

Application of Noble Metal Nanomaterials for Antibacterial and Disease Treatment

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Abstract. The research progress of nanotechnology has been developing rapidly in the past half century, and nanotechnology using noble metals as nanomaterials is particularly special. The emerging promise of medical treatments in this broad field has attracted the attention of many researchers. Several noble metal nanomaterials are gradually being used in the biomedical field. It is necessary to investigate the application direction and application prospect of noble metal nanomaterials. In this research, there will evaluate the current research and analysis the data to gain the potential of these nanomaterials. At the same time, this research also introduces the application of some special noble metal nanomaterials, including gold nanomaterials, silver nanomaterials, platinum nanomaterials, and other nanomaterials in clinical treatment, anticancer and other aspects, and analyzes these research results and application prospects, and some cases that have achieved excellent results in medicine are presented in the research. Noble metal nanomaterials have great advantages and potential, helping to overcome many technical obstacles in the medical field, and such materials will play an irreplaceable role in the future.

Keywords: Noble Metal Nanomaterials, Biomedicine, Application.

1. Introduction

Nanoscience and nanotechnology at the nanoscale which are science and engineering conducted (1 to 100 nm). Nanoscience and nanotechnology can be applied and used in all fields of science such as biology, physics, chemistry and engineering. Long before nanotechnology was used, the concept of nanotechnology is firstly introduced. An American physicist proposed a hypothesis: a new method that allows a scientist to manipulate and control individual atoms. With the development of the scanning tunneling microscope (STM), it shows that individual atom begins developing until 1981. Although nanotechnology is being developed in recent years, nanotechnology have been used in medieval times. And an example is stained glass windows, where its color is created by alternating-sized gold and silver particles. And formation of stained-glass windows led to a change in material composition.

In recent years, a diverse of different nanoparticles have become widely used in many fields such as food and medical industry [1]. Any others, they could be applied from contrast agents (for imaging) or drug delivery into tumours, and nanoparticles usage can also enable analysis and therapies that cannot be done otherwise. Metallic nanoparticles are now widely utilized in biomedical science and engineering, one of the most vital one of all the metallic nanoparticles used in biomedicine is the silver nanoparticle (AgNPs) and gold nanoparticles (AuNPs).

For the application of noble metal nanomaterials in biomedicine, AgNPs and AuNPs have properties to against different types of cancer have been widely demonstrated as part of various therapeutics *in vitro* and *in vivo* [1-4]. Because of its good performance on antimicrobial, it could induce rapid cell apoptosis by inducing oxidative stress in cells [1]. By modifying the surface of AgNPs, the interaction with cells can be affected. Therefore, it could achieve the effect of targeted therapy. In addition to treating cancer, AgNPs can also be used to treat various bacterial infections. As an antimicrobial agent, AgNPs have been used as composites in dental resin and in coatings of medical instruments. In the study by Bendale et al., biosynthesized platinum NPs have been tested for treatment human lung adenocarcinoma (A549), ovarian teratocarcinoma (PA-1) and pancreatic

cancer (Mia-Pa-Ca-2) cells [2]. The platinum NPs was proved that could be potent anti-ovarian cancer drugs. In a study by Gilson et al., ruthenium nps can be mixed with TiO_2 to make the photosensitizer to synergistically generate reactive oxygen species, where photodynamic therapy (PDT) is used for the treatment of various diseases [3]. Zhang et al. prepared palladium-containing nanoparticle photocatalyst (TiON/PdO) by sol gel method. The results confirmed that the nanoparticle photocatalyst (TiON/PdO) has an efficient photocatalytic disinfection effect on wheat macrospores under visible light illumination [4]. As a result, this research mainly analyzes the application of noble metal nanomaterials in the field of biomedicine, including antibacterial effect and cancer treatment.

2. Application of noble metal nanomaterials in biomedicine

2.1. The treatment

AgNPs are very important and vital in nanomedicine because it has the potential to be applied in cancer therapy and diagnosis [5]. One of the earliest discoveries of usages of silver in wound care was by Hippocrates. Surgeons often used silver as a method of reducing the chance of infection. Doctors used silver-containing eye drops to cure eye problems, and sometimes internally for certain diseases, such as tropical spruce, gonorrhea, and some cold, and soldiers in some wars used silver leaves to cure infections. Other purposes of AgNPs nowadays are medical device coating, orthopaedics, anti-cancer drugs and enchanting the effects of tumour killing anti-cancer drugs. Conventional physical and chemical methods seem to be very expensive and hazardous.

Silver has many medical uses. As shown in Figure 1, wound dressings that contain AgNPs are used to reduce or decrease the external infections [6]. Silver in the dressing materials can keep on releasing silver ions which is essentials in wound healing as silver could kill the bacterial cells by punching holes inside the membrane and destroy the cell. In the plastic surgery department, the application of silver nanoparticles on the surface of implants can effectively prevent postoperative infection. However, a recent study shows that 50 nm AgNPs can be highly toxic to the destruction of osteoblasts and osteoclasts (these two cells are the two main cells that maintain bone growth and metabolism) under the condition of lower than the effective antibacterial concentration, while 3 μm silver particles are very low toxic. However, the concentration of silver ions to exert antibacterial effect is 2-4 times higher than the toxic concentration. This may be due to the smaller the particle size, the larger the surface area, and the more silver ions released. This will affect the biocompatibility of the implant.

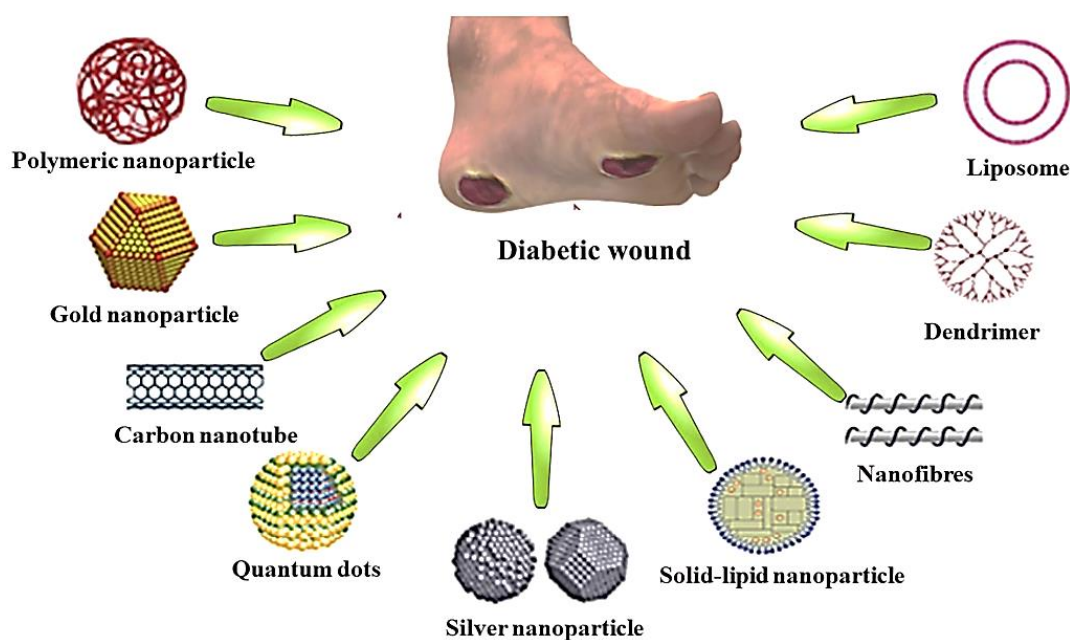


Figure 1. Applications of different nanomaterials for wound healing [6].

2.2. Antibacterial function

In recent years, the antibacterial function of nano-silver has been gradually discovered, and the preparation methods of nano-silver particles are also various. The following introduces some experiments to test the antibacterial function of nano-silver and some methods for preparing AgNPs. Gajbhiye et al. added AgNPs into fluconazole to try in this way to enhance the antibacterial activity of fluconazole against glomeruli, herbs, *Fusarium hemicalis*, *Trichoderma* and *Candida albicans* [7]. And evaluate its antifungal activity against human and plant pathogenic fungi. Fluconazole, an antifungal drug widely used to treat many fungal infections. The aim of Gajbhiye et al. was to try a combined approach, combining fluconazole with AgNPs, with the intention of amplifying the antibacterial effect of fluconazole. The fungal materials involved in the experiment include: glomerulus (MTCC-2710), herbal medicine (MTCC-2319), *Fusarium hemicalis* (USM-3794) and *Trichoderma* (MTCC-3201).

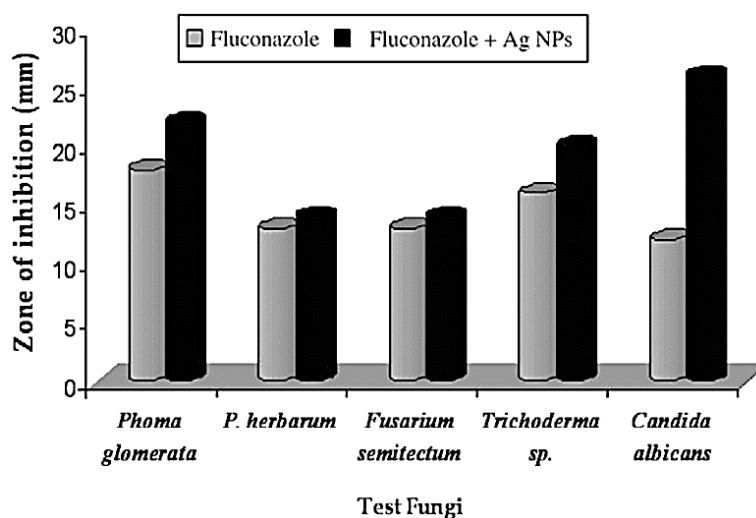


Figure 2. Antibacterial effect of the prepared silver nanomaterials [7].

In the experiment, *Alternaria alternata* was used to synthesize AgNPs, cell filtrate and biomass were extracted from the cultured *Alternaria alternata* fungal culture solution, and mixed with silver nitrate solution and prepared at room temperature for 4 hours. Nanoscale silver particles. The method used by Gajbhiye et al. is the UV-Vis spectrophotometer, an optical measurement that has been shown to be effective for the determination of AgNPs. Then use NADH-dependent nitrate reductase enzyme to reduce silver ions, and finally obtain AgNPs with an average size of 32.5 nm. A method was used to evaluate the antifungal activity of fluconazole in vitro called disk diffusion method. The experiment also set up a control group with fluconazole (negative) and combination of fluconazole-AgNPs (positive) to do two groups of experiments. The experimental results showed that the combination group (positive) had stronger antibacterial ability than the control group (negative), and the difference was expressed as the average surface area of the inhibition zone of each drug in the colony. The expression of AgNPs on the antibacterial effect of fluconazole, the combination of the two can exert more excellent performance. It was concluded that the antifungal activity of fluconazole was significantly increased in the presence of AgNPs. The highest antifungal activity was against *Candida albicans*, followed by *Trichoderma* and *Glomerularia*. On the other hand, the reflection in this paper shows that AgNPs can be used as a single antibacterial drug by itself, but this is not proved by experiments.

The coating material can effectively resist the bacterial infection that occurs during surgery. It is characterized as an antibacterial agent with long-term antibacterial ability. Since titanium nanomaterials are widely used in medicine, they are highly compatible with biomedicine, and titanium nanotubes (TiO₂-NTs) with lower elastic modulus have better advantages in biomechanical compatibility. At the same time, as an excellent antibacterial drug carrier, TiO₂-NTs can carry more functions in medicine. In terms of nano-antibacterial coatings, Zhao et al. made nano-structured

titania coating incorporated with silver nanoparticles [8]. This coating ensures the function of nano-silver to kill bacteria while limiting the cytotoxicity of silver, so that it will not cause damage to the human body. Figure 3 shows the morphology of the coating material under the optical microscope, where the nano-silver in B, C, D, and E come from different concentrations of silver nitrate solutions, respectively. It can clearly see that the number of nano-sized silver particles increases with the increase of silver nitrate solution concentration.

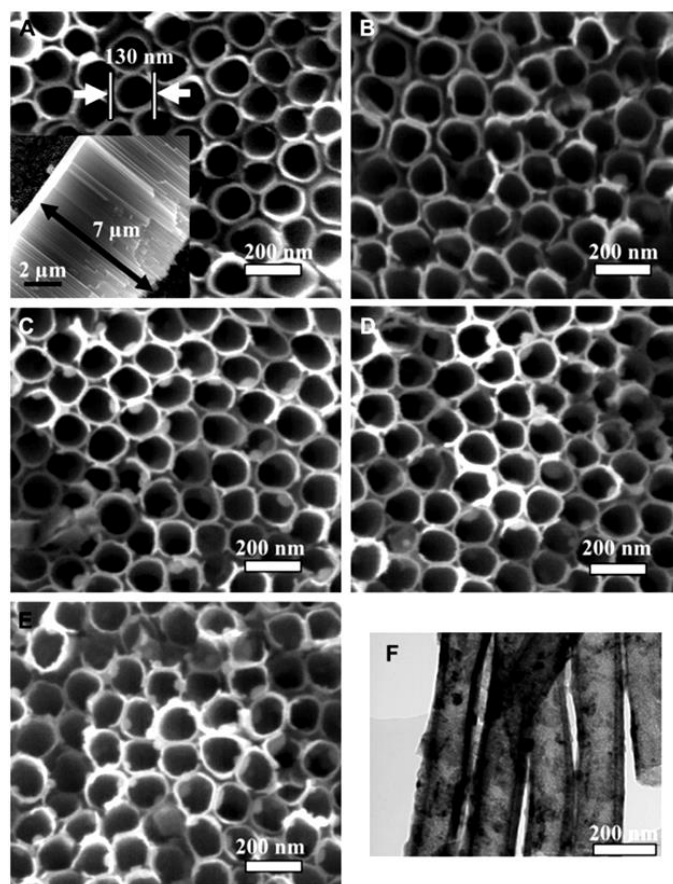


Figure 3. SEM images of the prepared TiO₂ samples [8].

The experiment used *Staphylococcus aureus* for antibacterial performance testing. After DNA analysis, it can be clearly observed that the reduction of bacteria with the increase of silver content also proves that the titanium nanotubes themselves also have certain antibacterial properties. After several days of observation, it can be seen that this antibacterial phenomenon has continued, and the performance of the surface coating material is persistent. It is very suitable as a material for preventing infection in clinical medicine.

2.3. Cancer therapy

Cancer is a condition where cells in specific parts of your body grows uncontrollably and spreads rapidly to other parts of the body. The formation of new cells to replace old and damaged cells, in this way human cells grow and reproduce through cell division. Sometimes the orderly process will break down and cells grow where they shouldn't, these cells form tumours which could become cancer usually cancer tumours may grow back. And the incidence rate of early-onset cancer had risen sharply worldwide since 1990. In recent times, there has yet to be an effective way to treat cancer. This method has some shortcomings, such as insufficient drug concentration to reach the tumor site, limited ability to monitor the response and development of multiple drug resistance, and insufficient cytotoxicity. Therefore, cancer treatment is far from optimal.

Nanotechnology could be applied in the cancer therapy. Similar to any cancer treatment, the purpose is to reach correct concentration on tumour sites, destroying cancer cells while ensuring the

minimal damage to normal cells. It is crucial to create single agents with the potential to contribute in cancer detection, detection and cancer treatment. Several strategy including immunotoxins, radioimmunotherapeutics and drug immunojungates are being developed to treat cancer without some of the problems of chemotherapeutic drugs. Although these have been more effective when compared to conventional chemotherapy drugs, there are still limitations in drug delivery which remains to be a major problem. Cancer nanotechnology is expected to have major improvements in cancer detection, diagnosis and also treatment. In addition to the antibacterial effect, the efficacy of noble metal nanomaterials has been demonstrated in clinical medicine. Try to combine nanotechnology with modern clinical medicine to achieve better clinical treatment effect. However, due to the potential biological toxicity of some nanomaterials, more caution is needed for clinical research. There must be more research on the influence of noble metal nanomaterials on the human body, so the research in this field is more focused on the research on the biological properties of nanotechnology, as well as some application prospects in clinical medicine.

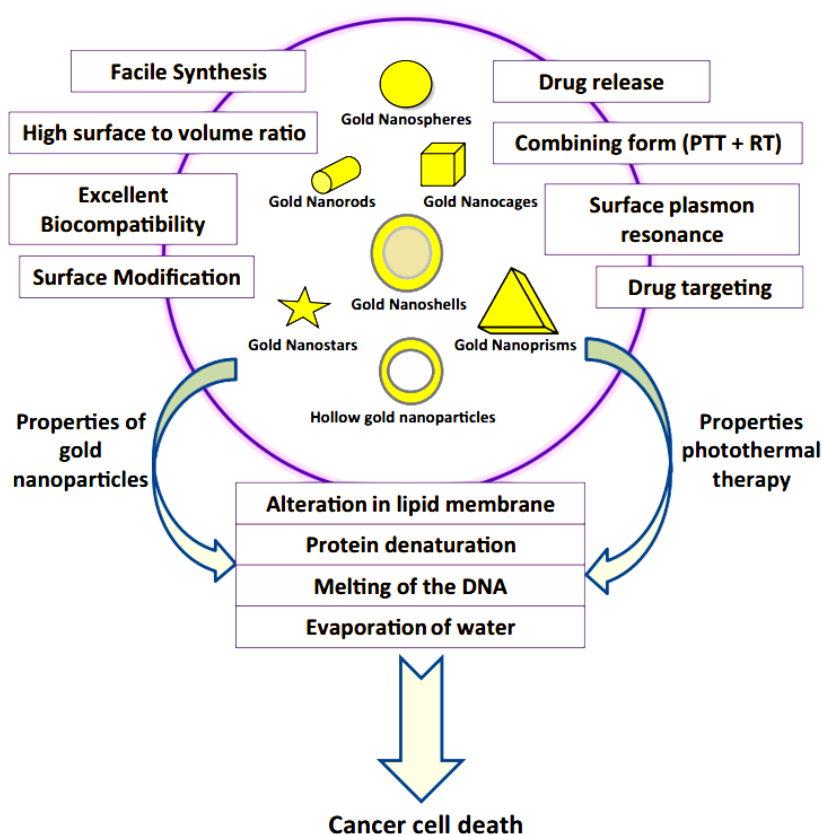


Figure 4. Application of various AuNPs for cancer therapy [9].

AuNPs are most commonly known for their cancer treatment. Chemotherapy drugs are used in clinical medicine to treat cancer through the systemic diffusion of drugs, which will undoubtedly produce toxicity to normal cells, leading to serious side effects for patients. Therefore, targeted drug therapy has become the most important method to treat the injured site, which can enhance the cytotoxicity to cancer cells and reduce side effects at the same time. As a cutting-edge targeted drug carrier, AuNPs have comprehensive properties of chemical and physical. As shown in Figure 4, the experimental results showed that AuNPs can target tumors [9]. When exposed to a light source, the AuNPs release heat and destroy adjacent cancer cells. Drugs can also be attached to the appearance of nanoparticles and then delivered to specific locations. Further research showed that spherical AuNPs coated with a polymer could boost the immune system. Several AuNPs models have been developed, and these modified gold nanoparticles have greater potential for drug delivery into different types of cells.

Nano-silver can affect the normal work of biological nerves by reducing the concentration of dopamine. It is well known that organisms transmit neural signals through currents in ion channels on

nerves, the characteristics of ion channels can be used as subtle indicators of cell conditions and viability, so it is speculated that nano-silver is used for neuromodulation in clinical medicine. Liu et al. used the cell patch-clamp technique to make slices of mouse hippocampus, and used nanosilver to test its effect on animal nerves [10]. Therefore, surface AgNPs can change the excitability of neurons by inhibiting the flow of potassium channels. Male wistar rats were selected as experimental objects. Hippocampus and mandible regions were prepared with a vibrator and incubated into slices. The particle size of AgNPs used in the experiment is 22~299 nm. The microtome is placed on the infrared dic microscope workbench. The current data is displayed on the TV monitor through a low sensitivity CCD camera. These two voltage dependent potassium channels are called instantaneous potassium current (IA) and delayed rectifier potassium current (IK). During the experiment, when the current was stable (about 3-5 minutes) and the final concentration of AgNPs of 10^{-5} g/ml was applied to the extracellular solution, the amplitude of IA and IK intensity decreased significantly. The results showed that AgNPs could inhibit the peak amplitudes of AI and IK, and regulate the biological neural regulation. However, due to the potential damage of AgNPs to cells, the impact of AgNPs on human body needs further study.

2.4. Diagnosis

Judgement of people's mental and physical state from the medical point of view. Judgment on the health status, labor capacity and a specific physiological process of normal people. It is the most widely used to recognize the diagnosis of diseases and is the premise of treatment, prognosis and prevention. With the development of nanotechnology, many high precision molecular phase formers appear in people's vision. By using the analytical instrument, it can see the diseased part of the patient and the distribution of the drug in the human body. After judging the disease, it can release the drug targeted and control the dosage, which can effectively avoid the side effects of the drug. Therefore, in addition to diagnosis, it is also necessary to study drug-controlled release, detect potential toxic reactions, and evaluate drug distribution in the body.

There are many methods of medical diagnosis, such as X-ray, computer tomography and other some technologies. By contrast, these techniques have limitations. Only when the disease is in the late stage can we effectively judge the disease and get the results according to the analysis. At present, there is a lack of appropriate clinical tools to clearly and non-invasive identify and characterize leaking and damaged systems. There is also a need for compositions and methods that can be used for patient specific tumor description and treatment. In this regard, nanosystems offer the possibility of multi-function and are being actively developed for biomolecular profiling and targeted drug delivery for in some imaging and biomarkers [11]. In this way, the development of nanoscale contrast agents plays an important role in clinical medicine.

Nanoparticles have many limitations in use. For example, in the X-ray test, some heavy atoms inevitably need to move to specific positions, which may cause toxic reactions in this case. Therefore, some inert metals are a good choice. Therefore, gold nanoshells have very high advantages, which is one of the most better cancer optical imaging materials. Gold nanoshells are cheap and also safe due to its non-invasive properties while also able to produce a high-resolution image. Nanosensors with high sensitivity utilise electrical, optical and acoustics properties improve the detection limits of analyses. The unique properties of nanomaterials are used for sensing purposes. Nanosensors are used to achieve early detection of diseases or toxic and biological threats as well as improving the environmental and clinical industrial outcomes. This is a new field, which is to build a project through cell therapy in order to repair and improve cells. Through this method, it may be able to control the birth, aging, disease and death of cells, and have some specific functional differentiation. Modern nanoparticles target specific tissues to provide diagnosis or anti-cancer drugs, and more complex nanotechnology will be produced in the next few years. The idea of nanorobot is to apply biological principles, discover new phenomena and then develop programmable molecular robot on nanoscale. Synthetic biology redesigns the network of cell signal transduction and gene regulation.

3. Conclusions

Nanotechnology has a lot of potential in the biomedical field and is already making some contribution. Despite some of the issues nanotechnology still faces, the future of nanotechnology use in the medical field looks promising, scientists are already using AgNPs or AuNPs in treatment and therapy in many diseases. In cancer treatment, the use of nanotechnology can conquer the problems that chemotherapy faces and can significantly improve drug delivery, diagnosis and detection, making it the most optimal tool against cancer. Noble metal nanoparticles are also widely used in the medical field. AgNPs are mostly used as an effective disinfectant, it can be used to treat and reduce risk of infections and also used for some eyedrops to treat ophthalmic problems. Nanoparticles are the best option for treatment when fully exploited as it can enter the body without damaging the cell therefore can be very useful for drug delivery, imaging and diagnosis. The usages of nanotechnology in the medical field are expanding significantly and perhaps in the future scientists can discover more ways to use the properties of metallic nanotechnology to treat diseases that we are unable to now.

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