nano-factories for nanoparticle production (Fortin and Beveridge, 2000).
Nanoparticles are also synthesized by varying approaches along with chemical, physical and biological (Iravani et al., 2014). The chemical technique of synthesis wants short quantity of it slow for the synthesis of the giant quantity of nanoparticles, this system wants capping agents for size stabilization of the nanoparticles. Chemicals used for nanoparticles synthesis and stabilization area unit cyanogenic and lead to non-ecofriendly by-products (Chikdu et al., 2015). The need for environmental non-toxic artificial protocols for nanoparticles synthesis finally ends up within the developing interest in biological approaches that are free from the employment of cyanogenic chemicals as by-products. Thus, there is an associate increasing demand for “green nanotechnology”.

Many studies have shown that metal nanoparticles, like gold, silver, gold-silver alloy, selenium, tellurium, platinum, palladium, silica, titanium, zirconium, quantum dots and iron ore is biosynthesized by various microorganism such as actinomycetes, fungi and viruses. Endophytes comprise of a very numerous cluster of microorganisms that are present in plants and maintain a well and unassertive union with their hosts for a minimum of an amount of their life cycle (Kusari et al., 2012). Fusarium spp. is filament-like fungi that are cosmopolitan in soil, water, subterranean and aerial plant elements, plant rubbish and different organic substrates (Nelson et al., 1994).

Nanotechnology is rapidly gaining importance in a number of areas such as health care, environmental health, biomedical sciences, chemical industries, drug-gene delivery, catalysis applications (Bindhiani and Panigrahi, 2014). An increasingly common application is the use of silver nanoparticles for antimicrobial coatings, medical textiles, wound dressings, and biomedical devices now contain silver nanoparticles that continuously release a low level of silver ions to provide protection against pathogenic bacteria.

The size, shape, and surface morphology of NP’s play an important role in dominant their physical, chemical, optical, and electronic properties. The NP’s that attract the eye of most researchers are made from bulk silver and gold (Gade et al., 2008). Nanoparticles can be engineered for shape, chemical nature, size, surface properties, surface modification to transmit special functionalities such as improved strength, catalytic properties and enhanced electrical and thermal conductivity. Different features of the engineered nanoparticles were shown in figure 1.

**Various methods for nanoparticle synthesis**

Silver nanoparticles are often synthesized by varying approaches. For example, silver ions can be reduced by chemical (Sun et al., 2002), electro-chemical (Yin et al., 2003), Langmuir-Blodgett (Zhang et al., 2006; Swami et al., 2004), phytochemical methods (Callegari et al., 2003), radiation (Dimitrijevic et al., 2001) and biological techniques (Naik et al., 2002). Plant extract plays an important role in the synthesis of nanoparticles as reducing agents and stabilizing agents (Kumar et al., 2009). Silver has long been known to exhibit a strong toxicity to a wide range of micro-organisms (Liao et al., 1997) for these reasons silver-based compounds have been used extensively in many bactericidal applications (Gupta et al., 1998; Nomiya et al., 2004). Silver nanoparticles can be synthesized by various types of methods (Figure 2).

**Chemical approach for synthesis of silver nanoparticles**

The production of nanoparticles majorly involves physical and chemical processes. Silver nanomaterials could also be obtained
by every the alleged ‘top-down’ and ‘bottom-up’ ways that. The top-down technique involves the mechanical grinding of bulk metals and resultant stabilization of the following nanosized metal particles by the addition of mixture protecting agents (Gaffet et al., 1996; Amulyavichus et al., 1998). The bottom-up ways that on the alternative hand embraces reduction of metals, natural science ways and sonodecomposition. A microwave synthesis of silver nanoparticles involves the reduction of silver nanoparticles by variable frequency microwave radiation as against the normal heating technique. The plan of action yields a faster reaction and offers an improved concentration of silver nanoparticles with identical temperature and exposure.

The most common approach for the synthesis of silver nanoparticles is a chemical reduction by organic and inorganic reducing agents. In general, completely different reducing agents like sodium citrate, ascorbate, sodium borohydride (NaBH₄), elemental hydrogen, polyol method, Tollens chemical agent, N, N-dimethylformamide (DMF) and poly-ethylene glycol block copolymers are used for reduction of silver ions (Ag⁺) in liquid or non-aqueous solutions. The same reducing agents cut back silver ions (Ag⁺) and result in the formation of metallic silver (Ag⁰), which is followed by agglomeration into oligomeric clusters. These clusters eventually result in the formation of metallic mixture silver particles (Wiley et al., 2005; Merga et al., 2007; Evanoff, 2004). It's necessary to use protecting agents to stabilize dispersive nanoparticles throughout the course of metal nanoparticle preparation and shield the nanoparticles that may be absorbed on or bind into nanoparticle surfaces, avoiding their agglomeration (Oliveira et al., 2005). The presence of surfactants comprising functionalities (e.g., thiols, amines, acids, and alcohols) for interactions with particle surfaces will stabilize particle growth, and shield particles from the geological phenomenon, agglomeration, or losing their surface properties.

Recently, an easy one-step method, Tollens technique, has been used for the synthesis of silver nanoparticles with a controlled size (Iravani et al., 2014). Within the changed Tollens procedure, silver ions are reduced by saccharides within the presence of ammonia, yielding silver nanoparticle films (50-200 nm), silver hydrosols (20-50 nm) and silver nanoparticles of various shapes (Yin et al., 2002).

**Physical approaches for synthesis of silver nanoparticles**

Most important physical approaches embrace evaporation-condensation and optical device ablation. Varied metal nanoparticles like silver, gold, lead sulphide, sulfide, and carbon have been synthesized victimization by the evaporation-condensation methodology. The absence of solvent contamination within the ready skinny films and also the uniformity of nanoparticles distribution square measure the benefits of physical approaches as compared with chemical processes (Kruijs and Rellinghaus, 2000; Magnusson et al., 1999). It absolutely was incontestable that silver nanoparticles may be synthesized via a tiny, low ceramic heater with a neighbourhood heating supply (Jung et al., 2006).

The gaseous vapour will cool at an appropriate speed rate, as a result of the gradient within the neighbourhood of the heater surface is incredibly steep as compared therewith of a tube chamber. This makes attainable the formation of tiny nanoparticles in high concentration. This physical methodology is helpful as a nanoparticle generator for long-run experiments for inhalation toxicity studies, and as an activity device for nanoparticle measure instrumentality (Jung et al., 2006).
Silver nanoparticles may be synthesized by optical device ablation of tiny bulk materials in solution (Mafune et al., 2001; Mafune et al., 2000; Kabashin, 2003; Dolgaev et al., 2002; Sylvestre et al., 2004). The ablation potency and also the characteristics of creating nanosilver particles rely upon several factors like the wavelength of the optical device contact the tinny target, the length of the optical device pulses (in the femto-, pico- and unit of time regime), the laser fluence, the ablation time length and also the effective liquid medium, with or while not the presence of surfactants (Kim et al., 2005; Link et al., 2000; Kawasaki, 2006; Tarasenko et al., 2006). One vital advantage of the optical device ablation technique compared to alternative strategies for production of metal colloids is that the absence of chemical reagents in solutions. Therefore, pure and uncontaminated metal colloids for more applications are ready by this method (Tsuji et al., 2002).

**Biological synthesis of silver nanoparticles**

Although chemical and physical methods are considered to be successful methods to produce well-defined nanoparticles, but they have certain limitations like an increase in the cost of production, the release of hazardous by-products, long time for synthesis and difficulty in purification (Nagajyothi and Lee, 2011).

It's degree inevitable proven fact that the silver nanoparticles synthesized need to be handled by humans and may be procurable at cheaper rates for his or her effective utilization; therefore, there is a need for degree environmentally and economically potential due to synthesize these nanoparticles. The growing needs to be compelled to develop environmentally friendly and economically potential technologies for material synthesis junction rectifier to the design for biomimetic ways in which of synthesis (Kalishwaralal et al., 2008).

Ahmed et al., (2016) reported three major sources of synthesizing silver nanoparticles: bacteria, fungi, and plant extracts (Table 1). The three major elements involved in the preparation of nanoparticles by biological ways in which are the solvent medium for synthesis, the environmentally friendly reducer, and a nontoxic useful agent (Iravani et al., 2014).

However, the natural event of infectious diseases caused by antibiotic-resistant infective microorganism has brought the main focus back on the silver and its mixture forms. At present, clothing, nine respirators, family water filters, contraceptives, antibacterial sprays, cosmetics, detergent, dietary supplements, cell phones, laptop computer keyboards, and children's toys are among the merchandise being marketed that supposedly exploit the antimicrobial properties of silver nanomaterials (Mirjalili et al., 2013).

**Nanoparticles synthesized from bacteria**

Inorganic nanoparticles like silver, gold, silicon oxide, magnesium, cadmium sulphide can be synthesized by many organisms. The resistance for silver ions caused by the bacterial cell in their environment is responsible for nanoparticles synthesis (Saklani et al., 2012).

The primary proof of microorganism synthesizing silver nanoparticles was established by the bacterium bacteria genus *Pseudomonas stutzeri* AG259 strain that was isolated from mine (Haefeli et al., 1984). The important and widely accepted mechanism of silver biogenesis is that the presence of the enzyme nitrate reductase (Kumar et al., 2007). The accelerator converts nitrate into
nitrite. In in vitro synthesis of silver by microorganisms, the presence of alphanicotinamide purine dinucleotide phosphate reduced kind (NADPH)-dependent nitrate protein would remove the downstream method step that is required in different cases (Prabhu and Poulouse, 2012).

Throughout the reduction, nitrate is regenerate into cluster and conjointly the lepton is transferred to the silver ion; hence, the silver particle is reduced to silver (Ag⁺ to Ag⁰). Various bacteria is used for synthesis of silver nanoparticles are Pseudomonas stutzeri (Klaus et al., 1999), Bacillus megaterium (Fu et al., 1999), Plectonema boryanum (Lengke et al., 2007), Enterobacter cloacae (Minaeian et al., 2008), Escherichia coli (El-Shanshouy et al., 2011), Bacillus licheniformis (Kalimuthu et al., 2008), Lactobacillus fermentum (Sintubin et al., 2009), Klebsiella pneumonia (Mokhtari et al., 2009), Proteus mirabilis (Samadi et al., 2009), Brevibacterium casei (Kalishwaralal et al., 2010).

Nanoparticles synthesized from fungi

If a comparison of fungi is made with bacteria then, fungi can manufacture larger amounts of nanoparticles as a result of secreting large amounts of proteins that directly translate to higher productivity of nanoparticles (Mohanpuria et al., 2008).

The mechanism of silver nanoparticle production by fungi is purported to the subsequent steps: trapping of Ag⁺ ions at the surface of the fungal cells and additionally the next reduction of the silver ions by the enzymes gift at intervals the fungal system (Mukherjee et al., 2001). The accelerators like NADPH-dependent nitrate reductase and a shuttle quinine extracellular process are a unit responsible for nanoparticle formation (Ahmad et al., 2003). A significant disadvantage of the microbes to synthesize silver nanoparticles is that it is an extremely slow technique once compared with plant extracts (Tashi et al., 2016).

Hence, the employment of plant extracts to synthesize silver nanoparticles becomes associate chance that is potential. Various fungi used for the synthesis of silver nanoparticles are Verticillium sp. (Mukherjee et al., 2001), Phoma sp. 3.2883 (Chen et al., 2003), Fusarium oxysporum (Duran et al., 2005), Phanerochaete chrysosporium (Vigneshwaran et al., 2006), Aspergillus fumigates (Bhainsa et al., 2006), Aspergillus flavus (Vigneshwaran et al., 2007), Fusarium semitectum (Basavaraja et al., 2008), Coriolus versicolor (Singaravelu et al., 2005), Fusarium solani (Gade et al., 2009), Aspergillus clavatus (Verma et al., 2010).

Nanoparticles synthesized by algae

In the plant kingdom, algae are diverse groups that are being explored for their application in nanotechnology. Hosea et al., (1986) reported the synthesis of Au nanoparticles on the alga Chlorella vulgaris. Lengke et al., (2006) reported the synthesis of Au nanoparticles having controlled shape by using the blue-green algae Plectonema boryanum by treating them with aqueous Au (S₂O₃)₃ and AuCl₄ solutions.

Singaravelu et al., (2007) reポートed the rapid formation of gold nanoparticles through extracellular biosynthesis in marine alga Sargassum wightii. Scarano and Morelli, (2003) reported the fabrication of phytochelatin coated CDS nano crystals by using the phyto-planktonic algae Phaeodactulum tricornutum. Konishi et al., (2007) reported the synthesis of Pt nanoparticles of 5 nm from aqueous PtCl₆²⁻ at neutral pH under room temperature by using Shewanella algae.
Table 1 Synthesis of different nanoparticles from biological sources

| Biological sources | NP’s produced | NP’s size | NP’s shape | Applications | References                  |
|-------------------|--------------|-----------|------------|--------------|----------------------------|
| Bacteria          |              |           |            |              |                            |
| *Bacillus subtilis* | Ag           | 5-60 nm   | Spherical and triangular |             | [Saifuddin et al., 2009]   |
| *Pseudomonas aeruginosa* | Au          | 15-30 nm  | Quasi-spherical           |             | [Husseiny et al., 2007]   |
| *Rhodopseudomonas capsulate* | Au         | 20-25 nm  | Nanowires           | Antifungal and antibacterial | [He et al., 2008] |
| *Escherichia coli* | Pd           | 20-50 nm  | Spherical           |             | [Deplanche and Macaskie, 2008] |
| *K. pneumonia*    | Ag           | 40 nm     | -                |             | [Deplanche et al., 2008]  |
| Fungi             |              |           |            |              |                            |
| *Aspergillus fumigates* | Ag        | 5-25 nm   | -            |             | [Ratnasri and Hemalatha, 2014] |
| *Fusarium semitectum* | Ag          | 20-25 nm  | Spherical       | Antibacterial | [Basavaraja et al., 2008] |
| *Verticillium sp.* | Ag           | 20.25 nm  | Spherical       |             | [Mukherjee et al., 2001]  |
| Algae             |              |           |            |              |                            |
| *Diatoms*         | SiO$_2$      | 50-100 nm | -           | Antibacterial and antifungal | [Singaravelu et al., 2007] |
| *Sargassum algae* |              |           |            |              |                            |
| Yeast             |              |           |            |              |                            |
| *Yeast MKY3*      | Ag           | 2-5 nm    | Hexagonal     |             | [Kowshik et al., 2002]    |
| *Candida glabrata* | Cds          | 20 A$^0$  | -            |             | [Haverkamp et al., 2007]  |
| *Schizosaccharomyces* | Cds        | 1-1.5 nm  | Hexagonal     | Antibacterial | [Kowshik et al., 2002]    |
| *P. jadini*       | Au           | Few 100 nm | -            |             | [Gericke and Pinches, 2006] |
| Plants            |              |           |            |              |                            |
| *Medicago sativa* | Au           | 4-10 nm   | Fcc twinned, crystal, icosahedral |             | [Gardea et al., 2002]    |
| *Chilopsis linearis* | Au          | 1.1 nm    | fcc tetrahedral, decahedral, hexagonal, icosahedral multitwinned, irregular, and rod shape | Antibacterial and antifungal | [Armendariz et al., 2004] |
| *Cupressus torulosa* | Ag          |           |             |              |                                |
| *Pelargonium graveolens* | Au      | 21-70 nm  | Spherical rods, flat, sheets and triangular |             | [Rajput et al., 2016]  |
| *Medica gosativa* | Ag           | 2-20 nm   | Icosahedral   |             | [Shankar et al., 2003]    |
| *Azadirachta indica* | Ag         | 50-100 nm | core-shell structure |             | [Shankar et al., 2004]    |
Fig. 1 Various features contributing to the diversity of wide variety of engineered nanoparticles

Engineered Nanoparticles

- **Chemical nature:** Metals, metal oxides, semiconductors, polymers, carbon, biomolecules
- **Shape:** Spheres, cubes, cylinders or needles, hollow tubes or spheres, core/shell structures
- **Dispersion medium:** Gases (aerosols), liquids, solid matrix, gels
- **Dispersion state:** Individually dispersed, aggregated irreversibly, aggregated reversibly, ordered structure

**Surface modification:** Unmodified, grafting charged ligand, attachment of DNA, enzymes or other biomolecules, surface coatings

Fig. 2 Different methods of silver nanoparticles synthesis

Nanoparticles synthesis methods

- **Chemical method**
- **Physical method**
- **Irradiation method**
- **Sol-gel method**

**Microorganisms:** Bacteria, fungi, yeast, algae

**Plants:** Gymnosperms to...
Nanoparticles synthesized by yeast

Yeast was used for the synthesis of various types of nanoparticles. Some of the strains which were used for the synthesis of nanoparticles are Yeast MKY3 for the synthesis of silver nanoparticles (Kowshik et al., 2002), Candida glabrata and Schizo saccharomyces for the synthesis of CdS nanoparticles and Pichia jadini for the synthesis of gold nanoparticles.

Nanoparticles synthesized from plants

The most necessary advantage of the plant extracts for silver nanoparticle synthesis is that they are merely gettable, safe, and nontoxic in most cases, have a broad quite metabolites which will aid among the reduction of silver ions, and area unit quicker than microbes among the synthesis (Prabhu and Poulse, 2012). The main mechanism used for the process is a plant-assisted reduction as a result of phytochemicals. Some main phytochemicals are terpenoids, flavones, ketones, aldehydes, amides, and carboxylic acids. Flavones, organic acids, and quinones are water-soluble phytochemicals that area responsible for the immediate reduction of the ions. Studies have discovered that xerophytes contain emodin, associate anthraquinone that undergoes tautomerization, leading to the formation of the silver nanoparticles (Al-Samarrai, 2012). Among the case of mesophytes, it completely was found that they contain three types of benzoquinones: cyperoquinone, dietchequinone, and remirin. It completely understands that the phytochemicals area unit involved directly among the reduction of the ions and formation of silver nanoparticles (Jha et al., 2009). Although the precise mechanism involved in each plant varies as a result of the phytochemical involved varies, the main necessary mechanism involved is that the
reduction of the ions. Plant extracts area unit simple and convenient various to chemical and physical strategies used for the synthesis of silver nanoparticles. Various plant extracts used for the synthesis of metallic nanoparticles such as Neem (Shankar et al., 2004), Geranium (Shankar et al., 2003), Aloe vera (Chandran et al., 2006), Cinnamomum (Huang et al., 2007), Mushroom (Philip, 2009), Mangifera indica (Philip, 2010), Mangolia kobus (Song et al., 2009), Pear fruit (Ghodake et al., 2010) and Tulsi (Philip et al., 2011).

**Mechanism for the synthesis of nanoparticles through biological component**

A possible mechanism behind the synthesis of silver nanoparticles using bacteria Bacillus licheniformis was investigated by Kalimuthu and coworkers (Kalimuthu et al., 2008). The enzyme which is involved in the synthesis of silver nanoparticle belongs to nitrate reductase and also present in B. licheniformis. The presence of nitrate reductase enzyme is the most accepted mechanism of silver nanoparticles synthesis. The enzyme nitrate reductase reduces the silver ions to metallic silver by the electrons donated by NADH. NADH plays a very important role as a reducing agent to donate electrons (Fig. 3).

Similarly, the gold nanoparticles were prepared on the surface of bacteria cells as a result of incubation of bacteria with AuCl₄⁻ ions. On incubation, the bacteria Rhodopsseudomans capsulate was adapted to the AuCl₄ containing growth medium and causes the bioreduction of gold ions (He et al., 2007). The aqueous chloroaurate ions were reduced during the contact with the bacteria cell groups such as amino, sulfhydryl and carboxylic groups. These groups had the positive charge which depends on pH of the solution. The adsorption of AuCl₄⁻ ions on the surface of bacterial cell occurred and bioreduction of gold ions is initiated by electron transfer from NADH by NADH-dependent reductase as an electron carrier. Thus, gold ions reduced to gold.

Eukaryotic microorganisms such as fungi can be used to synthesize nanoparticles of different sizes and chemical composition (Sadowski, 2010). The extracellular synthesis of silver and gold–silver nanoparticles has been observed by fungus Fusarium oxysporum biomass (Ahmad et al., 2003). The whole credit for reduction of silver ions by Fusarium oxysporum goes to the enzyme nitrate-dependent reductase and a shuttle quinine extracellular process.

The synthesis of silver particles using soil dwelled Aspergillus niger strains was investigated by Sadowski et al., (2008a, 2009b). The capacity of silver nanoparticles production has been dependent on the reductase/electron shuttle relationships. The extracellular enzymes such as naphthoquinones and anthraquinones showed excellent redox properties, they can act as electron shuttle in silver ions reduction (Sahayaraj et al., 2011).

Plants are easily available, safe, and nontoxic contains a variety of metabolites that can help in the reduction of metal ions. It was reported that plants extracts contain biomolecules including polyphenols, ascorbic acid, flavonoids, sterols, triterpenes, alkaloids, alcoholic compounds, polysaccharides, saponins, β-phenylethylamines, glucose and fructose, and proteins/enzymes which could be used as reductant to react with silver ions and therefore used as scaffolds to direct the formation of AgNPs in the solution (Prasad, 2014). It was also considered that some biomolecules like glucose and ascorbate reduce AgNO₃ and HAuCl₄ to form nanoparticles. In neem leaf broth, terpenoids
are the surface active molecules stabilizing the nanoparticles and reaction of the metal ions is possibly facilitated by reducing sugars (Shankar et al., 2004). The action of flavonoids resides mainly in their ability to donate electrons or hydrogen atoms. Hence, the presence of proteins, enzymes, phytochemicals within the plant extract reduces the silver salts and also provide excellent tenacity against agglomeration, which can be further studied to understand the mechanism of evolution by biological systems (Saxena et al., 2012).

In the recent years, noble nanoparticles have attracted and emerged in the field of biology, medicine and electronics due to their incredible applications. There were several methods have been used for synthesis of nanoparticles such as toxic chemicals and high energy physical procedures. To overcome these, biological techniques has been used for the synthesis of various metal nanoparticles. From the biotechnological point of view, the silver nanoparticles have wide potential applications in the biomedical field and also the procedure of biosynthesis has several advantages such as cost-effectiveness, less time consuming, large-scale commercial production, and compatibility for medical and pharmaceutical applications.

Moreover, the biological approach, in particular the usage of natural organisms has offered a reliable, simple, nontoxic and environmental friendly method. Hence, this article is targeted on the biological synthesis of silver nanoparticles. Silver nanoparticles show variable applications so that these can be used in medical purposes, advanced portable gadgets and also be used in the production of cloths, leather items, and coating because silver nanoparticles can protect these items from the attack of various harmful microorganisms.

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