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# Synthesis paradigm and applications of silver nanoparticles (AgNPs), a review

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ABSTRACT

Nanoscience is an inspiring and influential discipline of science which have accessible numerous novel and cost-effective yields and applications. Currently, nanotechnology research has been empowering more in agricultural sector, food process and medicinal industries. The surface area to volume ratio of nanoparticles is quite large which have 1–100 nm size. Nanomaterials have superior bioavailability than larger particles, resulting in greater utilization in single cells, tissues and organs. Referable to the growing demand of nanoparticles, it is essential to build up synthetic method which is profitable, environmentally sustainable and which can substitutes with effective and competent technology to synthesis environmentally benign nanoparticles (NPs). Nanomaterials are "deliberately engineered" to direct the enhancement of special properties at the nanoscale. Nanoparticles have been known to be used for abundant physical, biological, and pharmaceutical applications. Nano-silver is the most studied and utilized nanoparticle. Silver nanoparticles (AgNPs) have been the topics of researchers because of their unique properties. Thus, this review presents various synthesis methods of AgNPs and its application in different sectors.

## 1. Introduction

In science and engineering, sustainable nanotechnology is successful in giving solutions for the challenges in various sectors such as medicine, catalysis, industrial and agricultural activities [1]. Nanostructures are the issue of involvement for all applications of Nanotechnology anywhere in nature and dimension of the nanoparticles (NPs) decides their feature properties [2]. It is broadly accepted in the background of nanoscience and nanotechnologies, focus on the units of size, rather than of any other unit of scientific measurement [3,4]. Nano-sized particles are unique matter which falling in between the microscopic and mesoscopic. When compared to the dimension of nanoparticles with other "small" molecules, called the bacterium is large in contrast which have a high surface area to volume ratio and a high fraction of surface molecules. They have definite physicochemical properties such as optical property [5–9], magnetic property [9], catalytic property [10], antimicrobial property at the nano-stage [8–10] which characteristically consequences in superior chemical reactivity, biological activity, and catalytic behavior compared to larger particles of the identical chemical composition [3,4]. Nanomaterials are "deliberately engineered" to guide the improvement of special properties at the nanoscale. Nanomaterials may have superior bioavailability than larger units, ensuring in greater utilization of individual cells, tissues, and organs [9]. Nanomaterials that gain admission to our bodies just penetrate biological membranes and access cells, tissues, and organs. Materials with size 300 nm can be taken up by individual cells while nanometers, that quantify below 70 nm can still use up by our cells' nuclei, where they can cause principal damage [3,10].

Metal NPs are holding from small number of atoms to numerous metal atoms, stabilize by ligands, surfactants, polymers or dendrimers defensive their surfaces. They play a vital role in catalysis as they imitate metal surface activation and nanoscale increase efficiency to heterogeneous catalysis [3,5]. This method is likewise applicable to homogeneous catalysis, for the reason that there is a wide range among tiny metal clusters and bulky metal clusters, the end being also called colloids, sales or NPs [11].

Biosynthesis of metal, metal oxides and metal composite of nanoparticles are cleaner, nontoxic, and environmentally benign than the physical and chemical methods. Nowadays, metal based nanoparticles are synthesized for numerous applications from different plant parts

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such as leaves, roots, flower, seeds etc. For instance, Cu/$Fe_3O_4$ nanoparticles from *Silybum marianum* L. Seed extract [12], Cu/reduced graphene oxide/$Fe_3O_4$ nanocomposite from *Euphorbia wallichii* leaf extract [13], Gold nanoparticles (AuNPs) from *Anthemis xylopoda* flower aqueous extract [14], Palladium nanoparticles from *the Hippophae rhamnoides linen* leaf extract [15], Pd/$Fe_3O_4$ nanoparticles from *Euphorbia condylocarpa M. bieb* root extract [16], Palladium nanoparticles (PdNPs) from Sour Cherry tree Gum [10], Copper nanoparticles supported on bentonite (bentonite/CuNPs) from *Thymus vulgaris* L. leaf extract [17], Pd nanoparticles supported on graphene oxide from barberry fruit extract [18], Natrolite zeolite/Pd nanocomposite using *Piper longum* fruits extract [19], Cu/reduced graphene oxide (RGO-$Fe_3O_4$) using nanocomposite *Berberis vulgaris* fruit extract [20], CuO nanoparticles by aqueous extract of *Anthemis nobilis* flowers [21], AuNPs by *Anthemis xylopoda* flowers [22], CuNPs using *Ginkgo biloba* L. leaf extract [23], PdNPs using *Euphorbia thymifolia* L. leaf extract [24], CuNPs using *Euphorbia esula L* leaves extract [25], PdNPs using *Hippophae rhamnoides linn* leaf extract [15], Pd/$Fe_3O_4$ nanoparticles using *Euphorbia condylocarpa M. bieb* root extract [26], Au/Pd bimetallic nanoparticles from *Euphorbia condylocarpa M. bieb* [27], biosynthesis of AgNPs for application Ag/bone nanocomposite *Myrica gale* L. extract [28], Ag/RGO/$Fe_3O_4$ using *Lotus garcinii* leaf extract for nano-catalyst [29], AgNPs using *Gongronema latifolium* leaf extract [30], green synthesis of PdNPs using *Salvia hydrangea* extract for catalyitic reduction of dyes [31], green synthesis of AgNPs supported on waste peach kernel shell using *Achillea millefolium* L. extract [32], synthesis of Ag/Fe3O4 nanocomposite using *Euphorbia peplus Linn* leaf extract [33], and synthesis of Pd/perlite nanocomposite using *Euphorbia neriifolia* L. leaf extract [34].

Silver is a transition metal in one set with Cupper and Gold which is a soft, white, lustrous element possessing high electrical and thermal conductivity. It has been known extensively due to its medical and therapeutic benefits before the recognition that microbes are agents for infections. It is practiced in many forms as coins, vessels, solutions, foil, sutures, and colloids as lotions, unguents, and thus onwards. The medical properties of silver have been experiencing for over 2000 years. Since the 19th century, silver-based compounds have been engaged in the antimicrobial application [3,11].

AgNPs play a great role in the study of biology and medicine due to their attractive physicochemical properties. Silver products have extended been familiar to have strong inhibitory and bactericidal effects, as considerably as a wide spectrum of antimicrobial activities [8–10], which has been practiced for centuries to prevent and care for various diseases, most notably infections [35]. Silver nanoparticles are accounted to own antifungal, anti-inflammatory, antiviral, and antiplatelet activity [36]. AgNPs have been acknowledged to be developed for several physical, biological, and pharmaceutical purposes [8,9] that may be directed by an assortment of techniques, including spark discharging, electrochemical reduction, solution irradiation, and cryochemical synthesis and control approximately 20–15,000 silver atoms [10]. They may be engineered to have different forms, including, fields, particles, rods, square blocks, wires, film and coatings [8–10].

## 2. Synthesis of silver nanoparticles

Metals (Au, Ag, etc.), metal oxides (ZnO, $TiO_2$, $SiO_2$, $Fe_3O_4$, etc.) and metal composites, are the inorganic functional materials with exceptional optical [5–9], electrical and magnetic properties [4,9]. Green synthesis of AgNPs is a very simple and cost-effective approach that meets the demand of the research community and simultaneously rejects the possibility of ecological risks [6]. This review looks to offer superior opportunities of biosynthesis silver nanoparticles (NPs) which have been the topics of researchers due to their unique attributes (e.g., size and shape depending optical, antimicrobial, and electrical properties) [4,5,6,8].

Top-down and bottom-up are the two synthesis approaches of metallic nanoparticles involves by chemical, physical, and biological means. The usual production of nanoparticles involves physical and chemical processes. Both approaches apply for the synthesis of AgNPs. The mechanical grinding of bulk metals and subsequent stabilization of the resulting nanosized metal particles by the addition of colloidal protecting agents are some examples of the top-down method. Besides the bottom-up method, include the reduction of metals, electrochemical methods, and decomposition [7,9]. In this section, we introduce the overview preparation of silver nanoparticles using physical, chemical, and biological synthesis is highlighted.

### 2.1. Physical methods

The most important physical approaches are evaporation-condensation and laser ablation [37,38]. The absence of solvent contagion in the equipped thin films and the homogeny of NPs distribution are the compensation of physical synthesis methods in contrast with chemical processes. Tube furnace syntheses of silver NPs at atmospheric pressure has some disadvantages such as energy consumption, slow synthesis and call for high concentration [39]. Laser ablation of metallic bulk materials can be synthesized AgNPs in solution. Depends upon various factors, including the wavelength of the laser interrupting the metallic target, the period of the laser pulses, the ablation time extent and the efficient liquid medium, with or without the existence of surfactants, and the laser power are some of the factors which determine the ablation effectiveness and the characteristics of synthesized nano-silver particles [39,40]. From available methods, Laser ablation is a unique and significant method which results pure and clean metallic nanoparticles without using chemical reagents in solution [37,38].

### 2.2. Chemical method

#### 2.2.1. Chemical reduction

Chemical reduction is the most common approaches for the synthesis of AgNPs using organic and inorganic reducing agents. This is by continuing through a single process to generate a colored silver solution, this is due to the surface of a metal having free of charge electrons in the conduction band and positively charged nuclei. Then, the formation of long-lived clusters of silver is formed and confirms the synthesis of AgNPs [41]. In general, one-pot method of reduction of $AgNO_3$ using different reducing agents such as sodium citrate, ascorbate [9], Sodium borohydride ($NaBH_4$) [7,38,41], elemental hydrogen, polyol process, *N,N*-dimethylformamide (DMF) [38,41], Ascorbic acid, poly(ethylene glycol)-block copolymers [10], hydrazine, and ammonium formate [41] are applied for reduction of silver ions ($Ag^+$) in the aqueous or nonaqueous solution [38].

#### 2.2.2. Microemulsion techniques

Microemulsion technique has various applications in chemical and biological field due to their exceptional properties such as, ultralow interfacial tension, huge interfacial area, thermodynamic constancy and the capability to solubilize immiscible liquids [42]. The Microemulsion method assures to be one of the flexible preparation techniques which allows to organize the particle properties such as mechanisms of particle size control, geometry, morphology, homogeneity and surface area [42,43].

#### 2.2.3. Microwave-assisted synthesis

A microwave synthesis engages the reduction of silver nanoparticles with changeable rate microwave radiation in opposition to the conventional heating technique [44]. The technique gives up a more rapidly reaction and gives a higher concentration of silver nanoparticles with the same temperature and exposure [7,42,44].