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Review Article

Fabrication Approaches for Silver Nanoparticles, Characterization by Spectroscopic Techniques and Their Applications

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ABSTRACT

Research based on advanced Nanoparticles of noble metals like silver has conquered a lot of interest among scientists during the past decades for its Physical and chemical properties such as size, distribution and morphology, they have been studied for catalytic activity, optical properties, electronic properties, antibacterial properties, and magnetic properties and its application in various field such as biomaterial production, biochemistry, medical and Therapeutic products toothpastes, optical receptors, biosensing, etc. Silver based Nanoparticles are synthesized using various approaches, such as biological, physical, or chemical methods with the conditions to control the size/shape and stability of nanoparticles. To evaluate the synthesized NPs, many spectroscopic analytical techniques have been used. Silver based Nanoparticles of varying sizes and shapes have been utilized in a broad range of applications and medical equipments.

Keywords: Silver Nanoparticles; Fabrication; Spectroscopic Analysis; Nano scale

INTRODUCTION

Nanoscience is an important field of modern research dealing with Fabrication, strategy and manipulation of particle's structure ranging from approximately 1 to 100nm in size and involves a wide range of applications, including food packaging materials, personal care products, delivery systems of Therapeutic agents to improve medical treatments optics, chemical industries, space industries, mechanics, electronics, catalysis, light emitters, nonlinear optical devices and photo-electrochemical applications.

Silver is nontoxic, safe inorganic antibacterial agent that is capable of killing about 650 types of disease causing microorganisms. The conversion of silver into its nanoparticle form offers it unique Physio-chemical Properties that increase the efficacy of silver. Silver belongs to a group of noble metals. Symbol of silver is Ag and belongs to transition metals. It is 47th element in a periodic table, with atomic weight of 107.87. Its Melting Point is 961.78°C and boiling temperature is 2162°C. Silver has very high malleability and ductility and in its pure form its electrical conductivity and thermal conductivity are the highest of all metals. Pure silver does not react with water or air, but it reacts when in contact with compounds containing sulphur or chloride. Naturally, silver is in metallic state, and very rarely as sole metal, but in combination with sulphur, chlorine, arsenic, or antimony and very often in ores containing copper, lead, gold, and zinc [1]. Research based on advanced NPs of noble metals like silver has conquered a lot of interest among scientists during the past decades for its Physical and chemical properties such as size, distribution and morphology, they have been studied for catalytic activity, optical properties, electronic properties, antibacterial properties and magnetic properties and its application in various field such as biomaterial production, biochemistry, medical and Therapeutic products, toothpastes, optical receptors, biosensing, etc.

For instance, the antibacterial activity of different metal nanoparticles such as silver colloids is closely related to their size; that is, the smaller the silver nuclei, the higher and the antibacterial activity. Moreover, the catalytic activity of these nanoparticles is also dependent on their size as well as their structure, shape, size distribution, and chemical–physical environment. Thus, control over the size and size distribution is an important task. Generally, specific control of shape, size, and size distribution is often achieved by varying the Fabrication methods, reducing agents and stabilizers. Previous discoveries have shown that the physical, optical, and catalytic properties of Silver based NPs are strongly influenced by their size, distribution, morphological shape, and surface properties which can be modified by diverse synthetic

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methods, reducing agents and stabilizers [2].

Fabrication Approaches

Among several synthetic methods for Silver based NPs, biological methods seem to be simple, rapid, non-toxic, dependable, and green approaches that can produce well-defined size and morphology under optimized conditions for translational research. In the end, a green chemistry approach for the Fabrication of Silver based NPs shows much promise.

Metal nanoparticles are synthesized using various approaches, such as biological, physical, or chemical methods with the conditions to control the size/shape and stability of nanoparticles.

Generally, the Fabrication of nanoparticles has been carried out using three different approaches, including physical, chemical, and biological methods. Currently, many methods have been reported for the Fabrication of Ag-NPs by using chemical, physical, photochemical and biological routes. Each method has advantages and disadvantages with common problems being costs, scalability, particle sizes and size distribution

Top-Down and Bottom-Up Method:

The Fabrication methods of metal NPs are mainly divided into top-down and bottom-up approaches (Figure 1) the top-down approach disincorporates bulk materials to generate the required nanostructures, while the bottom-up method assembles single atoms and molecules into larger nanostructures to generate nano-sized materials. Nowadays the synthetic approaches are categorized into physical, chemical, and biological green syntheses. The physical and chemical syntheses tend to be more labor-intensive and hazardous, compared to the biological Fabrication of Silver based NPs which exhibits attractive properties, such as high yield, solubility, and stability.

Physical Methods

In order to fulfill the requirement of Silver based NPs, various methods have been adopted for Fabrication. Generally, conventional physical and chemical methods seem to be very expensive and hazardous. Interestingly, biologically-prepared Silver based NPs show high yield, solubility, and high stability.

In physical methods, nanoparticles are prepared by evaporation-condensation using a tube furnace at atmospheric pressure [3]. The source material within a boat centered at the furnace is vaporized into a carrier gas. Conventional physical methods including spark discharging and pyrolysis were used for the Fabrication of Silver based NPs. The advantages of physical methods are speed, radiation used as reducing agents, and no hazardous chemicals involved, but the downsides are low yield and high energy consumption, solvent contamination, and lack of uniform distribution.

The physical Fabrication of Silver based NPs includes the evaporation–condensation approach and the laser ablation technique. Both approaches are able to synthesize large amounts of Silver based NPs with high purity without the use of chemicals that release toxic substances and jeopardize human health and environment. The evaporation–condensation technique typically uses a gas phase route that utilizes a tube furnace to synthesize nanospheres at atmospheric pressure. Various nanospheres, using numerous materials, such as Au, Ag, and PBS, have been synthesized by this technique. The center of the tube furnace contains a vessel carrying a base metal source which is evaporated into the carrier gas, allowing the final Fabrication of NPs [4]. The size, shape, and yield of the NPs can be controlled by changing the design of reaction facilities. Nevertheless, the Fabrication of Silver based NPs by evaporation– condensation through the tube furnace has numerous drawbacks. The tube furnace occupies a large space, consumes high energy elevating the surrounding temperature of the metal source, and requires a longer duration to maintain its thermal stability. To overcome these disadvantages, Jung et al. demonstrated that a ceramic heater can be utilized efficiently in the Fabrication of Silver based NPs with high concentration.

However, the generation of Silver based NPs using a tube furnace has several drawbacks, because a tube furnace occupies a large space, consumes a great deal of energy while raising the environmental temperature around the source material, and requires a lot of time to achieve thermal stability. Another approach in physical Fabrication is through laser ablation. The Silver based NPs can be synthesized by laser ablation of a bulk metal source placed in a liquid environment as shown in Figure 1B. After irradiating with a pulsed laser, the liquid environment only contains the Silver based NPs of the base metal source, cleared from other ions, compounds or reducing agents. Various parameters, such as laser power, duration of irradiation, type of base metal source, and property of liquid media, influence the characteristics of the metal NPs formed. Unlike chemical Fabrication, the Fabrication of NPs by laser ablation is pure and uncontaminated, as this method uses mild surfactants in the solvent without involving any other chemical reagents. Moreover, Silver based NPs have been synthesized with laser ablation of metallic bulk materials in solution. The characteristics of the metal particles formed and the ablation efficiency strongly depend upon many parameters such as wavelength of the laser impinging the metallic target, the duration of the laser pulses, the laser fluence, the ablation time duration and the effective liquid medium, with or without the presence of the surfactant.

One advantage of laser ablation compared to other conventional method for preparing metal colloids is the absence of chemical reagents in solutions [5]. Therefore, pier colloids, which will useful for further applications, can be produced by this method.

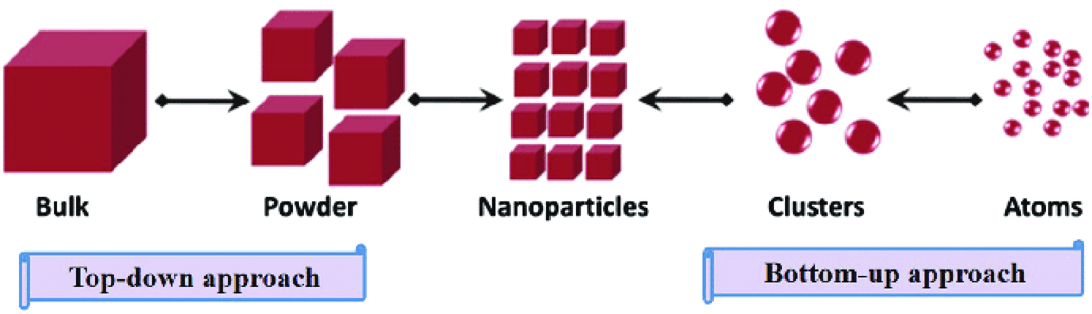

Figure 1: Top down and bottom up approach for the Fabrication of nanoparticles.

In another work Jung et al reported an attempt to synthesize metal NPs via a small ceramic heater that has a local heating area. The small ceramic heater was used to evaporate source materials. The results showed that the geometric mean diameter, the geometric standard deviation and the total number concentration of NPs increase with heater surface temperature. The particle generation was very stable, because the temperature of the heater surface does not fluctuate with time. Spherical NPs without agglomeration were observed, even at high concentration with high heater surface temperature. The generated Ag-NPs were pure silver, when air was used as a carrier gas. The geometric mean diameter and the geometric standard deviation of Ag-NPs were in the range of 6.2–21.5nm and 1.23-1.88nm, respectively.

In summary, the physical Fabrication process of Ag-NPs usually utilizes the physical energies (thermal, ac power, arc discharge) to produce Ag-NPs with nearly narrow size distribution. The physical approach can permit producing large amounts of Ag-NPs samples in a single process. This is also the most useful method to produce Ag-NPs powder. However, primary costs for investment of equipment should be considered.

Chemical Methods

Metallic nanoparticles can be synthesized using different approaches, such as electrochemical methods, extracellular Fabrication, chemical reduction, microwave-assisted techniques gamma irradiation, and wet chemical procedures. However, the chemicals used in those methods are usually flammable and highly toxic, which limit their applications in many areas because they may pose risks to human health. Therefore, there is an increasing need to promote a safe and environmentally friendly procedure to synthesize metallic nanoparticles without using toxic chemicals.

Chemical reduction is the most frequently applied method for the preparation of Silver based NPs as stable, colloidal dispersion in water or organic solvents commonly used reductants are borohydride, citrate, ascorbate and elemental hydrogen [6]. The reduction of silver ions in aqueous solution generally yields colloidal silver with particle diameters of several nanometers.

Biological Methods

Chemical, physical, and biological methods have been developed to Fabrication nanoparticles but chemical and physical methods are involved in the production of toxic byproducts which are hazardous moreover the methods are very expensive. The bioFabrication of metal nanoparticles can be based on utilizing plant extracts, which is cost effective for large-scale production. To Fabrication stable metal nanoparticles with controlled size and shape, there has been search for inexpensive, safe, and reliable and "green" approach. The novel methods so called green/bioFabrication have been recently developed by a variety of plant extracts. There are many reports in literature on the Fabrication of Silver based NPs using plant extracts such as coriandrum sativum leaf extract, Phyllanthus amarus leaf extract, turmeric extract, coffea arabica seed extract, elephantopus scaber leaf extract, banana peel extract, Carissa carandas berries, shikakai and reetha plant extract, Artemisia turcomanica leaf extract, Cinnamon, parsley (Petroselinum crispum) leaf extract, Pomegranate (Punica granatum) leaf extract, Coptidis rhizome herb, Tropaeolum majus L leaf extract, aqueous solution of neem gum (Azadirachta indica L.), grape seed extract, moringa oleifera seed extract, euphrasia officinalis leaf extract, aloevera leaf extract, ginkgo biloba, green tea extract, Jasminum auriculatum stem extract, etc for the green Fabrication of metal nanoparticles. The uses of microorganism to the green Fabrication of Silver based NPs are also reported.

Recently, the development of effective green chemistry methods has received much attention as an alternative approach to synthesize metal nanoparticles, which can eliminate or minimize the generation of toxic or hazardous waste materials and establish a sustainable process. A fundamental key to the strategy of green Fabrication is the use of nontoxic chemicals, renewable materials, or environmentally benign solvents. Various types of biomolecules, such as vitamins, fungi, enzymes, biodegradable polymers, and bacteria have been used to synthesize metallic NPs.

Plants provide a better platform for nanoparticles Fabrication as they are free from toxic chemicals. Plants based Fabrication is exceptionally cost effective and can be used as an economic and helpful alternative for large scale Fabrication of nanoparticles. Plant extracts including secondary metabolites, such as phenolic acids, flavonoids, alkaloids and terpenoids play a major role in revitalizing metal ions to form nanoparticles in an eco-friendly reaction.

In summary, the biological method provides a wide range of resources for the Fabrication of Ag-NPs, and this method can be considered as an environmentally friendly approach and also as a low-cost technique [7]. The rate of reduction of metal ions using biological agents is found to be much faster and also at ambient temperature and pressure conditions

Characterization of Silver based NPs

Most of the nanoparticle characterization techniques can be classified in two broad categories.

1. Local probe techniques

i. Scanning electron microscopy (SEM)
ii. Transmission electronic microscopy (TEM)
iii. Scanning tunneling microscopy (STM)
iv. Atomic-force microscopy (AFM)

2. Bulk sensitive techniques

i. Optical absorption spectroscopy
ii. Fourier transform infrared (FT-IR) spectroscopy
iii. Electron spin resonance (ESR) spectroscopy
iv. Raman scattering
v. X-ray-based techniques
vi. UV–visible spectroscopy

Spectroscopic Analysis

After Fabrication, precise particle characterization is necessary, because the physicochemical properties of a particle could have a significant impact on their biological properties. In order to address the safety issue to use the full potential of any nano material in the purpose of human welfare, in nanomedicines, or in the health care industry, etc., it is necessary to characterize the prepared nanoparticles before application. The characteristic feature of NPs, such as size, shape, size distribution, surface area, shape, solubility, aggregation, etc. need to be evaluated before assessing toxicity or biocompatibility.

Characterization of nano particles is important to understand and control nanoparticles Fabrication and applications. UV–visible absorption spectroscopy plays very important role to investigate the optical properties of nanoparticles. Quantitative formation can be monitored and size of nanoparticles can be studied with the help of this technique. It is basically study of response to electromagnetic waves in the wavelength range 190–700 nm by the sample.

These techniques are used for determination of different parameters such as particle size, shape, crystallinity, fractal dimensions, pore size and surface area [8]. Moreover, orientation, intercalation and dispersion of nanoparticles and nanotubes in nano composites materials could be determined by these techniques.

FT-IR spectroscopy is applied to find out information about the different functional groups from the peak positions in the spectrum. Information about capping and stabilization of the nanoparticles may also be inferred from this analysis. Now we cite some examples from recent literature to highlight the applications of FT-IR spectroscopy in nanoparticle characterization.

XRD is a primary technique for the identification of the crystalline nature at the atomic scale. X-ray diffraction (XRD) is a popular analytical technique which has been used for the analysis of both molecular and crystal structures, qualitative identification of various compounds, and quantitative resolution of chemical species, measuring the degree of crystallinity, isomorphous substitutions, and particle sizes.

For instance, morphology and particle size could be determined by TEM, SEM and AFM. The advantage of AFM over traditional microscopes such as SEM and TEM is that AFM measures three-dimensional images so that particle size distribution. Moreover, X-ray diffraction is used for the determination of crystallinity, while UV-Vis spectroscopy is used to confirm sample formation by showing the plasmon resonance.

Gel-electrophoresis (GE) has been demonstrated in recent decades to successfully sort a great variety of nanoparticles according to their size, charge, surface chemistry, and corona architecture. It has been evaluated the use of agarose GE for characterization of Ag nanoparticles (NPs) in an industrial product.

SEM or scanning electron microscope is an instrument which involves scanning of surface of the sample and backscattering of the ray is recorded. Since metal nanoparticles are highly electrically conductive, it is easy to scan them through SEM. Similarly, transmission electron microscope (TEM) helps in capturing images of nanoparticle samples based on the interaction of the electron beam in the high vacuum-conditioned chamber.

Application of Silver based NPs

Metal nanoparticles have been used in a wide-ranging application in various fields. In particular, silver NPs of varying sizes and shapes have been utilized in a broad range of applications and medical equipment, such as electronic devices, paints, coatings, soaps, detergents, bandages, etc.

Among NPs, Silver based NPs (NPs) are emerged as a promising candidate to fight against pathogens because of their high surface area-to-volume ratio and the unique chemical and physical properties. It was proposed that the high specific surface area and high fraction of surface atoms of silver NPs will lead to high antimicrobial activity.

Due to their unique properties, Silver based NPs have been used extensively in house-hold utensils, the health care industry, and in food storage, environmental, and biomedical applications. Herein, we are interested in emphasizing the applications of Silver based NPs in various biological and biomedical applications, such as antibacterial, antifungal, antiviral, anti-inflammatory, anti-cancer, and anti-angiogenic [9].

Antibacterial Activity of Silver based NPs

Silver based NPs have been used extensively as anti-bacterial agents in the health industry, food storage, textile coatings and a number of environmental applications. As anti-bacterial agents, Silver based NPs were applied in a wide range of applications from disinfecting medical devices and home appliances to water treatment. Moreover, this encouraged the textile industry to use Silver based NPs in different textile fabrics. In this direction, silver nanocomposite fibers were prepared containing Silver based NPs incorporated inside the fabric. The cotton fibers containing Silver based NPs exhibited high anti-bacterial activity against Escherichia coli.

Antifungal Activity of Silver based NPs

Fungi are increasingly recognized as major pathogens in critically ill patients, especially nosocomial fungal infections. Although the antibacterial activities of Ag-NPs are well-known, the antifungal activities of this material have not yet been studied adequately. This section aims to review the most important properties of Ag-NPs against common fungal strains

Antiviral Activity of Silver based NPs

In recent years, there was an increase in reported numbers of emerging and re-emerging infectious diseases caused by viruses such as SARS-Cov, influenza A/H5N1, influenza A/H1N1, Dengue virus, HIV, HBV, and new encephalitis viruses etc [10]. These viral infections are likely to break out into highly infectious diseases endangering public health

CONCLUSION

Among several synthetic methods for Silver based NPs, biological methods seem to be simple, rapid, non-toxic, dependable, and green approaches that can produce well-defined size and morphology under optimized conditions for translational research. Characterization of nano particles is important to understand and control nanoparticles Fabrication and applications. Characterization is performed using a variety of different techniques such as transmission and scanning electron microscopy (TEM, SEM), atomic force microscopy (AFM). Dynamic light scattering (DLD), X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), UV-visible spectroscopy. Among NPs, Silver based NPs (NPs) are emerged as a promising candidate to fight against pathogens because of their high surface area-to-volume ratio and the unique chemical and physical properties.

REFERENCES

1. Abdelghany T, Al-Rajhi AM, Al Abboud M A, Alawlaqi M, Magdah AG, Helmy E A, et al. Recent advances in green Fabrication of Silver based NPs and their applications: About future directions. A review. BioNanoScience. 2018; 8(3): 5-16.
2. Adhikari L, Larm NE, Bhawawet N, Baker G A. Rapid microwave-

assisted Fabrication of Silver based NPs in a halide-free deep eutectic solvent. ACS Sustainable Chemistry & Engineering. 2018; 6(5):5725-5731.

3. Ahmadi O, Jafarizadeh-Malmiri H, Jodeiri N. Eco-friendly microwave-enhanced green Fabrication of Silver based NPs using Aloe vera leaf extract and their physico-chemical and antibacterial studies. Green Processing and Fabrication. 2018; 7(3):231-240.

4. Ahmed M J, Murtaza G, Mehmood A, Bhatti T M. Green Fabrication of Silver based NPs using leaves extract of Skimmia laureola: characterization and antibacterial activity. Materials Letters. 2015; 153:10-13.

5. Ahme S, Ahmad M, Swami BL, Ikram S. A review on plants extract mediated Fabrication of Silver based NPs for antimicrobial applications: a green expertise. J Adv Res 2016; 7(1):17-28.

6. Ajitha B, Reddy YAK, Jeon HJ, Ahn C W. Fabrication of Silver based NPs in an eco-friendly way using Phyllanthus amarus leaf extract: antimicrobial and catalytic activity. Advanced Powder Technology.2018; 29(1):86-93.

7. Alsammarraie FK, Wang W, Zhou P, Mustapha A, Lin M. Green Fabrication of Silver based NPs using turmeric extracts and investigation of their antibacterial activities. Colloids Surf B Biointerfaces. 2018; 171:398-405.

8. Baghayeri M, Mahdavi B, Hosseinpor‐Mohsen Abadi Z, Farhadi S. Green Fabrication of Silver based NPs using water extract of Salvia leriifolia: Antibacterial studies and applications as catalysts in the electrochemical detection of nitrite. Applied Organometallic Chemistry. 2018; 32(2):40-57.

9. Balashanmugam P, Kim HJ, Singh V, Kumaran R S. Green Fabrication of Silver based NPs Using Ginkgo biloba and Their Bactericidal and Larvicidal Effects. Nanoscience and Nanoscience Letters. 2018; 10(3):422-428.

10. Balasubramanian S, Jeyapaul U, Kala S MJ. Antibacterial activity of Silver based NPs using Jasminum auriculatum stem extract. Int J Nanomedicine. 2020; 15: 9771–9781.