Mini Review

Metallic nanoparticles as alternative antimicrobials

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ABSTRACT

Metallic nanoparticles are currently widely used in biological and engineering research. Because of their enormous potential in nanotechnology, they have attracted a lot of attention. These materials can now be synthesized and modified with various chemical functional groups, allowing them to be conjugated with antibodies, ligands, drugs of interest, opening up a wide range of potential applications in biotechnology, magnetic separation, pre-concentration of target analyses, targeted drug delivery, and vehicles for gene and drug delivery, as well as diagnostic imaging. Furthermore, numerous imaging modalities such as MRI, CT, PET , Ultrasound, SERS and optical imaging have been created over time to aid in the imaging of various disease states. These imaging methods have different techniques and equipment, and they all require a contrast agent with certain physiochemical qualities. For use in these imaging modalities, several nanoparticulated contrast agents such as magnetic nanoparticles (Fe_3O_4), gold, and silver nanoparticles were developed. In addition, additional multifunctional nano shells and nano cages have been designed to utilize multiple imaging modalities simultaneously.

Key Words: *Gold nanoparticles; Iron oxide nanoparticles; Metallic nanoparticles; nano cages; nano shells; Silver nanoparticles.*

INTRODUCTION

Nanoparticles employed in biotechnology have particle sizes ranging from 10 nm to 500 nm, seldom surpassing 700 nm. Because of their nano size, these particles can communicate with biomolecules on cell surfaces and within cells in ways that can be decoded and assigned to various biochemical and physiochemical aspects of these cells. Similarly, its potential use in drug delivery systems and noninvasive imaging provided a number of benefits over traditional pharmaceuticals. In order to fully exploit nanoparticles, it is critical that the nano particulate systems be stable, biocompatible, and selectively directed to specific areas in the body following systemic delivery. Targeting systems that are more particular are meant to recognize certain cells, such as cancer cells. Once targeted (active or passive), these nano carriers can be designed to act as imaging probes for a variety of imaging techniques, including Ultrasound (US), X-ray, Computed Tomography (CT), Positron Emission Tomography (PET), Magnetic Resonance Imaging (MRI), optical imaging, and Surface-Enhanced Raman Imaging (SERS). As a result, these so-called "molecular imaging probes" can provide noninvasive information on distinguishing anomalies in various body structures and organs in order to establish the extent of sickness and assess therapy efficiency [1]. Monometallic NPs include only one type of metal with distinct chemical and physical properties, such as Ag, Au, Zn, Pd, Cu, Ti, Si, Al, Se and Mg, which have long been employed for antibacterial action.

Ag NPs are the most effective of these since they can kill both Gram-positive and Gram-negative bacteria, and they can even kill drug-resistant bacteria. Metal oxide NPs, such as Ag2O, ZnO, CuO, TiO_2, NiO, Fe_3O_4, $-Fe_2O_3$, CaO, MgO, $Al2O_3$, CeO2, Mn_3O_4 and ZrO_2 NPs, exhibit highly powerful antibacterial activities against a broad range of microbes [2]. Bimetallic NPs are made up of two different types of metal atoms fused together to form a single Nano metric substance with a variety of topologies, morphologies, and characteristics. Bimetallic NPs can be modified by selecting the proper metal precursors to obtain the required shape, size, structure, and morphology based on the atom configuration, resulting in alloy, core–shell, and aggregated nanoparticle types. Bimetallic NPs with unique surface activities include Ag/Au, Ag/Cu, Au/Pt, Au/Pd, Ag/Fe, Fe/Pt, Cu/Zn, Cu/Ni, Au/CuS and Fe3S4/Ag NPs [3]. For reducing metal consumption, atomic ordering, and fine-tuning the size and shape of these NPs, trimetallic NPs are synthesized from three distinct metals. In a variety of applications, such as biomedical, antibacterial, catalytic, active food packaging, and sensing, trimetallic NPs have greater catalytic selectivity/activity and efficiency. Trimetallic NPs were further characterized as alloys and intermetallic NPs by modifying the atomic distribution and surface compositions of different metals to adjust their catalytic performance [4].

Metal nanoparticles

Metal-based nanoparticles are the most widely used inorganic nanoparticles, and they offer a viable answer to antibiotic resistance.

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They not only use methods of action that are fundamentally different from those reported for classical antibiotics, demonstrating efficacy against bacteria that have already evolved resistance, but they also target several biomolecules, posing a threat to the formation of resistant strains [5]. Numerous techniques can be used to characterize metal-based nanoparticles. These approaches reveal important details regarding their shape, physicochemical, and electrical properties, all of which are important for their in vivo activity. Nanoparticles' most important qualities include their size, shape, roughness and surface energy [6].

Silver nanoparticles (AgNPs)

Silver has been used to treat wounds as an antibacterial agent, both in its solid state and in combination with salt solutions to clean wounds. Because of its chemical stability, excellent conductivity, catalytic, and antibacterial activity, silver has a lot of fascinating qualities. Furthermore, silver nanoparticles are one of the most investigated nanoparticles today. AgNPs have been used in a variety of industries, including textiles, cosmetics, the food sector, and biomedicine. They are gaining traction in the biomedical arena, owing to their applications as antibacterial agents, medical device coatings, and chemotherapeutic drug carriers [7].

Copper and Copper Oxide nanoparticles (CuNPs, Cu2ONPs and CuONPs)

Cooper is a semiconductor substance that is thought to be a good choice for making metal-based nanoparticles. It is also durable, stable, inexpensive and simple to synthesize, in addition to being heat resistant [8].

Gold nanoparticles (AuNPs)

AuNPs are colloidal or clustered particles with a gold core and a biocompatible inert coating. One of these particles' benefits is their synthetic adaptability, which allows them to be controlled in terms of size, shape, and surface features. Their coating can also be changed to influence particle solubility, stability, and environmental interaction. The surface of the AuNPs can also bind thiols and amines, giving functional groups for labeling, targeting and conjugating pharmaceutical compounds. Because of their optical and electrical properties, Au is a substance of great interest in the medical field. Biosensors and bio-imaging, drug delivery systems and the treatment of various diseases are only a few of the key areas of application for AuNPs [9].

Zinc Oxide nanoparticles (ZnONPs)

Zinc is an essential mineral that is widely distributed throughout the body tissue and is involved in the catalytic activity of various enzymes. Zinc oxide (ZnO) is a multipurpose and biocompatible semiconductor material that is used to make a variety of products, including plastics, paints, ceramics, batteries and antibacterial agents. The Food and Drug Administration (FDA) considers it to be one of the safest materials in the pharmaceutical industry.

The intrinsic features of Nano sized ZnO, such as its wide band gap (3.37 eV), high-exciton bingeing energy (60 MeV), high electronic conductivity, nontoxicity and chemical durability, have piqued industrial interest. ZnONPs have unique optical features that allow them to be employed as drug delivery systems, anticancer, antibacterial, antidiabetic and anti-inflammatory agents [10].

CONCLUSION

Metal-based nanoparticles are widely employed in biological sciences and engineering, and their use has skyrocketed in recent years with no signs of slowing down. The main characteristics of AgNPs, CuONPs, AuNPs and ZnONPs, which are commonly used in medical and pharmaceutical applications (e.g., as antibacterial, antifungal, antiviral, antiamoebial, anti-cancer, anti-angiogenic and anti-inflammatory medicines), are re-examined. Nanoparticles use different methods of action than traditional treatments, with the benefit of being effective against bacteria that have already developed antibiotic resistance, as well as targeting several biomolecules, which slows the spread of resistant strains. Metal nanoparticles' physicochemical qualities, dose, and delivery route, which influence their pharmacokinetics and pharmacodynamics, are to blame for any potential toxicological effects in humans.

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