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Synthesis, characterization, and applications of gold nanoparticles

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Abstract

The employment of diverse macromolecules to manufacture stable, non-toxic, and evenly sized particles is one of the most difficult issues in building carrier systems for biological, chemical, and medicinal applications. The new field of nanotechnology allows for the optimization of numerous synthesis strategies and procedures in this regard. Various nanoparticle synthesis processes are utilized depending on the particle's purpose. Because of their small size, silver nanoparticles have such a huge variety of novel applications in a variety of industries. The production of precious metal nanoparticles for applications in the environment, optics, electronics, catalysis, and biology is a hot topic. Physical and chemical processes are the two most common ways to make silver nanoparticles. These approaches have the drawback of absorbing harmful chemicals. Biomedical applications rely heavily on gold nanoparticles (AuNPs). AuNP is routinely utilized in diagnosis and is becoming more widely used in therapy. We present the findings of this research in this paper.

Keywords: *Silver nanoparticles, Gold nanoparticles, Therapeutic Approach, Diagnostics*

Introduction

Nanotechnology is a fascinating topic of study. Globally, there has been a significant increase in materials science and nanoparticle (NP) synthesis. Show of NP Specific qualities, such as size (1-100 nm), form, and structure, are taken into account while developing new or better features. Nanoparticles are divided into two categories. 1) Inorganic materials 2) Organic nanoparticles (1).

ZnS, ZnO, and CdS are inorganic NPs; gold, silver, copper, and aluminum are metal nanoparticles; cobalt, Fe, and Ni are magnetic nanoparticles; and fullerenes, quantum dots, and carbon nanotubes among organic nanoparticles (2).

The size of silver nanoparticles is commonly between 1 and 100 nanometers. Silver nanoparticles contain multiple optical, electrical, and thermal properties. In the industrial world, they're utilized in electronics, catalysis, and photonics. As a result, AgNP synthesis has emerged as a significant issue in the electronics sector. 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).

Gold nanoparticles (AuNPs) are frequently used in bio-nanotechnology because of their varied surface characteristics and properties. Due to the ease with which AuNPs can be functionalized, they can be used as a multi-functional platform for nanobiological assembly, oligonucleotide, single antibody, and protein. Bioconjugates, such as AuNPs, have demonstrated their potential in the development of novel biomaterials for research into biological systems (4).

Understanding the surface properties of metal nanoparticles can help identify the functional groups used for surface functionalization and lead to the discovery of novel applications for metal nanoparticles (5).

Gold Nanoparticles

For the synthesis of gold nanoparticles, there are numerous technologies and methodologies.

Synthesis methods of gold nanoparticles

Turkevich method

This method was developed by Turkevich in 1951. To make "trisodium citrate dehydrate," boil "HAuCl4 solution," then instantly pour it into the boiling solution while vigorously "stirring." Within a few moments, the solution's color will shift from bright yellow to wine red. This technique produces AuNPs with a diameter of roughly 20 nm. The citrate ions in this process act as both a “stabilizer and a reducing agent” (6,7)

Ferns updated the Turkevich method in 1973 by altering the ratio of “reducing agent/stabilizer” (trisodium citrate/gold) and producing AuNPs with diameters ranging from 15 to 150 nm.

Seeding growth method

Another approach for the manufacturing of gold nanoparticles that have been reported is seed growth. Gold nanoparticles with a diameter of 5-40 nm and a narrow particle size distribution have been manufactured in this approach. The particle size can be adjusted by changing the seed crystal to metal salt ratio, allowing any sizes between 5 and 40 nm to be created (8). The benefit of this procedure is that it is simple, quick, and inexpensive.

The method of electrochemistry

In 1994, the electrochemical synthesis of nanoparticles was studied for the first time. Their work showed that the use of “alkyl ammonium" salts as a solvent for stainless steel is an aqueous solution and that they can build special nanoscales to electrochemically change metal particles (9). The electrochemical synthesis process can be used to produce gold nanoparticles on the surface of multicolor carbon nanotubes with glassy carbon electrodes. Gold nanoparticles electrochemically form an oxidation anode and a reduction cathode in a simple two-electrode battery. Due to its simple equipment, low cost, low processing temperature, good quality, and easy yield control, electrochemical processes have proven to be superior to other nanoparticle synthesis methods (10-13).

Properties of Gold Nanoparticles

Gold nanoparticles (AuNPs) are being extensively researched as well as used for the diagnosis of tumors along with therapy due to their exceptional fundamental properties. AuNPs' inherent features, as well as the interrelationships between these traits, must be thoroughly investigated to make them more appropriate for tumor detection and treatment.

Physical Properties

Physical properties of nanoparticles include "color, density, melting temperature, tensile strength, and electrical conductivity", which are affected due to their size, structure, and surroundings. Physical properties like elasticity can differ significantly when a material's size approaches the nanoscale scale. Due to significant internal compressive stress, the mechanical properties of gold clusters are 2/3 that of bulk gold, according to various studies, indicating the possibility of ultra-hard materials (14).

Catalysis and Chemical Properties

AuNPs, varying from other nanoparticles, might create strong chemical interactions with groups containing S and N. As a result, AuNPs can be affixed to a broad range of chemical ligands or polymers having certain particular functionalities. AuNPs have excellent "biocompatibility, targeting, and drug delivery capabilities" thanks to these surface changes (15).

Optical and electronic properties

AuNPs have unique optical characteristics that make them excellent dyes for sensing, imaging, and labeling. Regardless of the size and shape of the nanoparticles, the AuNPs solution absorbs a lot of light and changes color. Gold nanoparticles' surroundings, size, and physical qualities all have an impact on how nanoparticles engage with light. The fluctuating electric field propagating near the colloidal nanoparticles interacts with free electrons, causing the electronic charge resonance and the coordinated oscillation of the visible light frequency. Surface plasmons are resonant oscillations of the resonant frequency. Small (30 nm) monodisperse gold nanoparticles absorb light in the cyan region of the spectrum (450 nm) and reflect red light (700 nm), producing a deep red color. As particle size increases, the wavelength of absorption associated with surface plasmon resonance shifts to redder wavelengths (16). A light blue or purple solution is created when blue light is reflected and red light is absorbed. When the particle size approaches the volume limit, the surface plasmon resonance wavelength changes to the infrared region of the spectrum, and the maximum of the visible light wavelength is reflected, giving the nanoparticles a translucent or semi-transparent appearance. The surface plasmon resonance could be modified by altering the diameter or structure of the nanoparticles so that they have adequate optical characteristics and are suited for a variety of applications (16,17).

Applications

Diagnostics

Biomarkers are detected in the diagnosis of heart disorders, malignancies, and infectious pathogens by using gold nanoparticles. They're also popular in lateral flow immunoassays, with the home pregnancy test being a good example (17).

Therapeutic

Therapeutic agents can also be coated on gold nanoparticles surfaces. The enormous surface-area-to-volume ratio of gold nanoparticles allows hundreds of molecules to be coated on their surface (including therapeutics, targeting agents, and anti-fouling polymers) (18).

Antibacterial (Drug)

Antibacterial agents, often known as antibiotics, as antibacterial agents that can kill or inhibit the growth of bacteria and are used to prevent and treat bacterial infection (19). The antibacterial activity of gold nanoparticles made using the green approach has been demonstrated in a variety of domains. As a reducing agent and stabilizer, a marine bacterial isolate was used whereas chloroauric acid ($HAuCl_4$) was utilized as a precursor in the synthesis of aluminum in Ibrahim et

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al investigation's (20). The antibacterial activity is done by changing the surface of viscose and cotton fabrics with O2 plasma by physiologically reducing AuNPs with ZnONP or TiONPs for further study. Furthermore, antibacterial activity was created by utilizing the rhizome of the Acorus calamus without a binder as a reducing agent (21).

As anti-cancer

The specificity and solubility of a drug's target determine its efficacy. The drug's negative effects should be linked to the increased dose used to treat human cell disorders. Traditional treatment procedures like chemotherapy, radiation therapy, and surgery have been abandoned by new NPs. Gold and silver nanoparticles are two new types of nanoparticles that have emerged as possible contributors to the controlled and long-term delivery of diverse therapeutic compounds to their target sites. Many researchers are interested in gold nanoparticles because of their potential to treat cancer and other diseases (18).

Catalysis

A variety of chemical processes use gold nanoparticles as catalysts. A gold nanoparticles' surface can be employed for selective oxidation or, in some situations, can minimize a process. For fuel cell applications, gold nanoparticles are being produced. The automobile and display industries would benefit from these innovations (20,21).

Antimicrobial mechanism of gold nanoparticles

To figure out how AuNPs function against bacteria, employed proteomics and transcriptomics analysis. AuNPs have two mechanisms of action against multidrug-resistant (Gram-negative) bacteria: they inhibit ATPase activity, which lowers membrane potential and hence ATP levels, and they block ribosomal subunit binding to tRNA (22). Gold nanoparticles have been shown to up-regulate genes involved in the flagellar activity and chemotaxis pathways in transcriptome studies (23).

References

1. Khan, I., Saeed, K., Khan, I., Nanoparticles: properties, applications and toxicities. Arabian J.Chem. 2019; 12: 908-931.
2. Ladj, R., Bitar, A., Eissa, M.,et al., Individual inorganic nanoparticles: preparation, functionalization and in vitro biomedical diagnostic applications. J Mater Chem B. 2013; 1: 1381.
3. Saadh, M.J., Synthesis, role in antibacterial, antiviral, and hazardous effects of silver nanoparticles. Pharmacologonline. 2021; 2: 1331-1336.
4. Bandyopadhyay, S., McDonagh, B.H., Singh, G., et al., Growing gold nanostructures for shape-selective cellular uptake. Nanoscale Res Lett. 2018; 13: 254.
5. Bhatia, S., Nanoparticles Types, Classification, Characterization, Fabrication Methods and Drug Delivery Applications. In: Natural Polymer Drug Delivery Systems. Springer, 2016 Cham.
6. Turkevich, J.S.P., Nucleation and growth process in the synthesis of colloidal gold. Discuss Faraday Soc. 1951; 11: 55–75.
7. Hu, M., Chen, J., Li, Z., et al., Gold nanostructures: engineering their plasmonic properties for biomedical applications. Chem Soc Rev. 2006; 35: 1084-1094.
8. Jana, N.R., Gearheart, L., Murphy, C.J., Seeding growth for size control of 5–40 nm diameter gold nanoparticles. Langmuir. 2001; 17: 6782-6786.
9. Reetz, M.T., Helbig, W., Size-Selective Synthesis of Nanostructured Transition Metal Clusters. J Am Chem Soc. 1994; 116: 7401–7402.
10. Mohanpuria, P., Rana, N.K., Yadav, S.K., Biosynthesis of nanoparticles: technological concepts and future applications. J Nanopart Res. 2002; 10: 507-517.
11. Chen, S., Yang, Y., Magnetoelectrochemistry of Gold Nanoparticle Quantized Capacitance Charging. J Am Chem Soc. 2002; 124: 5280-5281.
12. Freeman, R.G., Grabar, K.C., Allison, K.J., Self-Assembled Metal Colloid Monolayers:

An Approach to SERS Substrates. SCIENCE. 1995; 267: 1629-1632.

13. Kamat, P.V., Manipulation of Charge Transfer Across Semiconductor Interface. A Criterion That Cannot Be Ignored in Photocatalyst Design. J Phys Chem Lett. 2012; 3: 663-672.
14. Alex, S., Tiwari, A., Functionalized Gold Nanoparticles: Synthesis,. J Nanosci Nanotechnol. 2015; 15: 1869-1894.
15. Johal, M.S., Johnson, L.E., Understanding nanomaterials. Boca Raton, FL, USA:: CRC Press; 2011.
16. Nghiem, T.H.L., La, T.H., Vu, X.H., et al., Synthesis, capping and binding of colloidal Au nanoparticles to proteins. Adv Nat Sci: Nanosci Nanotechnol. 2010; 1: 025009.
17. Hassan, M.E.A., Mai, M.H.M., In vitro diagnostic prospects of nanoparticles. Clinica Chimica Acta. 2009; 403: 1-8.
18. Singh, P., Pandit, S., Mokkapati, V.R., et al., Gold Nanoparticles in Diagnostics and Therapeutics for Human Cancer. Int J Mol Sci. 2018; 19:1979.
19. Prasad, T.E.E., Biofabrication of Ag nanoparticles using Moringa oleifera leaf extract and their antimicrobial activity. Asian Pac J Trop Biomed. 2011, 1: 439-442.
20. Chinnappan, S., Kandasamy, S., Arumugam, S., et al., Biomimetic synthesis of silver nanoparticles using flower extract of Bauhinia purpurea and its antibacterial activity against clinical pathogens. Environ Sci Pollut Res. 2018; 25: 963-969.
21. Tripathi, R.M., Shrivastav, A., Shrivastav, B.R., Biogenic gold nanoparticles: As a potential candidate for brain tumor directed drug delivery. Artif Cells Nanomed Biotechnol. 2015; 43: 311-317.
22. Cui, Y., Deng, R., Wang, G., Pan, D., A general strategy for synthesis of quaternary semiconductor Cu_2MSnS_4 (M = Co^{2+}, Fe^{2+}, Ni^{2+}, Mn^{2+}) nanocrystals. J Mater Chem. 2012, 22: 23136-23140.
23. Achmad, S., Razman, S., Ahmad, B., et al., Review of silver nanoparticles: Research trends, global consumption, synthesis, properties, and future challenges. J Chin Chem Soc. 2017; 64: 732-756.