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An Overview on Facile Green Synthesis Approaches and Optical Sensing Applications of Silver Nanoparticles

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ABSTRACT

Ag particles with the nano dimensions possess exceptional physical as well as chemical properties that mainly depends on the synthetic route. The traditional methods for synthesizing nanostructures are expensive, hazardous, and environmentally unfriendly. To address these challenges, various economical, biocompatible routes have been adopted for Ag nanostructures using natural origin like fungi, plants, bacteria and so on. This review compiles the various natural sources, which are being examined in the fabricating Ag nanostructures, which may be plants, bacteria, fungi, and biopolymers. The mechanism for the growth of Ag nanostructures have also been explored. Finally, the review asses the optical sensing application of Ag nanostructures.

Key words*: Green synthesis, Silver nanostructures, Plant intervened synthesis, Optical sensing*

Introduction

Nanotechnology is a concept that refers to the manufacturing, representation, manipulation, and use of things at the nanoscale by regulating shape and size (Ng *et al.*, 2018; Sarsar *et al.*, 2013). The properties of nanostructures are completely novel and magnificent when we take into account its features based on shape, structure also size (Thakur *et al.*, 2020). Gold and silver (Ag) nanostructures are gaining popularity because they combine exceptional properties with useful flexibility. On comparing it with larger particles having the similar chemical distribution, surface zone of Ag nanostructures is quite symbolic, in turn harvest their remarkable biological reactiveness, atomic conduct and catalytic action. As they have remarkable capability in optics, electronics biological sensors, plasmonics, antimicrobial activities, DNA sequencing, Surface-Enhanced Raman Scattering (SERS), the formation of Ag nanostructures has piqued the interest of many researchers. Since the previous decade, in the branch of nanotechnology has a great possibility, which has been successfully presented with the production of nanostructures. Figure 1. Pictorial representation for the biosynthesis of Ag nanostructures.

Chemical reduction is the most common method for the production of Ag nanostructures in the bottom-up strategy. Capping agents are also utilized to keep the size of the nanostructures stable. One of the most significant advantages of this technology is the ability to synthesize a large number of nanostructures in a short amount of time. The chemicals utilized in this type of synthesis are hazardous, resulting in toxic byproducts (Thakur *et al.*, 2020). Therefore, green biosynthesis of nanostructures with-

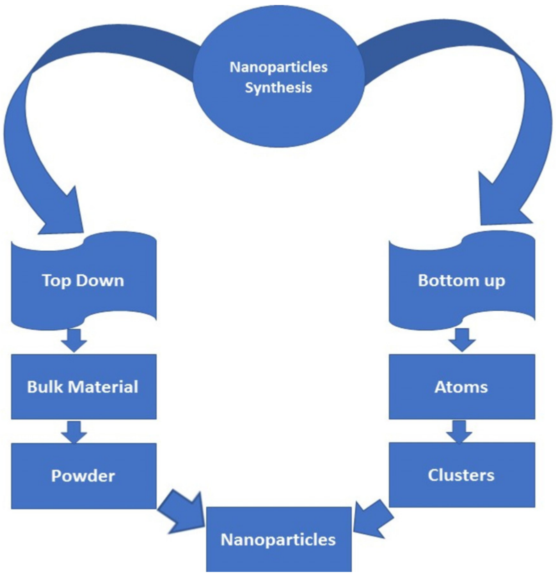

Fig. 1. Pictorial representation for the biosynthesis of Ag nanostructures.

out the usage of hazardous chemicals has been explored to a greater extent. As a result, the advancement of greener route for Ag nanostructures is progressing as most demanding part of nanotechnology, where the utilization of greener component has been used such as plant extract and biomass, microorganisms, and other biological entities. Green synthesis, as opposed to physical and chemical approaches, is environmentally benign, economical, and readily scaled for synthesis of nanostructures, due to its low temperature and energy requirement, nor there is any pressure condition and nor toxic chemical requirements. Metal nanostructures have long piqued attention on the grounds of its high conductivity, huge surface area per unit volume quotient, plasmonic features, including other characteristics. Because the SPR of Ag nanostructures is heavily influenced by surface-adsorbed molecules, and the wavelength of SPR may be controlled by the concentration of adsorbed molecules, Ag nanostructures are appealing for biosensing applications. Unlike previous reviews, this one highlighted on the production procedures, utility, characterization techniques and so on derived out of possession of various greener Ag nanostructures production processes.

Greener approaches for the synthesis of Ag nanostructures

Traditional routes for the fabrication of nano-structures are costly, hazardous, and leaves toxic effects to the environment system. To encounter these challenges, researchers have exact green routes, or natural resources like plant, enzymes, bacteria, polymers, so on and their extracts, that can be utilized to fabricate nanostructures (Hebbalalu *et al.,* 2013).

Following section describes, greener routes using plants, bacteria, fungus and plant extracts. Ag nitrate and a natural reducing agent are required for the greener routes for producing Ag nanostructures.

Greener route for the formation of Ag Nanostructures by opting plant extract

Gardea-Torresdey *et al.* (2003) demonstrated a certain initial strategy to employ plants for producing metallic nanostructures used *Alfalfa sprouts* was the first report of Ag nanostructures synthesis utilising a living plant system. Roots pertaining to *Alfalfa* transfers the Ag to the plant's shoots in the same oxidation state that is being taken from the agar medium, together with all the transition takes place this way. These Ag atoms organised themselves in shoots to form Ag nanostructures. Hemlata *et al*. described the greener routes to produce Ag nanostructures by using leaf extract *Cucumis prophetarum* and evaluated its antibacterial and antiproliferative activity. Characterization of biosynthesised Ag nanostructures can be easily done with the help of numerous techniques like UV- visible spectroscopy, XRD, SEM, TEM so on. The antibacterial activity was determined with the help of 2,2-diphenyl-1-picrylhydrazyl and 3-ethylbenzo-thiazoline-6-sulfonic acid assays. Their anti-proliferative activity was evaluated using 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide assay on selected cancer cell lines (Hemlata *et al.,* 2020). Kasthuri *et al.* (2009) manufactured Ag nanostructures of an average diameter 21 nm- 39 nm by reducing aqueous Ag ions with *Apiin* leaf extract, according to TEM data (Kasthuri *et al.,* 2009). Shankar *et al.* (2003) revealed manufacturing of Ag nanostructures extracellular with the usage of leaf extract of *Geranium* and produced the stable nanostructures having size 40 nm (Shankar *et al.,* 2003). Aldebasi *et al.* reported Ag nanostructures in a different approach with the help of extract of leaf *Ficus carica* (Yousef *et al.,* 2014). Plants are easily available and safe to handle, which makes them ideal for the creation of nanostructures. Every part of plant like stems so on, is quite useful in the production of nanostructures. Phytochemicals are the main factor, which leads to reduction reaction of Ag ions and further stabilization of nanostructures (Veerasamy *et al.,* 2011). Green synthesis employing plants and with the usage of its extract is quite accelerated as compared to microbes, according to research. Green synthesis which is being done by plants and with their extracts is quite in demand due to quick production, unitary approach, cost-effective agreement, and their environmental friendliness.

Optical sensing applications of Ag nano-structures

In industrial development, sensors were critical in averting fire explosions, conducting atmospheric environmental monitoring, and identifying hazardous and dangerous substances. However, selectivity, stability, and other features of sensitive material synthesis appear to be lacking at the time. Materials processing procedures to create the necessary microstructures and morphologies are necessary since the microstructures of sensing materials are important to their performance (Tarannum *et al.,* 2019; Thakur *et al.,* 2021). For future technical applications, it's vital to understand how nanoscale materials behave while functioning and how controllably they're treated. Low CO concentrations cause a rapid and powerful response in these materials, as well as a remarkable insensitivity to humidity. Nanotechnology has enabled the creation of precise, it has tremendously sensitive system and the methods for detection are quite selective, all these factors are quite beneficial and can easily overcome the limits of traditional detection methods. Au and Ag nanostructures have become key tools, due to their unexpected optical characteristics in the field of imaging and sensing. With the exception of surface enhanced spectroscopies-based sensors, Ag has a number of utility at an end of Au, in a number ways it has proved whether it may be of its extinction coefficients and so. This is due to the fact that Ag nanostructures have a poorer chemical stability than gold. Ag nanostructures that have had anions or polymers absorbed on their surfaces are prevented from aggregating. Nanoparticle aggregation and destabilization can be triggered by variance including dispersion correspondence, for instance pH and ionized pressure. As the nanoparticle aggregates, its LSPR becomes red-shifted and widened. Silver in its nanoscale form shows excellent optical properties. Brett *et al.* combined both materials using thin-film large-area spray-coating to study the fabrication of optical response utility. Morphology and optical properties of nanocellulose film are compared to the rigid reference surface SiO_2. The results clearly show the potential to tailor the energy band gap of the resulting hybrid material (Brett *et al.,* 2021). Sangar *et al.,* biosynthesized Ag nanostructures for optical sensing of Hg^{2+} ions and found its detection limit of 2.0 µM (Sangar *et al.,* 2019). Alex *et al.* (2020) synthesized Ag nanostructures using different plant extracts for the successful sensing as well as photodegradation of mancobez pesticide with the sensitivity of 39.1 nm/mM (Alex *et al.,* 2020). Recently, Vashisht *et al.* (2021) have fabricated Ag nanostructures by greener route using *Piper nigrum* concerning to optical sensing of chlorite (ClO_2^-) as well as for mercuric (Hg^{2+}) ions. The limit of detection that is being reported to be 1.11 and 7.47 µM for ClO_2^- and Hg^{2+} respectively (Vashisht *et al.*, 2021). Xie *et al.* used homogenous silver-coated nanoparticle substrates to improve fluorescence detection. A monolayer of Fluorescein isothiocyanate (FITC)-conjugated Human Serum Albumin (FITC-HSA) was employed in their investigation to determine the degree of fluorescence enhancement, which was measured using laser scanning microscopy at a wavelength of 488 nm. Aggregation sensors have been developed using this effect. The correct analyte for the task can help nanostructures clump together in certain conditions (Lee *et al.,* 2007; Liu *et al.,* 2005). Fascinating illustration of the same category of analyte-induced detection device which was discovered by Huang and colleagues. Reporters developed a colorimetric analytical method to identify the berberine hydrochloride, an anti-inflammatory medication, using citrate stabilized Ag nanostructures (Huang *et al.,* 2007). Citrate stabilized Ag nanostructures have a negatively charged surface due to electrostatic repulsion between nanostructures, resulting in yellow stable dispersions in water. Citrate stabilized Ag nanostructures have a negatively charged surface due to electrostatic repulsion between nanostructures, resulting in yellow stable dispersions in water. DNA is an ideal choice for aggregation sensing applications due to its capacity to hybridize (Ling *et al.,* 2008). Ag nanostructures coupled to oligonucleotides have lately emerged as excellent instruments for detecting target DNA sequences, and have been utilized to develop colorimetric assays based on sequence-specific hybridization-induced aggregation. Diversified nanoparticle that belong to the oligonucleotide conjugates, they are being suggested towards this ambition (Sharma *et al.,* 2020; Vashisht *et al.,* 2019). Bio mediated Ag nano-structures were used in a highly selective copper (II) ion sensor in another work. According to the findings, the generated Ag nanostructures with no surface modification were successful in detecting even the tiniest amount of heavy metal copper (II) ion and in detecting specific metal ions with high efficiency.

Conclusion

In the synthesis and application of nanostructures, biological resources are gaining ground. Humans have used plant-based nanoparticles, and biosynthetic nanoparticle production has emerged as a safer, more cost-effective, nontoxic, environmentally friendly, and superior alternative to conventional methods. Other benefits belonging to synthesis from plant extracts include a sanitary working environment, health and environmental protection, less waste, and the most stable products. The numerous chemicals naturally incorporated in plant extracts can be employed as reducing and stabilizing agents during the manufacture of silver nanoparticles, as shown in this review. Because natural capping agents prevent the particles from agglomerating, green synthesized Ag nanostructures are stable. The use of plant extracts in a green approach to generating Ag nanostructures has a number of advantages, including the ability to produce stable products in less time, decreased waste, a pleasant working atmosphere, environmental friendliness, and low cost.

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