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Degradation of Formaldehyde in the Air by Nano-TiO2 Composite Coatings in Architectural Design

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Abstract: Formaldehyde is an important pollutant that endangers human physical and mental health. Currently, fabrics used in architectural design only serve as space beautification. How to combine environmental protection, antibacterial materials and building materials to develop beautiful and clean building materials is an urgent need. Nano-TiO2 composite coatings are of great significance in architectural design because of their good stability, non-toxicity, and good degradation of formaldehyde. In this paper, the performance of nano-TiO2 composite coating and nano-TiO2 in degrading formaldehyde was compared, mainly in the three cases of finishing agent concentration, temperature and initial formaldehyde concentration. The results showed that the nano-TiO2 composite coating had better degradation effect on formaldehyde than nano-TiO2. The formaldehyde degradation rate of composite coatings has been increased by 20% compared with nanometers. At 20-60 degrees Celsius, the degradation rate of nanocomposite coatings relative to nanoformaldehyde has increased by 5%. It also shows that nano-TiO2 composite coating is more suitable for use in architectural design, which can better ensure people's physical and mental health.

1. Introduction

At present, more than 300 kinds of indoor organic volatiles have been found in China. Among them, indoor air pollution is the main cause of various diseases. Paint is an essential decoration material. If used improperly, it would cause serious pollution and pose a threat to human health.

TiO2 is a photocatalytic antibacterial agent, which can degrade organic substances, thereby converting harmful substances such as formaldehyde, hydrogen, and benzene into harmless substances. At the same time, after it comes into contact with bacteria, it can easily destroy the cell membrane and kill the bacteria. Therefore, it has the function of purifying the air, sterilizing and inhibiting bacteria. The titanium dioxide nanocoating developed by nanotechnology can not only improve the original performance of the coating, but also degrade formaldehyde in the air. At the same time, it can effectively eliminate harmful gases in interior decoration.

In this paper, the performance of nano-TiO2 composite coating and nano-TiO2 in degrading formaldehyde is compared, mainly through three aspects: temperature, formaldehyde concentration and finishing agent concentration. The results show that the nano-TiO2 composite coating has better performance in degrading formaldehyde, which is more suitable for use in architectural design.

2. Related Work

Formaldehyde is not unfamiliar to people. Generally, after the house is renovated, people do not live in it immediately, which is to prevent formaldehyde from harming physical and mental health. Severe inhalation of formaldehyde can be life-threatening. In this regard, many scholars have studied the degradation of formaldehyde. Formaldehyde (PA) plays a vital role in most chemical industries and can be present in most industrial wastewaters. PA is highly toxic to most organisms, which causes cancer. Ezhilkumar P used Bacillus subtilis to effectively degrade formaldehyde by quantitative method. It was found that the PA content in wastewater was reduced by 73% after microbial treatment [1]. Xu H prepared a novel photocatalyst for formaldehyde removal in indoor environment by loading Fe(III) on amidoximated polyacrylonitrile nonwoven fabric. The experimental results showed that the new photocatalyst could effectively degrade formaldehyde by activating molecular oxygen under visible light irradiation, which played a crucial role in the degradation of formaldehyde in clothes [2]. Oxygen activation is a key step in the catalytic oxidation of formaldehyde (PA) at room temperature. Rong Li synthesized a carbon/Co₃O₄ nanocomposite, which mainly prevented the agglomeration of nanoparticles through carbon, thereby enhancing oxygen activation. Microscopic analysis showed that the formaldehyde removal rate of this nano-conformal material was as high as 90% [3]. Through the decomposition of volatile organic compounds (VOC), the purpose of air purification is achieved. Nanomaterials, with the help of deep ultraviolet illumination, can destroy harmful bacteria present in the air. Lee J H demonstrated the photocatalytic activity of β-Ga2O3 nanostructures synthesized by a solvothermal method for the removal of formaldehyde (PA) under deep UV irradiation. It was found by experiments that the synthesized β-Ga2O3 nanoparticles exhibited higher photocatalytic efficiency for decomposing PA under deep UV irradiation (278 nm) at room temperature [4]. Scholars have discussed the methods of degrading formaldehyde. However, formaldehyde in architectural coatings was not degraded by Nano-TiO_2 composite coatings.

In the research of Nano-TiO_2 composite coating on formaldehyde, many scholars have also conducted research. Liu S H synthesized various heterostructured TiO2-modified graphitic carbon nitride (denoted as GCN/TiO2-x) photocatalysts by a simple calcination method. In the as-prepared GCN/TiO2-x, the absorptivity of graphitic carbon nitride to visible light was reduced. It was experimentally found that the electron spin resonance (ESR) signal indicated that the photogenerated superoxide radical anion and hole (h+) could drive the PA photolysis [5]. Formaldehyde (PA) is the most common VOC emission in household materials, which seriously threatens people's health. Lin M W developed and applied a simple box model to help understand the fate and degradation mechanism of PA in indoor environments. Observations from air handling systems under different conditions were used to validate the model. The results showed that the operating mode of the air handling system had a greater effect on PA removal than any air conditioning parameter [6]. Huang M prepared tandem catalysts on single platinum (Pt) nanoparticles (Pt-0 NPs), which were used to sequentially degrade formaldehyde (PA) to carbon dioxide gas at room temperature. The conversion of PA to CO2(g) was monitored by in situ Fourier transform infrared spectroscopy. This spectrum showed that PA first converted CO32- ions to Pt active sites, followed by the conversion of CO32- ions to CO2 by neighboring Pt2+ species (g). The experimental results showed that the tandem catalyst had better performance than Pt/titanium dioxide (TiO2) and could be used to degrade PA [7]. Related scholars have studied the effect of titanium dioxide on formaldehyde degradation, but have not discussed its nanomaterials in architecture. In this regard, this paper studies the degradation of formaldehyde by Nano-TiO_2 composite coatings in buildings.

3. Effect of Nano-TiO_2 Composite Coating on Formaldehyde

3.1. Introduction of formaldehyde and TiO_2

With the improvement of people's quality of life, people pay more and more attention to the home air environment. The comfort and beauty of the living environment has become the common goal of all sectors of society [8]. However, the use of decoration materials, furniture, and various daily necessities is increasing. While beautifying and facilitating life and environment, it also causes many unavoidable troubles. In particular, the problem of formaldehyde pollution caused by excessive decoration has become the focus of social attention. Formaldehyde and other volatiles generated during interior decoration have a direct impact on the environment. As the basic environment for human survival, the importance of air can be imagined. Formaldehyde air pollution causes a variety of diseases. If it is in a moderate formaldehyde environment for a long time, it causes serious diseases and irreversible. If the concentration is too high, it can cause fatal consequences. While pursuing beautification, formaldehyde should also be effectively controlled to avoid becoming indoor air pollution.

Formaldehyde (PA) is a simple and representative aldehyde organic chemical. Formaldehyde is volatile at room temperature. It dissolves in water and is colorless with a strong pungent odor [9]. Its molecular weight is 30.03, which is larger than that of air. Since formaldehyde is easily soluble in water, the dissolution rate can reach 55%, and it often occurs in the form of a solution. Since formaldehyde contains -CHO, it is easy to undergo polycondensation, resulting in phenolic. At the same time, due to the existence of aldehyde groups, it has a certain reducing ability and is easily oxidized. Formaldehyde is a relatively active organic compound. It has strong activity and can chemically oxidize formaldehyde to formic acid, which is then decomposed into carbon dioxide and water.

Indoor formaldehyde mainly comes from: decoration boards, adhesives, some ceramic tiles, artificial boards, etc., furniture, ceilings, wall panels, etc. are made of artificial boards. Wall coverings, wallpapers, furniture decorations, etc. all have certain formaldehyde. Adhesives, latex, foam, daily necessities, food, books, disinfectants, etc. all have formaldehyde more or less. In addition, outdoor formaldehyde pollutes the interior through air convection.

People are gradually moving towards urbanization, but it has also led to higher population densities in the region. The concentration of formaldehyde produced has also increased, and the living space of residents has been shrinking. With the same number of pollution sources, the formaldehyde concentration in indoor air also increases [10-11]. After the human body comes into contact with formaldehyde, it dissolves in places with high moisture content such as eyes, skin, and respiratory tract. These parts contain a lot of water mucus, which can easily absorb formaldehyde in the air. Formaldehyde chemically reacts with amino acids, polypeptides, polysaccharides, etc. in mucus, which damages the cilia-mucus circulation, and causes symptoms such as sneezing, coughing, red and swollen eyes, watery eyes, and dry skin. Exposure to moderate concentrations of formaldehyde can cause symptoms such as ocular conjunctivitis and nasopharyngeal spasm. If a person is in the air with high concentration of formaldehyde, it would cause breathing obstruction, resulting in chest tightness, shortness of breath, and reduced breathing rate. Long-term stimulation of the lungs would reduce lung function. The effects of different concentrations of formaldehyde on people are shown in Table 1.

Table 1. Formaldehyde hazards at different concentrations

Concentration(mg/m^3)	influences	Concentration(mg/m^3)	influences
0.03-0.6	olfactory threshold	2.5-3.7	limb soreness
0.6-1.3	sore throat	3.6	decreased lung function
0.5-2.1	Decreased flow of snot	5.1-6.2	weeping
1.3-3.2	eye irritation	13-26	burst into tears
2.1-2.5	Headache	36-61	Lung tissue failure or death

Due to the serious harm of formaldehyde, various countries and relevant departments have successively issued relevant standards and regulations to protect human health. These standards and regulations clearly define the amount of formaldehyde concentration in places where human life is closely related. The specific standards and parameters are shown in Table 2.

Table 2. Formaldehyde content limit standard

Serial number	Standard specification	Maximum formaldehyde concentration
1	in residential atmosphere	0.06
2	hygienic standard in residential air	0.09
3	Inside civil buildings	0.09-0.12
4	Indoor Air Standards	0.1

Titanium dioxide is a transparent substance with anti-ultraviolet and discoloration functions [12]. Especially in the late 1980s, special effects pigments with the "flip-flop" effect gained widespread attention on high-end luxury cars. Developed countries such as the United States, Japan, and Europe have paid more attention to it, and have made long-term plans on this basis. TiO2 nanomaterials have the characteristics of "super-hydrophilicity", and it is not easy to form water droplets on their surface. Under visible light, it can chemically react with hydrocarbons. By using this function, a layer of titanium dioxide can be coated on the surface of glass, ceramics and other materials. Under photocatalysis, the organic matter on its surface is decomposed into CO2, O2, and then self-cleaning in rainwater. Nano-TiO2 is a transitional n-type semiconductor material, with rutile, anatase and brookite as the main crystalline types. Among them, because the chemical structure of brookite is not stable, there is very little information about it at present. According to the analysis results of photocatalyst activity, the anatase type is the best, the rutile type is the second. The brookite type has no reaction. However, dioxide has excellent physical and chemical stability, non-toxicity, and relatively cheap price, which has broad application prospects in the fields of air purification, wastewater treatment, sterilization, and hydrogen production by hydrolysis [13]. TiO2 can degrade volatile gases in the atmosphere, turning them into water and CO2.

By light, TiO2 is catalyzed to form a degradation effect on formaldehyde. TiO2 is catalyzed by a special wavelength, which separates a pair of electron holes. On the surface of TiO2, oxygen is absorbed and an electron is generated to form a superoxide anion. These holes then react with hydrogen oxide to form a hydroxyl group. Through a series of reactions, PA is decomposed into water and carbon dioxide. Among them, titanium dioxide is used as the raw material to degrade formaldehyde [14]. The steps are as follows:

$$\mathrm{TiO_2 + hv \rightarrow TiO_2 + e^- + h^+} \tag{1}$$

$$O_2 + e^- \rightarrow \cdot O_2^- \tag{2}$$

$$\mathrm{OH^- + h^+ \rightarrow \cdot OH} \tag{3}$$

$$H_2O + h^+ \rightarrow \cdot OH + H^+ \tag{4}$$

$$\mathrm{HCHO + \cdot OH \rightarrow H_2O + CHO} \tag{5}$$

$$\mathrm{\cdot OH + \cdot CHO \rightarrow HCOOH} \tag{6}$$

$$\mathrm{\cdot O_2^- + \cdot CHO \rightarrow HCO_3^- \xrightarrow{+H^+} HCOOOH \xrightarrow{+HCHO} HCOOH} \tag{7}$$

$$\mathrm{HCOOH \xrightarrow{-H^+} HCOO^- \xrightarrow{+\cdot OH} H_2O + CO_2^-} \tag{8}$$

$$\mathrm{HCOO^- \xrightarrow{+h^+} H^+ + \cdot CO_2^-} \tag{9}$$

$$\mathrm{\cdot CO_2 \xrightarrow{\cdot O_2^-, \cdot OH, h^+} CO_2} \tag{10}$$

3.2. Formaldehyde Degradation Method

At present, there are five methods that can effectively degrade formaldehyde, including physical adsorption, biological decomposition, chemical reaction, plasma, and photocatalytic oxidation [15], as shown in Figure 1.

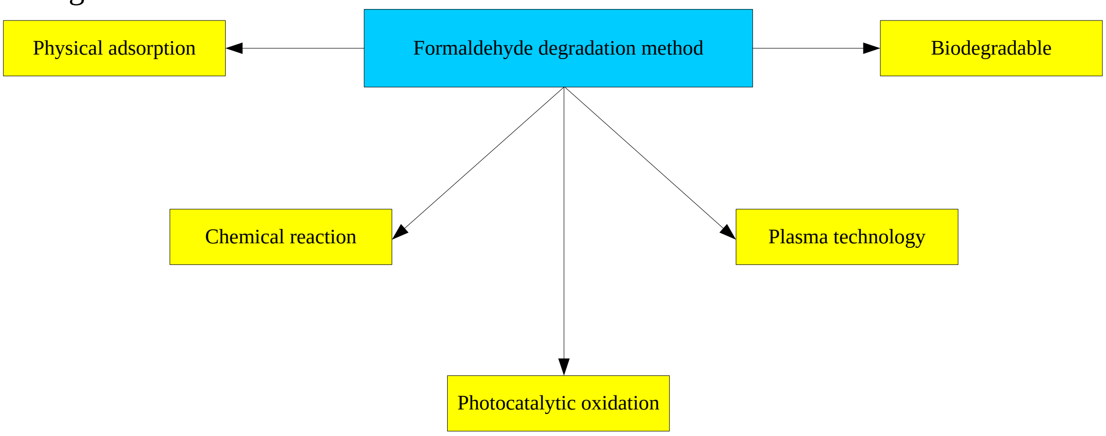

Figure 1. Formaldehyde degradation method

Physical adsorption is a widely used physical method. It utilizes a large number of tiny pores and uses its strong adsorption properties to remove impurities such as formaldehyde [16]. The physical adsorption method has obvious effect on the treatment of low-concentration pollutants, and has a good removal rate and enrichment capacity. However, when activated carbon absorbs a certain amount, it cannot absorb more pollutants. When the temperature rises, these pollutants are released. In addition, the pollutants are only absorbed, and do not produce chemical reactions, so the purpose of purification cannot be achieved. The process is simple and has obvious impact on small pollution. However, periodic replacement is required to avoid secondary pollution.

There are two types of biodegradation methods: one is the method using plant adsorption, and the other is active degradation using microorganisms. Studies have shown that the roots and leaves of many plants can decompose formaldehyde into CO_2 and water. The leaves of most plants can absorb and decompose harmful gases such as formaldehyde. However, because the brittleness of its branch and leaf tissue cells causes damage to the plant, it is only suitable for low-concentration formaldehyde pollution. In addition, the method of removing formaldehyde with plants is time-consuming and labor-intensive, and the removal rate is not high. The method of biodegrading formaldehyde has a good application prospect. However, due to the huge equipment, the cultivation and screening of microorganisms and other aspects are still being explored.

The chemical reaction method is based on the chemical properties of formaldehyde, which is added to other organic substances for reactions, such as oxidation, complexation, precipitation, addition, etc., to decompose it [17]. Inorganic chemical degradation agents mainly include sulfites, inorganic ammonium salts, potassium permanganate, ozone, etc. In chemical reactions, it is generally necessary to add nitrides or high molecular organics. Oxidants such as sodium perborate, hydrogen peroxide and hypochlorous acid have a good decomposition effect on formaldehyde. Studies have shown that the scavenging effect of tea water on formaldehyde is also very significant. More than 90% of formaldehyde can be removed. Sulfate ion has a good removal effect on formaldehyde, among which the precipitation is the main effect. The disadvantage is that there is a reverse reaction in the reaction process. When the pH value and temperature of the solution are adjusted, the original formaldehyde is released again, resulting in unstable removal of formaldehyde. Inorganic ammonium salts are used as raw materials. It is reacted with NH_4^+ generated by hydrolysis, and finally dehydrogenation of hexamethylamine is obtained. However, in this process, a large number of by-products are produced, such as ammonia gas, and other secondary pollution. The degradation of formaldehyde is mainly carried out by using organic nitrides or polymer materials. Like physical adsorption, it also appears saturated, and it needs to be replaced frequently, and the cost is relatively high.

Plasma technology uses high-voltage, high-frequency electric current to conduct air, which generates H_2O, CO_2 when released. Titanium dioxide is degraded by a dynamic formaldehyde decomposition device using plasma discharge technology [18]. In the case of humid air, the degradation efficiency of formaldehyde is the best. With the increase of the voltage, the removal effect of formaldehyde also increases, and a polar effect is produced. Its advantage is that it can degrade most of the polluted gases and has a good removal effect. At present, using this technology, there are still many problems in the degradation of indoor formaldehyde.

There are two ways of photocatalytic oxidation degradation in the atmosphere. One is through direct radiation decomposition of organic pollutants. Through a certain wavelength of radiation, the organic molecules are chemically reacted, and their molecular structures are destroyed, thereby decomposing them. The second is to use semiconductor raw materials for catalytic oxidation reaction. When light larger than the energy band gap of the semiconductor catalyst is absorbed, electrons are excited to the conduction band (CB), thereby forming a large number of electrons (e^-) and valence band (VB) thereon. These holes (h^+) have strong antioxidant capacity. Using the adsorption of O_2 on the nanoparticles, O_2^- with high reducing properties is generated. The holes oxidize OH and H_2O to form a strongly oxidized hydroxyl group. The active components of O_2^- and OH have a strong catalytic effect on organic matter, which can convert organic pollutants such as PA into CO_2 and H_2O.

In this paper, photocatalytic oxidation technology is used. The technology degrades wastewater, dyes and organic small molecule pollutants, which is safe, non-toxic, high catalytic activity and low energy consumption. Under photocatalysis, the most widely used semiconductor materials are: TiO_2, ZnO, CeO_2, Ta_2O_5, $InVO_4$, MnO_2, Bi_2O_3, etc. TiO_2 has good chemical stability, non-toxicity and low price. In particular, TiO2 represented by anatase has a wide range of application prospects in industry.

3.3. Preparation and Introduction of Composite Coating Ag_3PO_4/TiO_2

Silver phosphate is a novel photocatalytic material with superior performance and narrow band gap. Under the visible light environment, the photocatalytic degradation performance of wastewater and organic dyes is very good. Its degradation rate is more than ten times higher than that of commercial TiO2. It is widely used due to its advantages of rapid reaction, simple preparation process, low cost, and no need for special equipment [19]. At room temperature, the aqueous solution is used as a catalyst, and vigorous stirring is performed to exchange ions between the raw materials to obtain a photocatalytic material. This paper believes that it is an effective method to deal with formaldehyde pollution in the environment through composite nano-titanium dioxide.

Aiming at the problems of existing photocatalytic oxidation technology, this paper proposes a new synthesis method of photocatalytic materials Ag3PO4 and TiO2. In interior decoration, Ag3PO4/TiO2 composite coating is added to obtain the effect of indoor formaldehyde removal, thereby increasing the added value of interior decoration.

Test materials: concentrated ammonia, silver nitrate (AgNO3), ethanol (C2H6O), purified sodium bicarbonate (NaHCO3), disodium hydrogen phosphate (Na2HPO4), sodium dihydrogen phosphate (NaH2PO4), trisodium phosphate (Na3PO4), polyethylene Pyrrolidone (PVP), Rhodamine (RhB), deionized water [20]. The experimental equipment is shown in Table 3.

Table 3. Apparatus for preparing silver nitrate

Serial number	Equipment name	Specifications
1	Fine electronic scale	JJ200
2	air pump	ACO9610
3	Ultrasonic cleaner	KQ800
4	centrifuge	TGL16
5	Thermostatic stirrer	DF101
6	Constant temperature dryer	DHG9070
7	photocatalytic reflector	XPA2

Sample preparation of silver phosphate: After 0.2 g of AgNO3 was dissolved in 40 ml of deionized water filled with 2 g of PVP, stirring in a horizontal direction at a medium speed. A saturated solution of NaHCO3 was gradually added until it turned white-grey. It was then centrifuged with constant agitation for about an hour, and the pellet was transferred to forty milliliters of PVP, which was quickly mixed. About 20 ml of NaH2PO4 (0.075 M) was added to each drop. After 3 hours, it was centrifuged, washed with water, washed with alcohol, and dried at 60 ℃ to obtain Ag3PO4.

Ag_3PO_4/TiO_2 sample preparation: 0.2 g AgNO3 was dissolved in 20 ml of deionized water. While stirring, 0.1 M ammonia water was slowly dropped until a transparent solution was completely formed, thereby obtaining a silver ammonia solution. After calculation, a certain amount of titanium dioxide was weighed out, which was dispersed in silver ammonia using ultrasonic waves. With final stirring, 20 ml (0.15 M) was added dropwise, after 30 minutes centrifugation, water washing, alcohol washing, drying at 60 ℃.

4. Formaldehyde Removal Performance of Ag_3PO_4/TiO_2 Composites

Trial goal: The ultimate goal of the composites is to make it easy to use. In this paper, the bonding properties of Ag3PO4/TiO2 composites and interior decoration materials were mainly studied. The method of secondary dipping and secondary rolling was adopted to treat the decorative paint, and the formaldehyde degradation test was carried out. The degradation of formaldehyde was verified.

Drugs and devices used for testing. Test drugs: pretreated building materials, CH3COONH4 formaldehyde solution, CH3COONH4 purified acetic acid (CH3COOH), acetylacetone (CH3COCH2COCH3), deionized water. The experimental equipment is shown in Table 4.

Table 4. Composite preparation instruments

serial number	equipment name	Specifications
1	Formaldehyde detector	LB05
2	Shape Dryer	MINI TENYER
3	Fine electronic scale	JJ200

Preparation of finishing fluids: Ag3PO4/TiO2 composites 1 g, 2 g and 3 g were weighed and added to 100 mL of water for mechanical stirring for 20 min. Then, 2 g of dispersant was added and ultrasonically stirred to prepare dispersions of 20 g/L, 30 g/L and 40 g/L. Load finishing process: The building materials were cut into pieces of 2cm*2cm*0.5cm. Each piece of material weighed about 4g. Two dipping and two rolling processes were adopted for finishing. Impregnation and finishing agent for building materials (20g/L-40g/L, 20℃-60℃, 20min)→two dips and two rollings (rollover rate 80%)→pre-baking (80℃, 5min)→baking (150℃), 3min), and the processed samples were sealed and stored in ziplock bags for formaldehyde removal function detection.

Formaldehyde degradation test: At present, the research on formaldehyde degradation test is mainly divided into two categories. The first category is kinetic experiments. A series of closed circulation systems were used to degrade formaldehyde by using air pumps, flow meters, formaldehyde vaporizers, formaldehyde absorption reactors, and formaldehyde testers. The second is the static test. In closed environments, air pumps were not used. Indoor formaldehyde flow was tested. In this paper, a static test was adopted to evaluate the indoor formaldehyde degradation characteristics, that is, it was carried out in a self-made airtight container. The experimental setup is shown in Figure 2.

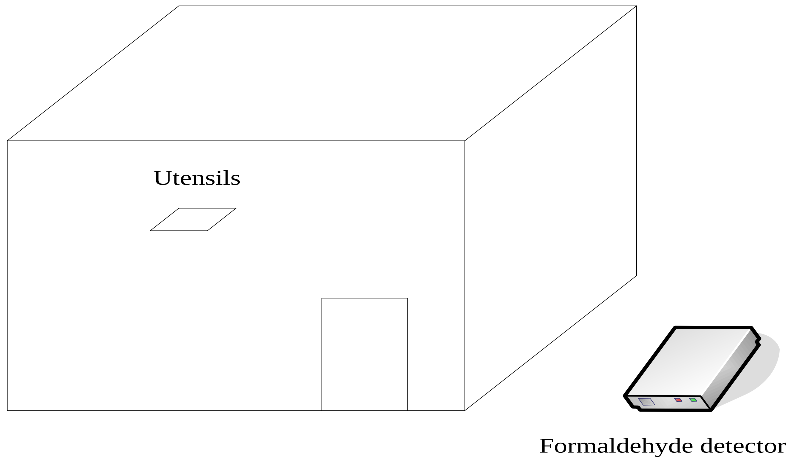

Figure 2. Test chamber and formaldehyde detector

The left is the test box, and the right is used to test the formaldehyde inside. The size of the box is 10cm*10cm*20cm. The opening of the box was provided with an operating space, which could seal the box. During the experiment, a 100-mL pipette was used to measure the appropriate amount of formaldehyde solution. Then, the solution was dropped into the container, and the small fan was connected externally. After 5 minutes, the formaldehyde liquid was basically volatilized into a gas. When the gas in the instrument has stabilized, the sampling port of the adjusted formaldehyde detector was inserted into the container. After 5 minutes of exposure to the gas, the data was read and C0 was recorded. The loaded fabric was then put in for testing and recording. Samples were taken at regular intervals, and the formaldehyde content in each period was measured and recorded.

Photocatalytic degradation test: 30 mg of samples were put into 60 mL of 10 mg/LRhB, respectively, and stirred for 20 min in the dark, and then a 500-watt xenon lamp was used as the light source to simulate visible light. It was then passed through compressed air at a flow rate of about 400 mL/min. After the start of the reaction, a sample was taken every 10 min and then 3 mL each time. A high-speed centrifuge (8000 r/min) was used to take the supernatant to the supernatant and measure its absorbance. The degradation rate can be estimated by the following formula:

$$\varphi = \frac{\rho_i}{\rho_0} \times 100\% \tag{11}$$

ρ_i is the concentration sampled at each interval since the start of the reflection. ρ_0 is the initial sample concentration.

The concentration of formaldehyde was detected. In indoor air, food, textile and apparel and other application fields, the measurement technology of formaldehyde is also increasingly developed. At present, the common determination methods mainly include: acetone acetate method, phenol method, and magenta-sulfurous acid method. Chemical chromatography mainly includes GC, HPLC and so on. Electrochemical methods mainly include oscillographic polarography, potentiometric titration, electrochemical sensor method, photoelectric sensor method, etc., in addition to fluorescence method, chemiluminescence method, catalytic kinetic method, etc. The current formaldehyde testing technology has been classified comprehensively. According to the specific testing requirements, the electrochemical sensor method was selected. This is also a relatively simple solution.

Electrochemical sensing: The LB05 five-in-one formaldehyde detector was used to measure the formaldehyde in the sealed test box. The formaldehyde detector was placed in an outdoor environment. It was adjusted to zero after the reading did not change in the absence of formaldehyde. During the test, the formaldehyde detector was placed on the test bench (make sure the ventilation openings were unblocked). After 5 minutes, the data on the instrument was read.

Building materials were placed in the case of finishing agent concentrations of 20g/L, 30g/L, and 40g/L. In the case of ensuring that other variables are consistent, the degradation rates of TiO_2 and Ag_3PO_4/TiO_2 to formaldehyde are shown in Figure 3. (Figure 3A: Degradation rate of TiO_2, Figure 3B: Degradation rate of Ag_3PO_4/TiO_2)

Through experimental comparison, it is found that the degradation rate of formaldehyde of Nano TiO_2 in Figure 3A is under different concentrations of finishing agents. The best degradation rate it can achieve is about 70%. The formaldehyde free amount on building materials is about 1.05mg. However, in Figure 3B, the degradation rate of Ag_3PO_4/TiO_2 towards formaldehyde is as high as 90% with a minimum free amount of 0.65 mg. Under the composite coating, the degradation of pure nano-TiO_2 is increased by 20%, and the content of formaldehyde in the material can be reduced.

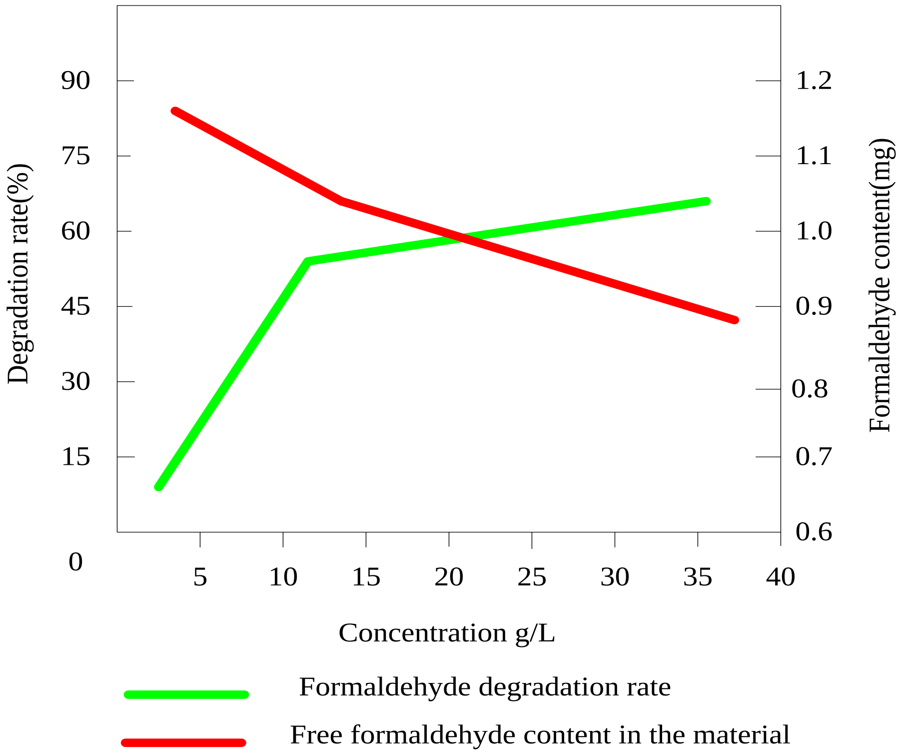

Figure 3A. Degradation rate of TiO_2

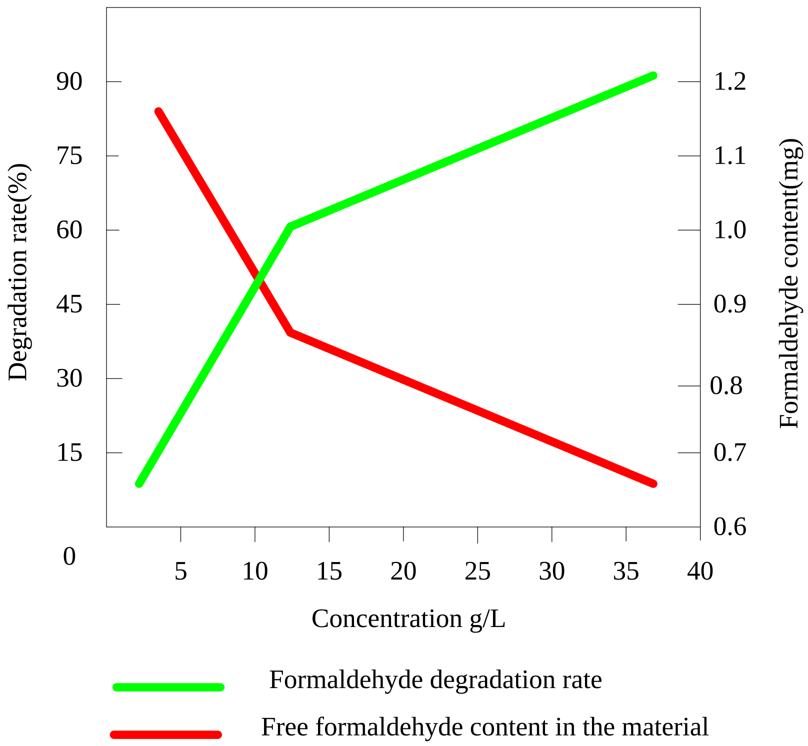

Figure 3B. Degradation rate of Ag_3PO_4/TiO_2

Figure 3. Comparison of the effect of finishing agent concentration on the degradation rate

The degradation rates of the two coatings are also quite different at different temperatures. From the degree of degradation of the two coatings, the degradation rates of the two coatings at different temperatures are different. Their degradation rates at various temperatures are shown in Figure 4. (Figure 4A: Degradation rate of TiO_2, Figure 4B: Degradation rate of Ag_3PO_4/TiO_2)

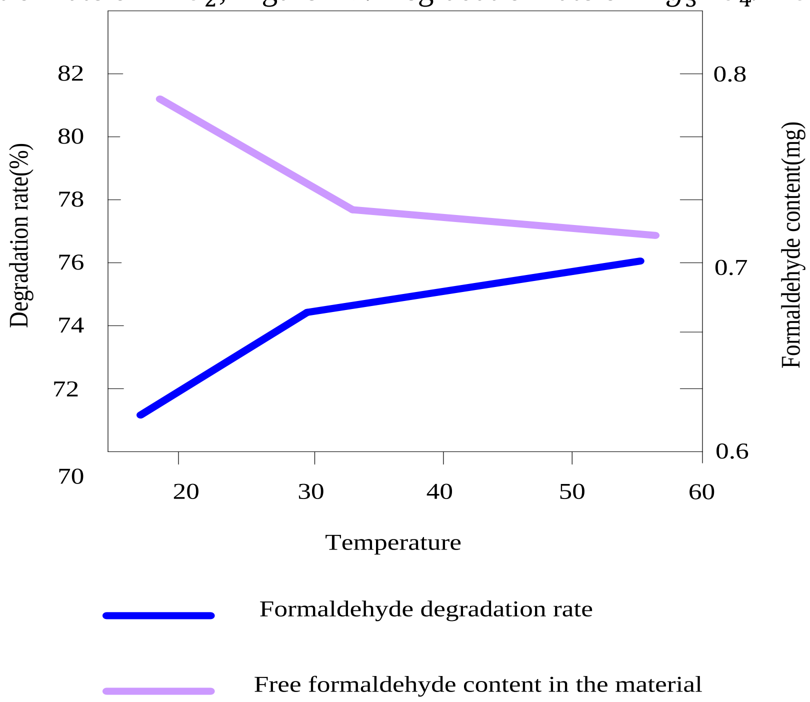

Figure 4A. Degradation rate of TiO_2

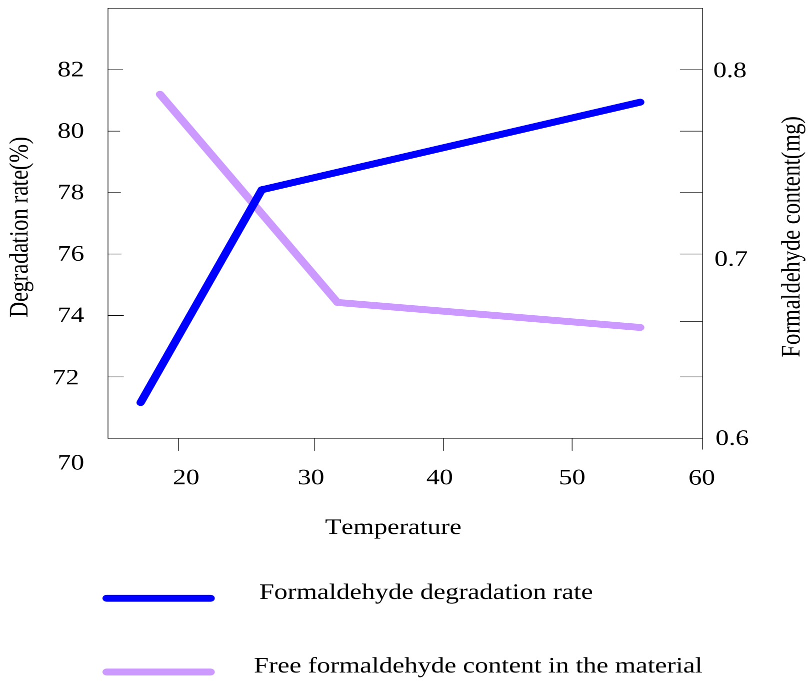

Figure 4B. Degradation rate of Ag_3PO_4/TiO_2

Figure 4. Comparison of the effect of temperature on the degradation rate

It can be seen from Figure 4A that the degradation rate of formaldehyde increases from 71% to 76% when the degradation rate of Nano TiO_2 is at 20-60 degrees Celsius. The degradation rate is not high, about 5%. The formaldehyde content in the TiO_2 paint does not drop much. However, in Figure 4B, with the increase of temperature, the degradation rate of Ag_3PO_4/TiO_2 increased significantly, from 71% to 81%. Compared with Nano TiO_2, the degradation rate of formaldehyde is increased by 5%. The content of formaldehyde in the paint is also less than that in Figure 4A. There is an upward trend as the temperature increases. It also shows that under the influence of temperature, the composite coating of TiO_2 has a higher degradation rate of formaldehyde.

When other conditions are the same, the degradation of the two can be judged by the initial concentration of formaldehyde at 0.6, 1.2, and 1.8 (unit: mg/m^3). A comparison of the two is shown in Figure 5. (Figure 5A: Degradation rate of TiO_2, Figure 5B: Degradation rate of Ag_3PO_4/TiO_2)

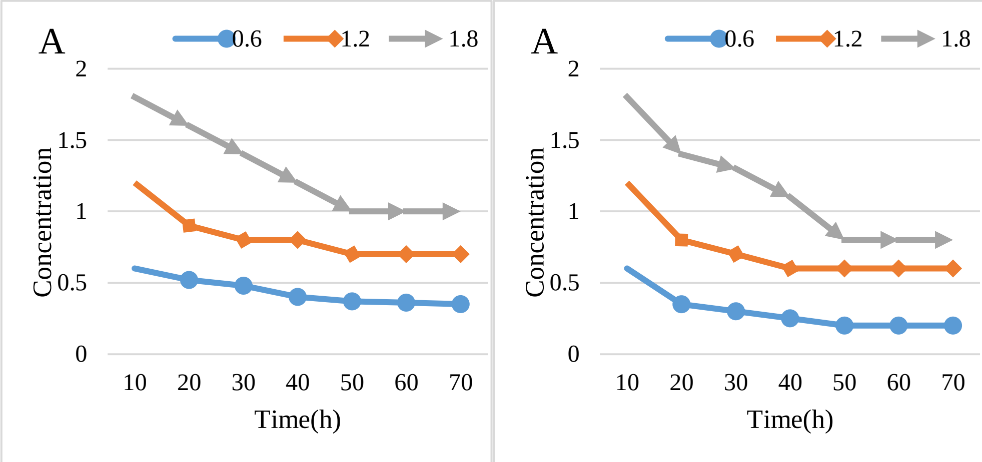

Figure 5A. Degradation rate of TiO_2 Figure 5B. Degradation rate of Ag_3PO_4/TiO_2

Figure 5. Comparison of the effect of different initial concentrations on the degradation of formaldehyde

It can be seen from the comparison of Figures 5A and 5B that when the initial concentration is 0.6 mg/m^3, the degradation rate of TiO_2 relative to Ag_3PO_4/TiO_2 is slower, and the lowest value after reduction in Figure 5A is also higher than the composite coating value. At the initial concentration value of 1.2 mg/m^3, the formaldehyde decline slope is higher in Figure 5B. Compared with Figure 5A, the rate of formaldehyde degradation is faster. At the initial concentration of 1.8 mg/m^3, the formaldehyde concentration in Figure 5A decreases relatively uniformly, which finally decreases to 1.0 mg/m^3 and no longer decreases. However, in Figure 5B, the formaldehyde concentration does not change when it drops to 0.8 mg/m^3 at the same time. The final concentration obtained after 70 hours, the formaldehyde concentration under the composite coating is lower than the concentration of nano-TiO_2. It also shows that the composite coating Ag_3PO_4/TiO_2 can better degrade formaldehyde.

5. Conclusion

The development of high-performance, environment-friendly and multi-purpose building materials has become an international research hotspot. The dispersion properties of nanomaterials and the application of functional nanocomposites in architectural coatings can effectively degrade formaldehyde and improve indoor environment. In this paper, the method of degrading formaldehyde was described by describing the properties of nano-titanium dioxide and formaldehyde. The Ag_3PO_4/TiO_2 composite coating and Nano TiO_2 were introduced to compare the ability to degrade formaldehyde by comparing at different temperatures, different initial concentrations, and different finishing agent concentrations. It was found that the composite coating of Nano-TiO_2 had better ability to degrade formaldehyde than Nano-TiO_2. Moreover, it was also applicable in a variety of environments, indicating that the Nano-TiO_2 composite coating was more suitable for architectural design. The deficiency of this paper was that the content of silver phosphate in the composite material had no description on the ability of degrading formaldehyde. Furthermore, the photocatalytic principle of the composite material was not described in detail. In the future, nanocomposites would also be used in many ways to improve the health problems caused by the materials.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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