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# Research and Application of Antibacterial Materials for Environmental Friendly Wood Decorative Materials

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**Abstract:** Wood based panel is a kind of panel or molded product made of wood or other non wood plants as raw materials, which is separated into various unit materials by certain mechanical processing, and then glued with or without adhesives and other additives. The rapid development of China's wood-based panel industry is mainly used in the field of wood decorative materials. In recent years, the harm of pathogenic microorganisms such as Xinguan and monkeypox to the society has prompted people to pay attention to disease control and prevention. The public's health requirements for living, working and living environment have been greatly improved. This situation has effectively promoted the rapid development of antibacterial technology and antibacterial materials. Wood and wood products are widely used in public environment such as restaurants, vehicles and ships, hospitals and other places. Due to inadequate daily cleaning and disinfection, these places have become the focus of microbial and bacterial reproduction. Therefore, the wood reinforced with antibacterial agents is used as building materials. Because of its strong antibacterial properties, the surface of wood materials can inhibit and sterilize pathogenic microorganisms. The research and appearance of antibacterial decorative wood-based panels show important practical significance. Antibacterial materials are usually obtained by adding antibacterial agents. Antibacterial agents are highly sensitive substances to some bacteria, molds and other microorganisms. They have a wide variety and different properties. With the development of nanotechnology, inorganic nano materials have been used as antibacterial materials, which can effectively inhibit bacteria to a certain extent. This paper introduces several main antibacterial materials used in wood decorative materials, such as nano silver activated carbon, nano silver zeolite, nano silver zinc oxide, nano silver titanium dioxide, and discusses their antibacterial mechanism and preparation methods.

**Keywords:** Antibacterial Materials, Antibacterial Agents, Wood Decorative Materials, Finishes, Wood Panel

## 1. Introduction

Wood based panel is a kind of panel or molded product made of wood or other non wood plants as raw materials, which is separated into various unit materials by certain mechanical processing, and then glued with or without adhesives and other additives [1-4]. It mainly includes plywood, particleboard and fiberboard, with hundreds of extension products and deep-processing products. The use of wood-based panels marks the beginning of the modernization of the wood industry. In addition, wood-based panels can also improve the comprehensive utilization rate of wood. For example, 1 cubic meter of wood-based panels can replace 3-5 cubic meters of logs [5].

The surface decoration of wood-based panel refers to the coating or covering of the surface of wood-based panel. It can beautify the surface and improve the wear resistance, heat resistance, water resistance and chemical corrosion resistance of the surface. There are three methods of wood-based panel surface decoration, among which

veneering decoration is to stick various decorative materials on the surface of various wood-based panel substrates. Such as veneer decoration with precious tree species sliced into veneers, or printed decorative paper veneer. Synthetic resin impregnated paper veneer decoration. This kind of resin, represented by melamine resin, is attached to the surface of the wood-based panel in the form of impregnated paper. After hot pressing, the impregnated paper is glued with the base material wood-based panel, and a hard resin film is formed on the surface of the wood-based panel [6]. The cured film generally has good heat resistance, wear resistance, chemical pollution resistance and other properties. In addition, there are PVC film or polyethylene film veneer decoration, and some are coated with unsaturated polyester resin on the surface after the substrate sticker. It can also be used to stick textiles, metal sheets, fiber veneers, etc. on wood-based panel substrates to meet various special requirements. Veneer decoration is the most common decorative method with the largest number of wood-based panel decoration at present.

Modern buildings have good air tightness, insufficient ventilation and heat insulation, resulting in condensation and humidity on the wall. In this environment, it is conducive to promoting the reproduction and proliferation of fungi and other microorganisms. Wood based panels and their products are widely used in public environments, such as cars and ships, restaurants, hospitals, schools, entertainment places, etc. due to insufficient daily cleaning and disinfection, these places often become breeding grounds for microorganisms and bacteria, seriously affecting people's physical and mental health. Studies have shown that fungal spores scattered in the air can cause eye congestion, chronic rhinitis, asthma, fatigue, headache and so on. The use of antibacterial building materials, antibacterial coatings and water-based antibacterial paints can greatly reduce the bacterial density on the surface of furniture, interior walls and indoor air, which is an effective way to reduce the probability of bacterial cross infection and contact infection [7]. Antibacterial is a nutrient and propagule that can inhibit the growth and reproduction of microorganisms and kill microorganisms. It shows the performance of antibacteria and antimold. Although the wood decorative board made of wood and non wood raw materials can meet the requirements of furniture and structural board in terms of mechanical strength, the raw materials contain certain sugar and starch substances, which are conducive to bacterial reproduction. Therefore, the surface of this kind of board is vulnerable to bacterial pollution, affecting its use. The use of antibacterial agents can effectively kill bacteria, inhibit the concentration of bacteria in people's living space, improve the quality of indoor environment and reduce the occurrence of diseases [8].

With the development of science and technology and the improvement of living standards, people have higher and higher requirements for the health of living, working and living environment, which has promoted the rapid development of antibacterial technology and antibacterial materials. Antibacterial materials are usually prepared by adding antibacterial agents. Antibacterial agents are a kind of sensitive substances of bacteria, molds and other microorganisms. They have many kinds and different properties. At present, antibacterial agents are mostly used to treat the surface of wood-based panels, and their antibacterial effects can meet the basic needs. However, this method has a great impact on the surface bonding strength of the plate, and there is secondary pollution. The vast majority of antibacterial plates are coated with antibacterial paint or added with antibacterial materials in the surface sticker. The plate itself does not have antibacterial effect. The organic antibacterial agent has quick effect and strong bactericidal ability, but it is easy to develop resistance to microorganisms, and has the disadvantages of short antibacterial time, easy migration, poor heat resistance, etc. when used, the drug release is concentrated, which can not achieve long-term effective effect, and too high concentration will also cause harm to the environment and human beings. In recent years, with the continuous development of nanotechnology, inorganic nano antibacterial materials including nano zinc oxide, nano silver and nano titanium dioxide have emerged, which can effectively inhibit bacteria to a certain extent. This paper introduces several main antibacterial materials in the market and their application in the field of wood decorative materials [9].

## 2. Classification of Antimicrobial Agents

Antibacterial agents can be divided into inorganic, organic and biological antibacterial agents. Inorganic antibacterial materials are a kind of antibacterial materials developed rapidly in the mid-1980s. They have the advantages of heat resistance, durability, continuity and safety, but they also have some disadvantages. Inorganic antibacterial agents include two categories, one is inorganic containing antibacterial active metals, such as silver, copper, zinc, etc., and the other is photocatalytic semiconductors, such as titanium oxide, zinc oxide, etc. Inorganic antibacterial agents have the advantages of good chemical stability, thermal stability, convenient molding and processing, long-term effect and no drug resistance. They can be well used in the fields of plastics, fibers and ceramics. The bactericidal function of photocatalysis semiconductor antibacterial agent can only work with the help of light, which limits its application to a certain extent. Metal inorganic antibacterial agents are the most studied antibacterial agents at present, of which the most commonly used is silver ion antibacterial agent. Silver ion has a strong killing effect on more than ten kinds of gram-negative and Gram-positive bacteria. Silver is the most widely used because of its non-toxic, broad-spectrum and good antibacterial properties. Nano silver loaded inorganic antibacterial agent is a complex of silver and nano inorganic carrier. It is prepared by using the high surface activity and large specific surface area of nano carrier particles to fix silver on the nano carrier by physical adsorption, ion exchange and other methods [10]. The large specific surface area and surface activity of nanoparticles create good conditions for the full contact between antibacterial agents and bacteria, and can reduce the amount

of antibacterial agent. Therefore, nano silver antibacterial agent has the advantages of long-lasting antibacterial activity, high efficiency, not easy to decompose at high temperature, non-toxic and broad-spectrum. It can be widely used in antibacterial applications of wood, plastics, coatings, ceramics, etc.

# 3. Nano Silver Antibacterial Agent

The antibacterial mechanism of silver nano inorganic antibacterial materials is similar to that of inorganic silver, which mainly depends on the strong antibacterial activity of silver. Nano silver antibacterial agent belongs to broad-spectrum antibacterial agent, which is a kind of antibacterial agent prepared by using the bactericidal or antibacterial properties of silver and its ions. Through nano modification of the carrier, the antibacterial performance of the antibacterial agent can be greatly improved and its service life can be prolonged [11].

### *3.1. Nano Silver Activated Carbon*

Activated carbon has the characteristics of the largest specific surface area and narrow pore size distribution. Traditionally, it is considered that it has organic gas, organic matter in aqueous solution and precious metal ions have large adsorption capacity and fast adsorption rate, and can be regenerated. Because activated carbon has good adsorption, silver loaded activated carbon is the most studied silver loaded material. But its antibacterial effect is poor. Moreover, the activated carbon is black, and the appearance is not beautiful, which is difficult for consumers to accept. At present, the main research object is activated carbon fiber, but its cost is very high [12].

### *3.2. Nano Silver Zeolite*

Zeolite is an alkali metal or alkaline earth metal aluminosilicate compound. Its structure is a three-dimensional skeleton ring structure composed of silicon oxygen tetrahedron and aluminum oxygen tetrahedron by sharing oxygen atoms. The aluminum oxygen tetrahedron in the framework structure is negatively charged because aluminum is trivalent and the negative valence of an oxygen atom cannot be neutralized. This negative charge is balanced by the introduced alkali metal or alkaline earth metal ions. Silver loaded zeolite inorganic antibacterial agent is prepared by introducing silver ions into zeolite by using the cation exchange capacity of zeolite. Nano silver loaded zeolite antibacterial material can overcome the shortcomings of common silver loaded zeolite antibacterial materials, such as easy discoloration and insufficient comprehensive properties. It is an ideal material to replace the common silver loaded zeolite inorganic antibacterial agent.

### *3.3. Nano Silver Zinc Oxide*

Nano zinc oxide powder is insoluble in water, tasteless, non-toxic, fine texture, and has good antibacterial properties and UV shielding function. However, the antibacterial mechanism of nano zinc oxide belongs to photocatalysis mechanism, that is to say, it shows excellent antibacterial properties only under the action of ultraviolet light. Silver atoms can be added into the zinc oxide lattice by a special process during the crystallization of nano zinc oxide to prepare nano silver loaded zinc oxide inorganic antibacterial agent, which can not only improve the antibacterial ability of the antibacterial agent, but also solve the discoloration of silver ions, and can produce antibacterial properties without light source irradiation.

### *3.4. Nano Silver Titanium Dioxide*

Titanium dioxide is a white inorganic material, non-toxic, tasteless, non irritating, good thermal stability and heat resistance, and non combustible. Nano titanium dioxide has strong visible light reflection ability, strong ultraviolet absorption and shielding ability, high surface catalytic activity, broad-spectrum sterilization function, etc. As an antibacterial agent, nano titanium dioxide has the following characteristics: (1) good sterilization effect; (2) Long lasting sterilization effect; (3) High security. However, the sterilization mechanism of nano titanium dioxide belongs to the photocatalysis mechanism, that is, it can only play the role of sterilization with the help of ultraviolet light, so its application scope is limited. The composite nano inorganic antibacterial agent can be prepared by using nano titanium dioxide as the main component and adding silver compound, which has excellent antibacterial performance. In addition, the doping of silver and other metals on the surface of nano titanium dioxide particles changes the properties of the particle surface and further improves the sterilization efficiency. At the same time, the doping of silver greatly enhances the catalytic effect of nano titanium dioxide under visible light. This kind of antibacterial agent can not only use the photocatalysis of nano titanium dioxide for sterilization, but also overcome its lack of antibacterial ability in the dark place. It not only makes use of the good antibacterial ability of silver, but also realizes the gradual release of silver, so the antibacterial performance is good [13].

### *3.5. Nano Silver Silica*

Nano silica is a non-toxic, tasteless and pollution-free white non-metallic powder. Like other nano materials, nano silica has a large specific surface area, and there are unsaturated residual bonds and hydroxyl groups in different bonding states on the surface. The surface deviates from the stable silicon oxygen structure due to lack of oxygen. Therefore, nano silica has high activity and produces many special properties such as optical shielding. Silver nano antibacterial agents with large silver loading can be prepared by physical adsorption or precipitation. Nano silver / zinc loaded silica inorganic antibacterial agent can play a synergistic role in antibacterial activity through the combination of silver and zinc ions, and significantly improve the antibacterial performance of the antibacterial agent.

## 4. Antibacterial Mechanism

The dissolution theory shows the antibacterial effect through the contact reaction between silver ions and bacteria: after the silver ions contact with cells, they are adsorbed on the negatively charged cell wall by electrostatic attraction. There are excess silver ions on the surface of the cells, and they can penetrate the cell membrane and react with the components of the cell body. The ryukyl group that replaces the enzyme protein in the cell makes the substances in the cell leak out; It interferes with the synthesis of chitosan, hinders the formation of cell wall, inhibits cell reproduction and growth: silver ions and DNA reactions reach the cell, destroys the normal activities of some functional systems in the cell (such as respiratory system, electron transport system and material transport system), and hinders the progress of metabolism. These reactions must consume some silver ions. However, when the cell loses its activity, silver ions will dissociate from the cell and repeat the sterilization activities, so its antibacterial effect can continue [14].

Active oxygen theory: silver and other heavy metals have high polar catalytic capacity, especially in a stable activated state in the carrier. They can produce living substances by interacting with oxygen in water and air. These reactive oxygen species can destroy various important biopolymers and membranes in cells, and can also form other active oxides. This is extremely unfavorable to the continued growth and reproduction of the bacteria, thus playing an antibacterial role. One of the reasons for this statement is that some antibacterial products containing silver loaded antibacterial agents do not dissolve silver ions during use, but still show antibacterial ability; Another basis is that adding scavengers of free radical functional groups to silver loaded antibacterial agents will reduce the antibacterial ability of antibacterial products. Therefore, it is considered that the emergence of antibacterial ability is caused by the formation of superoxide free radicals through photocatalytic reaction. The generated reactive oxygen species and hydroxyl groups have strong redox effect, resulting in lasting antibacterial effect [15].

## 5. Preparation Method of Nano Silver Antibacterial Agent

The antibacterial agent can be prepared by adding a certain amount of nano carrier particles into the soluble silver salt solution of different concentrations, stirring slowly for a certain time at a certain temperature, and filtering. By analyzing the concentration of silver ions in the filtrate, the silver carrying capacity of nano carrier particles was determined. The amount of silver loaded on nano carriers is related to the adsorption temperature, adsorption time, the original concentration of soluble silver salt solution and the particle size of nano carriers. The method requires that the carrier itself is insoluble and has good dispersibility in silver salt solution, and the amount of silver loaded in the antibacterial agent is large.

The nano carrier particles with cation exchange performance are made into suspension, added to the soluble silver salt solution in a certain proportion, stirred at a certain temperature for a certain time, filtered and washed to prepare the antibacterial agent. Or the nano carrier particles with cation exchange performance are installed into a column adsorption tower, and the soluble silver salt solution is prepared by the adsorption column at a certain flow rate. The method requires that the nano carrier must have cation exchange performance, and the exchange capacity of silver ions can be controlled by adjusting the concentration, pH value, temperature and flow rate of soluble silver salt solution.

Add nano carrier powder or its suspension to a certain concentration of silver ion soluble salt solution, and then add precipitant or reductant to make silver precipitate from the solution in the form of various insoluble substances or simple substances with nano particles as carriers. The antibacterial agent is prepared by filtration, washing, low-temperature dehydration and high-temperature solidification. The surface of the nano antibacterial agent prepared by this method may agglomerate with the increase of curing temperature, which makes it difficult for the silver atoms and their compounds entering the pore of the nano carrier to dissociate and play an antibacterial and bactericidal role. On the other hand, the curing temperature has a great influence on the existing form of silver in the antibacterial agent, so the curing temperature should be controlled when preparing nano antibacterial agent by this method.

## 6. Future Work

Future research on the antibacterial materials for wood decorative panels will be focused on low cost, non-toxic, harmless, spectrum antibacterial and efficient antibacterial agent. Organic polymer antibacterial materials and composite antibacterial materials should be the fields with great development potential in the future.

## 7. Summary

Nano silver loaded inorganic antibacterial agents are widely used in plastic products, textile and construction industries because of their broad-spectrum antibacterial properties, safety, non-toxic, durability, no drug resistance, heat resistance and good processability. With the deep research on nano silver loaded inorganic antibacterial agents, the performance of antibacterial agents will be further improved, the application range will be wider and wider, and its market capacity will also be increasing. When using nano inorganic antibacterial agents, attention should be paid to the following aspects: (1) good antibacterial activity against a variety of bacteria and fungi; (2) Sustainable antibacterial effect; (3) No resistance to bacteria and fungi; (4) It is safe for human body and environment: (5) it meets the basic functions of building materials; (6) The price can be accepted by users.

From the current research of antibacterial agents and the development status of wood decorative materials, nano silver loaded inorganic antibacterial agents with green, safe, stable performance and lasting antibacterial effect will be the mainstream research direction in the future. With the in-depth study of nano silver loaded inorganic antibacterial agents, the antibacterial technology will be continuously improved. Wood decorative materials with surface antibacterial function will also become the mainstream materials in the decorative building materials industry, and the market prospect is broad.

## Author Contributions

The Manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript. Zhiyong Zheng and Ruixue Jia contributed equally and should be considered as co-first authors.

## Conflicts of Interest

The authors declare that they have no competing interests.

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