11. Synthesis and Applications of Silver Nanoparticles

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1. Introduction

Nanoscience is a new multidisciplinary science that has just emerged. It may be characterised as a comprehensive understanding of the fundamental characteristics of nanoscale things. The prefix 'nano' stands for one billionth of a unit, or 10-9. Nanochemistry is now one of the fastest expanding areas of nanoscience. As a result, maintaining control over the size and size distribution is critical. Changing the synthesis processes, reducing agents, and stabilisers is widely used to obtain particular control of shape, size, and size distribution. Metal nanoparticles can be made in one of two ways. The second method is a chemical one in which the concentration of metal ions in solution is lowered in order to promote the creation of tiny metal clusters or aggregates. Chemical methods can be divided into two types based on the nature of the reducing agent: classical chemical, which uses well-known chemical reducing substances and radiation-chemical, which uses solvated electrons generated by ionising radiation to initiate the reduction process. Chemical methods can also be divided into those that use a nondetergent solvent and a naturally occurring reducing agent such as polysaccharides or plant extracts as reductants. The stabilisation of nanoparticles is typically divided into two categories: electrostatic and steric stabilisation. Anionic species, such as halides, carboxylates, or polyoxoanions, are coordinated to metal particles to achieve electrostatic stability. This creates coulombic repulsion between the nanoparticles, resulting in the creation of an electrical double layer. Steric stabilisers include polymers and large cations like alkylammonium. The choice of stabiliser also allows the nanoparticles' solubility to be adjusted.

2. Silver Nanoparticles are Synthesised

2.1. Physical Approach

Metal nanoparticles are often made through evaporation–condensation in physical processes, which may be done in a tube furnace at atmospheric pressure. The source material is vaporised into a carrier gas inside a boat centred around the furnace. The evaporation/condensation approach has previously been used to make nanoparticles of several materials such as Ag, Au, PbS, and fullerene.

2.2. Chemical Method

Chemical reduction is the most frequent method for producing AgNPs as stable, microspheres in water and organic solvents. Colloidal silver with particle sizes of several nanometers is produced by reducing silver ions (Ag^+) in aqueous solution. The reduction of different complexes with Ag^+ ions first results in the creation of silver atoms (Ag^0), which are then agglomerated into oligomeric clusters. Colloidal Ag particles are formed as a result of these clusters. However, even when using a weaker reductant, such as citrate, the size distribution remained large. During the preparation of metal nanoparticles, it is critical to utilise protective agents to stabilise dispersive nanoparticles. The most frequent technique for preventing nanoparticle agglomeration is to shield them using protective chemicals that can be absorbed on or bound to the nanoparticle surface. AgNPs can also be made inside a microemulsion. Metal clusters generated at the interface are stabilised because their surfaces are covered with nonpolar aqueous medium stabiliser molecules.

The interphase transporter then transports it to the organic medium (Krutyakov et al., 2008). This technology enables for the creation of nanoparticles that are homogenous and size-controllable. This approach, on the other hand, uses an extremely toxic organic solvent. As a result, A significant amount of surfactant and organic solvent supplied to the system must be removed from the end product and discarded before the system can be considered operational. As a result, making silver nanoparticles with this process is costly. Zhang et al., on the other hand, employed dodecane as the oily phase, which is a low-harmful and even nontoxic solvent. As a result, the produced silver solution does not need to be removed from the reaction solution and may be utilised immediately for antibacterial purposes. Scientific professionals in a variety of sectors, on the other hand, realise the benefits of creating particles that are easily disseminated in organic media. In practical applications, it is critical to transfer nanoparticles to various chemicophysical conditions. Nanoparticles created in nonpolar fluids, on the other hand, are uncommon and difficult to obtain (Andrews and Ozin, 1986; Nakao and Kaeriyama, 1989; Cozzoli et al., 2004). Huang and Yang, for example, created AgNPs by photoreducing $AgNO_3$ in layered inorganic clay solutions (laponite, which acts as a stabilising agent to prevent nanoparticle aggregation). Silver nanoparticle characteristics were investigated as a function of UV irradiation time. When silver nanoparticles were exposed to ultraviolet light for three hours, a bimodal size distribution and relatively large silver nanoparticles were generated. After additional irradiation, the AgNPs disintegrated into smaller sizes with a single mode distribution, indicating that they were oxidised. resulting in a very stable size and size distribution (Huang and Yang, 2008). Environmentally friendly chemistry, which makes AgNPs by utilising naturally occurring reducing agents such as polysaccharides, biological microorganisms such as bacteria and fungus, or plant extracts, has recently emerged as a simple and viable alternative to more complex chemical synthetic approaches.

3. Silver Nanoparticles are Being Characterised As

Nanoparticles must be characterised in order to understand and manage their production and usage. This is essential. Material characterization techniques include transmission and scanning electron microscopy (TEM and SEM), atomic force microscopy (AFM), dynamic light scattering (DLS), X-ray photoelectron spectroscopy (XPS), powder-X-ray diffractometry (XRD), Fourier transform infrared spectroscopy (FTIR), and ultraviolet–visible spectroscopy (UV–Vis). These approaches can be used to determine a variety of attributes such as particle size, shape, crystallinity, fractal dimensions, pore size, and surface area, among other things. Additional benefits include the possibility of applying these approaches to research nanoparticles and nanotubes in nanocomposites, such as their orientation, intercalation, and dispersion. For example, TEM, SEM, and AFM can be used to determine the morphology and particle size. Unlike SEM and TEM, AFM has the ability to measure three-dimensional pictures, allowing for the calculation of particle height and volume. For determining particle sizes, dynamic light scattering is employed. The crystallinity of the sample may be determined by using X-ray diffraction, while the plasmon resonance of the sample can be confirmed using UV–Vis spectroscopy.

4. Applications

As anti-bacterial agents, AgNPs have been widely employed in the medical field as well as food storage, textile coatings, and a variety of other environmental contexts. The proof of silver's toxicity is still unclear despite its widespread use for decades. Products using AgNPs have been approved by the US Food and Drug Administration, the US Environmental Protection Agency, Japan's SIAA, and Korea's Testing and Research Institute for Chemical Industry, and the FITI Testing and Research Institute. The textile industry was also urged to utilise AgNPs in various textile fabrics as a result of this. Toward this end, silver nanocomposite fibres containing silver nanoparticles were created. Escherichia coli was very resistant to the antibacterial properties of cotton fibres containing AgNPs. Nanoscale sensors with quicker reaction times and lower detection limits are now possible because to AgNPs' electrochemical characteristics. A good example of this is the remarkable sensitivity to hydrogen peroxide of AgNPs electrodeposited onto alumina plates by Manno et al. (2008) using a gold micro-patterned electrode (Hahm and Lieber, 2004). In contrast to the chemical characteristics of bulk materials, nanoparticles have unique catalytic capabilities. For example, silver-containing nanoparticles were shown to significantly improve the bleaching of organic colours using potassium peroxodisulphate in aqueous solution at ambient temperature by Ko et al. AgNPs also outperformed Au and Pt colloid in catalysing the chemiluminescence produced by a luminol–hydrogen peroxide combination (Guo et al., 2008). The reduction of 4-nitrophenol with NaBH4 in alkaline aqueous solutions was catalysed, according to Liu and Zhao, by silver nanoparticles supported halloysite nanotubes (Ag/HNTs) with an Ag concentration of approximately 11 percent, according to the researchers (2009).

5 Conclusion

It is the surface plasmon resonance of metallic nanoparticles that determines their optical properties. In this context, the plasmon refers to the collective oscillation of all free electrons within a nanoparticle. Nanoparticle size and shape, the metallic species, and the surrounding medium all influence plasmon resonant peaks and line widths. Optical data storage might, for example, be based on nanoclusters made of 2–8 silver atoms each. In addition, the clusters' fluorescent emissions might be employed in biological labelling and electroluminescent displays in the future.

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