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Synthesis, characterization, and applications of silver nanoparticles

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Abstract

Using different macromolecules to create stable, non-toxic and uniformly sized particles is one of the most difficult problems in constructing carrier systems for biological, chemical and medical applications. The new field of nanotechnology allows many synthetic strategies and procedures to be optimized in this regard. Depending on the use of the particles, various nanoparticle synthesis processes are used. Because of their small size, silver nanoparticles have so many novel applications in a variety of industries. The production of precious metal nanoparticles for environmental, optics, electronics, catalysis and biology is a hot topic. Physical and chemical processes are the two most common methods for preparing silver nanoparticles. This review focuses on the development of methods for the production of silver nanoparticles and their synthesis, Properties application, and mechanism of action.

Keywords: *Silver nanoparticles, Silver nanoparticles characterization, Silver nanoparticles applications.*

Introduction

Nanotechnology is a fascinating research topic. Globally, there has been significant growth in materials science and nanoparticle (NP) synthesis. Demonstration of NPs Specific qualities such as size (1-100 nm), form, and structure are considered when developing new or better features. Nanoparticles fall into two categories. 1) Inorganic materials 2) Organic nanoparticles (1).

Silver nanoparticles are typically between 1 and 100 nanometers in size. Silver nanoparticles have various optical, electrical and thermal properties. In industry, they are used in electronics, catalysis and photonics. Therefore, AgNP synthesis has become an important issue in the field of electronics. AgNPs are said to have a good prospect and real-world qualities in the creation in development of "new antibacterial agents, drug delivery agents, testing and diagnostic platforms, biomaterials" along with "medical device coatings, tissue repair and regeneration materials, and complex medical problems" (3).

Understanding the surface properties of metal nanoparticles helps to identify functional groups for surface functionalization and leads to the discovery of new applications for metal nanoparticles (5).

Nanoparticles of silver

Chemical or physical approaches are commonly used to create nanomaterials. Some approaches are simple and reestablish the reaction environment, allowing the crystallite size to be controlled. However, there are still issues with applying these approaches to produce general product stability and monodisperse nanoscales.

Silver nanoparticle synthesis methods

Physical method

To synthesize AgNPs with a nearly narrow size distribution, physical energy is commonly used in the physical synthesis approach. This approach allows for the rapid manufacture of a large number of AgNP samples. As a result, it is a worthwhile method for producing powder, although the cost of equipment investment must be considered (6).

Biological method

In comparison to other procedures, the biosynthetic method is a straightforward and reasonable procedure. Natural reducing agents, such as biological microbes, are used in this procedure. Both inside and outside the cell, bacteria can produce inorganic substances. This is also a cause for why microbes can be used for manufacturing nanoparticles such as gold and silver on an industrial scale (7,8).

Chemical Method

The chemical technique has been the most frequently used method due to its simplicity and convenience of usage. To regulate the production of metal nanoparticles, small nanoparticles that have a spherical form with confined diameter dissemination are essential.

Silver nanoparticles may be manufactured at a minimal expense, which is very well known. Reducing agents, metal precursors, and blockers/stabilizers are the three primary components of the chemical production of AgNPs in solution (9).

Properties of AgNPs

The last phase of synthesis, requires surface chemistry, shape, size distribution, particle composition, size, aggregation, dissolution rate, particle morphology, coating/capping, particle reactivity in solution, ion release efficiency, cell type, and the type of reducing agent. All are critical aspects that determine cytotoxicity (10).

AgNPs are prepared into various shapes, including spheres, rods, octagons, hexagons, triangles, and flower-like geometric shapes, by biological reducing agents, like culture supernatants of different Bacillus species (3, 10).

Prior studies indicate that small nanoparticles with large surface areas might generate greater toxicity than larger nanoparticles. The toxicity partly depends on the structure of the nanoparticle. For example, in biomedicine, nanocubes, nanoplates, nanorods, spherical nanoparticles, and flower-shaped nanostructures have all been used (11).

Surface Chemistry of Silver Nanoparticles

When molecules attach to the surfaces of nanoparticles in solution, an electric double layer

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forms, which stabilizes the particles and prevents them from clumping together. According to Aldrich Materials Science, many silver nanoparticles are suspended in a dilute citrate buffer, which binds poorly to the nanoparticles' surface (12).

Silver nanoparticle applications

In commercial nanomaterial applications, silver nanoparticles are commonly used. Industrial electronics, sanitary antimicrobial agents, textile coatings, food storage, and a range of other application areas have all used them (13)

Diagnose

Light is efficiently absorbed and scattered by AgNPs. A single AgNP can be seen using a dark-field microscope due to the "nanosphere's enormous scattering cross-section". AgNPs are used in a wide range of fields, including bioimaging (14), wound healing (13,14) and cancer cell detection.

Multiplexed lateral flow assay LFA diagnosis may differentiate several infections, making diagnostic studies more efficient. Multicolor AgNP binds to antibodies that recognize "Dengue Virus (DENV) NS Protein", "Yellow Fever Virus (YFV) NS1 Protein", and "Zaire Ebola Virus (ZEBOV) Glycoprotein (GP)".

Cancer Treatment

Nanoparticles known as AgNPs are used to diagnose and treat cancer as a therapeutic method. In a variety of labs, enhanced AgNPs have been working as based delivery chemotherapeutics, "Nanocarriers", and enhancers in radiation and photodynamic therapy (15).

Plasma magnetic nanoparticles are made up of a variety of nanoparticle components integrated on a single system and covered with silver-gold covered nanoparticles to enhance MRI image, according to Lim et al research (16).

The exact mechanism of AgNPs' destructive effect on the virus is still unclear. However, it has been observed that AgNPs interact with structural proteins on the surface of extracellular viruses to inhibit early infection, by preventing the binding or entry of the virus or by destroying the surface protein to cause the effect of virus infection. [17]. It has been shown that AgNPs preferentially bind to sulfhydryl-rich viral surface proteins and cleave disulfide bonds to make the protein unstable, thereby affecting viral infectivity [18]. It has also been proposed that AgNPs have intracellular antiviral effects by interacting with viral nucleic acids [19]. Zinc-containing AgNPs have antiviral activity against influenza viruses H5N1, H9N2, SARS-Cov2 and PPRV [20-24].

Silver Nanoparticles' mechanism of action

Various antibacterial effects have been considered, although the actual mechanism of action of "silver nanoparticles" is still not fully understood. Silver nanoparticles can emit silver ions indefinitely, making them a disinfectant (25). Due to the electrostatic attraction and adhesion of the proteins, silver ions can attach to "the cell wall and cell plasma membrane" (26). The attached ions can destroy the bacterial envelope by increasing the penetration of the cell plasma membrane. When free silver ions are combined with cells, respiratory enzymes are inhibited and various free radicals are produced, but adenosine triphosphate cannot be synthesized (27,28). Various free radicals can assist the stimulation of cell membranes and the conversion of deoxyribonucleic acid (DNA). Because the basic components of DNA are sulfur and phosphorus, the reaction of silver ions with these elements might prove problematic with DNA replication (3).

Since sulfur and phosphorus are the basic components of DNA, the interaction of these elements with silver ions may disrupt "DNA replication", "cell creation", and even cause microorganism death. Silver ions can also release ribosomes into the cytoplasm and inhibit protein formation (3).

Silver nanoparticles are highly toxic to Gram-negative bacteria. Gram-negative bacteria have a smaller cell wall than gram-positive bacteria. The rigid cell wall prevents nanoparticles from entering the cell (29). The antibacterial actions of silver nanoparticles on Gram-negative and Gram-positive bacteria are distinct, which indicates that the detection of silver nanoparticles is necessary for antibacterial action. Silver nanoparticles smaller than 10 nm have long been known to affect cell penetration, invade bacterial cells, and cause cell damage.

Methods used in metal nanoparticles

Energy dispersive "X-ray (EDX) spectroscopy," "Fourier transform infrared spectroscopy (FTIR)," "X-ray crystallography (XRD)," and "fluorescence correlation spectroscopy (FCS)" are used to investigate the elementary chemical and molecular composition of metal nanoparticles. Imaging techniques such as "SEM, TEM, Scanning Tunneling Microscope (STM), Environmental SEM (ESEM), and Tip Enhanced Raman Spectroscopy (TERS)" are used to investigate morphology and morphology (5)

SEM

This instrument operates similarly to an “optical microscope” in that it uses a light source and a glass lens to amplify an image. Electron microscopy is a technique for obtaining information on a sample's atomic composition and topographical properties by scanning it laterally. SEM is a surface sensing imaging programmed with three analysis ways: "backscattered electron (BSE) mode, secondary electron (SE) mode, and X-ray energy dispersive spectroscopy: TEM". The SE way (with a 1 nm resolution) is the most commonly used of these modes. Many non-conductive biological molecules pick up charge and are unable to adequately refract the electron beam, resulting in imaging inaccuracies (30). Biomolecules are coated with ultra-thin conductive materials during sample processing to avoid these artifacts.

SEM, on the other hand, can't photograph low-temperature materials like surface groups linked to cancer.

Transmission Electron Microscopy

For acquiring quantitative measurements of particle size, diameter, and shape, TEM is a powerful, widely utilized, and vital technique.

Fixing should be done with plastic inserts or negative staining materials to aid in the processing and synthesis of NPs that can withstand the instrument's vacuum. You can also freeze the NP sample and then freeze it in liquid nitrogen (31). The transmission electron microscope (TEM) is commonly used to produce contrast pictures with some good crystal surfaces (32). The size, shape, and aggregation state of "selenium nanoparticles," "silver nanoparticles," "copper nanoparticles," "iron nanoparticles," as well as other metal nanoparticles can all be determined using TEM (33).

Ultraviolet-Visible Spectroscopy

Plasmon resonance spectroscopy and UV visible spectroscopy are non-destructive measurements of matter's “light absorption”, “emission”, and other “radiation” as a function of wavelength.

Visible light (185400 nm) and UV (185400 nm) are used in a range of applications (400700 nm). Via looking at the absorbed light, Beers Lambert's equation can be used to estimate the concentration of various solutions. MNPs with spectral qualities, such as “iron and selenium”, exhibit spectral features in general, particularly after synthesis, since the color of the reaction mixture varies. Absorption rises to brilliantly colored solution characterized by plasmon resonance in MNP, particularly gold and silver (34).

X-Ray Crystallography

Bragg's law is the foundation of X-ray crystallography (XRD) (27). Diffracted X-rays are monochromatic X-rays that effectively interfere with the crystal sample. The process of identifying simple crystalline compounds without destroying them. In contrast, to sample purity evaluation, XRD may be used to measure crystallization rates, recognize tiny spark elements in nanoparticles and nanoclays, and perform “unit cell size analysis”. Ground and homogenized materials are required for proper XRD analysis. In 1915, Bragg and Nishikawa discovered orthogonal, cubic, hexagonal, tetrahedral, octahedral, and polymorphic iron oxide crystal structures (hematite, maghemite, and magnetite). Selenium nanoparticles, magnetite iron oxide nanoparticles (36) silver nanoparticles (37), gold nanoparticles, and copper nanoparticles (38), are just a few examples.

Fourier transform infrared spectroscopy

Absorption or emission infrared spectra are recorded using FTIR spectroscopy. A light that spans the full frequency spectrum (5000400 cm21). Williams, 1995 studied the oscillations of useable groups linked with nanoparticles and dangerous biological chemicals by measuring functional groups in plants before creating green metal nanoparticles (39).

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