THE PREPARATION AND PROPERTIES OF THE BIO-FUNCTIONAL NANO-COATING OF ALUMINUM-PLASTIC COMPOSITE PANEL WITH THE METAL FEEL

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ABSTRACT*: In order to improve the performance of the aluminum-plastic composite panel (ACP), the preparation method and performance of the ACP coating are studied. First of all, the related knowledge of ACP and ACP coating are introduced. Second the preparation and performance of the fluorocarbon resin are analyzed. Then, antimony tin oxide (ATO) and nano titania (TiO_2) are used to modify the waterborne fluorocarbon resin to generate a bio-functional nano coating; Finally, through experiments, the modified coatings are analyzed for the heat insulation, light transmittance, and self-cleaning properties. The results show that ACP is not only a kind of safe fireproof material, but also a third-generation curtain wall material with excellent performance. The modified waterborne fluorocarbon resin coating retains the metal feel of the ACP and ensures the heat insulation and self-cleaning functions of the coating. When the ATO are added to the coating, the light transmittance and thermal insulation perform best with the mass fraction within 2.5%. When adding titanium dioxide with a fraction of 0.1%, the coating has excellent self-cleaning properties. It is found that the addition of ATO and TiO_2 nanoparticles to the waterborne fluorocarbon resin coating can improve the heat insulation and self-cleaning performance of ACP, while retaining the metal feel of it. It is hoped that this can be applied to practical projects and at the same time provide a certain reference value for improving the performance of ACP.*

KEYWORDS*: aluminum-plastic composite panel; bio nano coating; nano titanium; waterborne fluorocarbon resin; antimony tin oxide*

1 INTRODUCTION

Polyvinylidene fluoride (PVDF) is a polymer resin obtained by the addition polymerization of 1,1-difluoroethylene. This resin has a particularly stable chemical structure and high crystallinity as well as the good weather resistance (Peng et al., 2019). Fluorocarbon coatings that use PVDF as the film-forming material also have excellent outdoor durability and substrate protection properties. Furthermore, PVDF fluorocarbon coatings also have advantages such as self-cleaning, low friction, and low surface tension (Lu et al., 2015). PVDF fluorocarbon resin coating is applied to the field of building materials, especially in the use of some peripheral materials. The current PVDF fluorocarbon resin coatings can be divided into two types: oily resins and environment-friendly resins, of which the oily resins are widely used, but in response to national policies, environment-friendly resins have become an important developing branch in the coatings industry. Environment-friendly PVDF fluorocarbon coatings mainly has two forms: water-based and powder-based (Boo et al., 2016). Water-based PVDF resins usually use seed emulsion polymerization technology, which allows acrylic molecules to be added evenly inside the PVDF molecular structure, or the waterborne PVDF resins can also be achieved in the way of core-shell wrapping.

The ACP uses plastic as the core layer, and the two sides of the core layer are aluminum materials, which makes it a three-layer conforming plate. It is usually covered with a coating on its surface as a decorative layer of the product to presents a variety of colors (Siddiqui et al., 2019). The coating is a composite functional material prepared by inorganic pigments, fillers, organic film-former and auxiliary through high-speed shearing dispersion, sand grinding dispersion, and other processes. Nano-coatings were prepared by uniformly dispersing inorganic functionally stable nanoparticles into coatings (Fathi et al., 2018). Because of the limited size and the relatively high surface free energy of nanoparticles, it is very easy to form agglomerates within the particles. Therefore, when preparing nano-coatings, the dispersibility and stability of nanoparticles must be paid great attention to (Liu et al., 2017).

Based on the existing research results, the concept and preparation method of ACP are analyzed and explored; then, the waterborne fluorocarbon resin is modified with ATO and TiO_2 to generate a bio-functional nano-coating; in addition, the optimized coating is analyzed through experiments for its heat insulation, light transmittance, and self-cleaning performance.

2 MATERIALS AND METHODS

2.1 ACP

ACP is composed of different metallic and non-metallic materials and is a new type of building decoration material. The ACP is composed of multiple layers of materials, whose upper and lower layers are high-purity aluminum alloy materials and the middle core board is non-toxic low-density polyethylene. A layer of coating is usually added on the front of the ACP as a protective film. In terms of the aluminum-plastic panels used outdoors, its coating is usually the PVDF, which is the main film-former material of fluorocarbon resin. For indoor aluminum-plastic panels, the coating can be made of non-fluorocarbon resin (Li et al., 2019). ACP retains the main characteristics of metal aluminum and polyethylene (PE) plastic. Metal aluminum is a metal material that is extremely difficult to burn. The PE plastic core board is a flame-retardant material. Therefore, ACP is a safe and fireproof material. ACP adopts a new technique, which makes the peel strength of it reach the best, and improves the flatness and weather resistance. The weight of ACP, within 6 kg per square meter, is relatively light so it is very convenient to carry. At the same time, the convenient constructability of ACP makes it possible to. achieve a series of processing operations like cut with a simple woodworking tool, which makes it easy to obtain various shapes. The shape of ACP is variable and its installation is simple, which reduces the construction cost to a certain extent.

ACP is a new type of environment-friendly construction materials with good characteristics; due to its light weight per unit area, relatively high strength, and convenient to fabricate and install, it is widely used in indoor and outdoor decoration, car decoration, furniture, building materials, propaganda plaque and airport, large gymnasium, and other landmarks. It is widely used in indoor and outdoor decoration, car and ship decoration, furniture and building materials, publicity plaques, and landmark buildings such as airports and large stadiums. ACP has become the third-generation curtain wall materials. Figure 1 below is the aluminum plate preparation process diagram.

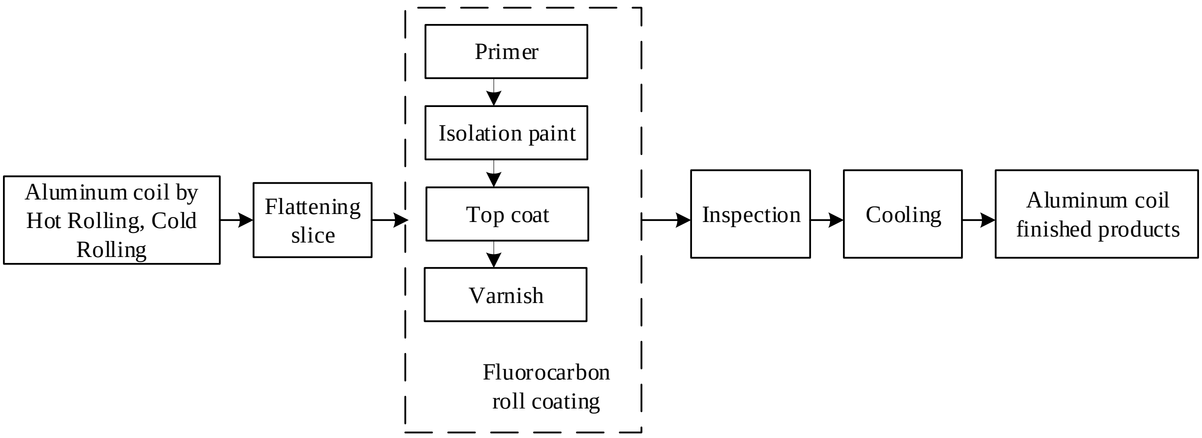

Figure. 1 Preparation process diagram of aluminum plate

2.2 The coating of ACP

This research is mainly about the ACP used outdoors, whose front side usually uses fluorocarbon resin as the coating material. Bond energy of the C-F bond in the PVDF resin is relatively high, and it has strong electronegativity. Therefore, the PVDF resin processes good chemical inertia. Applying it can resist the degradation of the outdoor environment. Although PVDF can resist the degradation in the outdoor environment, its strong chemical inertia is not conducive to the combination of the basements. When it is used as a coating for aluminum-plastic panels, the adhesion to the substrate is low, and the pigment is wet, resulting in poor paint dispersibility (Schroeder et al., 2019). In order to overcome the defects of PVDF, it is usually modified with acrylic resin. In order to make the PVDF resin waterborne, the chemical polymerization method is usually used to achieve the blending of PVDF and modified acrylic resin. In this way, while achieving waterborne environmental protection, the mixing state between the two has been further improved. The molecular structure of PVDF is shown in Figure 2 below.

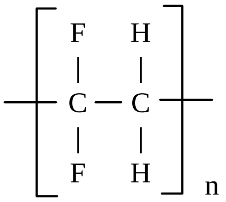

Figure. 2 PVDF molecular structural formula

The polymerization of waterborne PVDF resin emulsion generally is divided into two stages. The first stage is to generate fluorocarbon resin homopolymer by conventional emulsion polymerization. The second stage is to combine the acrylic modified resin and the fluoropolymer to produce a micro-nano-scale mixture with interpenetrating network polymer, graft or ionic bond. At the same time, in this period, acrylate monomers with different functions can be added according to the actual application requirements so that the waterborne fluorocarbon resin has different functions (Vasundhara et al., 2017).

Among them, acrylic resins are prone to photochemical reactions, for which the acrylic resins are likely to have problems of chain scission and degradation. Different photochemical degradation occurs under the action of ultraviolet radiation of different wavelengths. Compared with oilborne fluorocarbon resin coatings, the existing waterborne fluorocarbon resin coatings still have many deficiencies, and their performance in outdoor weather resistance and solvent resistance is still poor.

2.3 Preparation of coating considering the metal feel of ACP

Nanomaterials were used to modify the PVDF resin coating to improve the performance of the coating. In order to keep the metal feel of ACP, it is necessary to choose transparent ACP coating material. The heat-insulating and transparent nano-functional coating has the advantages of corrosion resistance and aging resistance, and its mechanical properties are also excellent. Meanwhile, this coating can also ensure its heat insulation and light transmission. Therefore, environment-friendly water-prone fluorocarbon resin was used as the main film-forming substance, and nano-tin antimony oxide and titanium dioxide were added to the fluorocarbon emulsion to ensure the heat insulation and self-cleaning function, and then, through a series of process, the self-cleaning, transparent and heat-insulating paint was produced.

Due to the high surface activity of nano tin antimony oxide (ATO) and nano titanium dioxide (TiO_2), it is necessary to modify the surface of the surface to reduce the surface activity. Then, an appropriate dispersing agent and other auxiliaries are added to them; a stable waterborne suspension could be produced with high-speed shear dispersion, ball milling dispersion, ultrasonic disruption, etc. The resulting waterborne suspension is added to the fluorocarbon film-forming emulsion; after certain processing, the coating is prepared. The finished product is painted on the surface of the ACP to form a transparent heat-insulating film. Due to its transparency, the metal feel of the ACP is greatly retained. The preparation process of ACP coating is shown in Figure 3 below.

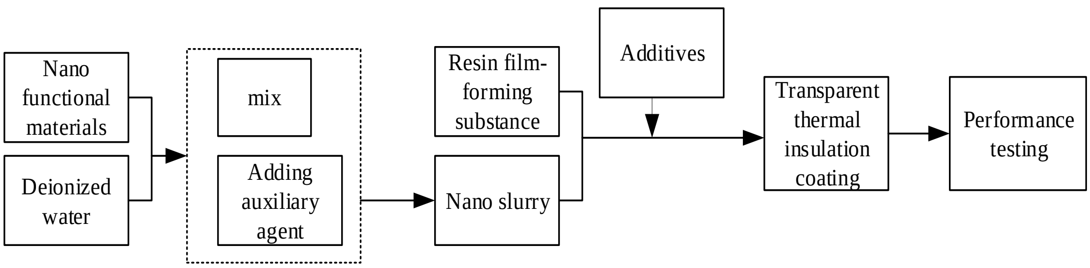

Figure. 3 Preparation process diagram of ACP coating

2.4 Research on the properties of the coating

By reviewing the existing research results, it is found that the coating is mainly composed of fluorocarbon emulsion, ATO, TiO_2, wetting agent, flow agent, defoamer, alcohol 12, dispersing agent, thickening agent, and deionized water. Among them, the mass fraction of fluorocarbon emulsion is 50%-75%, the mass fraction of ATO is 0.5%-4%, and the mass fraction of alcohol is 3%-6%. Except for ionized water, the mass fraction of other components is 0.1%-1%, and the mass fraction of deionized water is matched according to the slurry mass fraction of 1.

The ratio of the suspension is calculated according to the above standards, and the required nanoparticles and deionized water are weighed.

Then they are put in the dispersion tank, while stirring at a low speed, adding auxiliaries such as suitable wetting agent, flow agent, defoamer in sequence. The pre-dispersed liquid was prepared after 30 to 40 minute-shearing dispersion with the speed of 800 to 1000 rpm in the dispersion barrel under the acid-base balance (pH) at the range of 8-9 that adjusted with ammonia. Then the liquid is sanded for 2 hours, and dispersed with ultrasonic technology for ten to fifteen minutes. After being let stand and filtered, the obtained slurry is the required aqueous nano-functional suspension.

The required waterborne fluorocarbon is weighed and put into a clean stainless steel dispersion kettle whose stirring speed is set to 400 to 600 rpm. At this shearing and dispersing speed, deionized water, film-forming additive such as alcoholic vinegar 12, flow agent, defoamer, thickening agent and other additives are added for 20 minutes of low-speed shearing and dispersing. Then the prepared stable aqueous nano-functional suspension is added into the kettle and sheared at a speed of 800 to 1100 rpm for 1 to 1.5 hours. With 2 hours-stand and filtration, the transparent fluorocarbon coating was obtained.

The prepared coating is applied to the surface of ACP in a size of 150 mm × 100 mm × 5 mm with a 50μm wire rod coater, only the front of the ACP, and then it is dried naturally at the room temperature. The obtained samples are used for heat insulation, photocatalysis, adhesion and water resistance test experiments; moreover, the prepared coating is applied to the surface of a glass slide in a size of 25.4 mm×76.2 mm×1 mm using a 50 μm wire rod coater, which is dried to test the light transmission performance of the coating.

3 RESULTS AND DISCUSSION

The main performance of the coating is determined by the added functional particles, which are nano ATO and nano TiO_2 in this study, so the properties and the amount of these two particles determine the performance of the fluorocarbon composite coating. The influence of the amount of nano-TiO_2 added on the self-cleaning performance of the coating, the photocatalytic mechanism of TiO_2, the relationship between the number of nano-ATO particles added and the light transmittance and thermal insulation effect of the coating are studied in the research. Meanwhile, the basic performance of the coating is also analyzed.

3.1 Analysis of the transmittance of the coating

Since the fluorocarbon emulsion is transparent after film formed, the determinant of the transparency of the coating is the nature of the pigments and fillers added. The amount of nano-TiO_2 added is very small, so it is the nano-ATO particles that play a major role in the transmittance of the coating. The light transmittance curve of the specimen with a size of 25.4 mm×76.2 mm×1 mm is measured in the wavelength range of 300 to 800 nm with an ultraviolet-visible spectrometer. The test results obtained are shown in Figure 4 below.

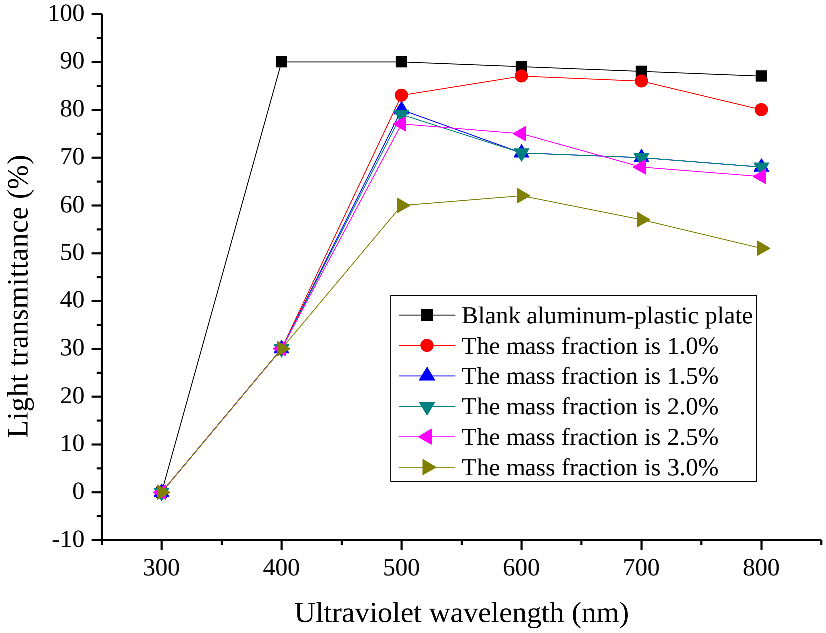

Figure. 4 Analysis diagram of light transmittance test of ACP coating

It can be seen from the figure 4 that the light transmittance of the coating is tested when the mass fraction is 1%, 1.5%, 2.0%, 2.5% and 3% respectively, with blank slides as the control experimental group. Compared with blank slides, it is found that the overall light transmittance of nano-ATO particles with a mass fraction of 1% only decreases by about 5%. When the mass fraction increases to 2.5%, the overall transmittance of the coating decreases by 25%. Relatively speaking, the light transmittance of the coating material at this time can meet the basic requirements, but when the mass fraction of ATO rises to 3%, the light transmittance drops by more than 30%. The light transmittance of the coating becomes poor and cannot meet the basic requirements. Therefore, in consideration of retaining the metal feel of the ACP, the mass fraction is best within 2.5% when adding ATO nanoparticles.

3.2 Analysis of thermal insulation performance of the coating

In the coatings study, the heat insulation effect of the coating is mainly ATO nanoparticles. When the prepared ACP samples with the size of 150 mm×100 mm×5 mm are used for the heat insulation test, the mass fractions of the ATO added in the paint are selected as 1%, 1.5%, 2.0%, 2.5% and 3%. The heat insulation device used is shown in Figure 5.

Figure. 5 The picture of thermal insulation experimental device

A piece of coated ACP and a piece of uncoated ACP are placed on the left and right sides respectively, the temperature of the two ACP boards under the light is recorded, and the thermal insulation performance of the coating is analyzed. The analysis results are shown in Figure 6 below.

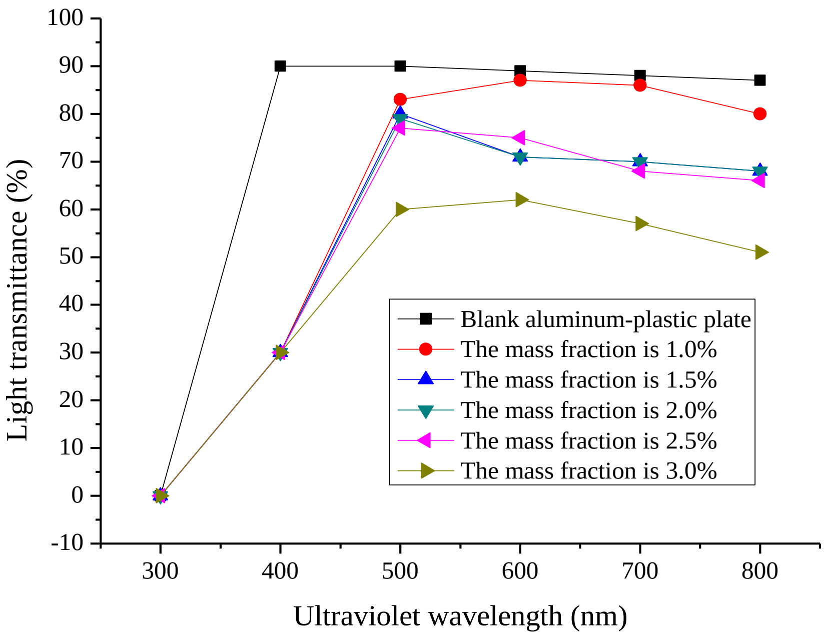

Figure. 4 Analysis diagram of light transmittance test of ACP coating

As can be seen from Figure 6 above, after the test starts, the temperature in the two boxes begins to rise rapidly, and after an hour or so, the temperature shows a tendency to rise slowly. On the whole, the temperature of the box on the side of the uncoated ACP is always higher than the temperature of the box on the side of the coated one. Furthermore, when the mass fraction of ATO is

1%, the temperature difference between the two sides of the cabinet is only 4. When the mass fraction of ATO particles continues to increase, the temperature difference between the two sides also increases. When the mass fraction of ATO is at 2.5%, the temperature in the box is basically stable. When the mass fraction increases to 3%, the temperature in the box is basically unchanged. According to the analysis, the higher the ATO mass fraction is, the better the heat insulation performance of ACP coating is, but when the ATO mass fraction reaches 2.5%, the heat insulation performance remains basically unchanged. Therefore, considering the economic issue, the ATO quality score should be within 2.5%.

In the preparation of ATO particles, the phenomenon of free carrier absorption occurs in ATO. The absorption coefficient and the wavelength of light show a power function relationship, so most of the infrared light can be absorbed by the coating. While the ATO particles absorb infrared light energy, there will be a transition, which means the temperature of the coating will be higher than the surrounding environment temperature. At this time, the coating will dissipate heat through the thermal convection between ACP and the surrounding environment. When the mass fraction of ATO increases, more infrared light can be absorbed, and the thermal insulation effect will also be enhanced.

3.3 Analysis of self-cleaning properties of the coating

TiO_2 plays a major role in the quality of the self-cleaning properties of the coating. Keeping the mass fraction of ATO nanoparticles constant, the TiO_2 is selected with mass fractions of 0.05%, 0.1%, and 0.15% respectively to prepare ACP samples in the dimension of 150 mm×100 mm×5 mm for self-cleaning performance test experiment. A methyl red saturated solution is prepared, and the ACP boards are brushed with different mass fractions coatings respectively and the ACP board without coating is used to form a control. The experiment groups and control group are placed in an ultraviolet ray box for irradiation after dried and observed for the catalytic decomposition of methyl red in them. Taking the covering condition of methyl red after irradiation as the evaluation index, the analysis results are shown in Figure 7 below.

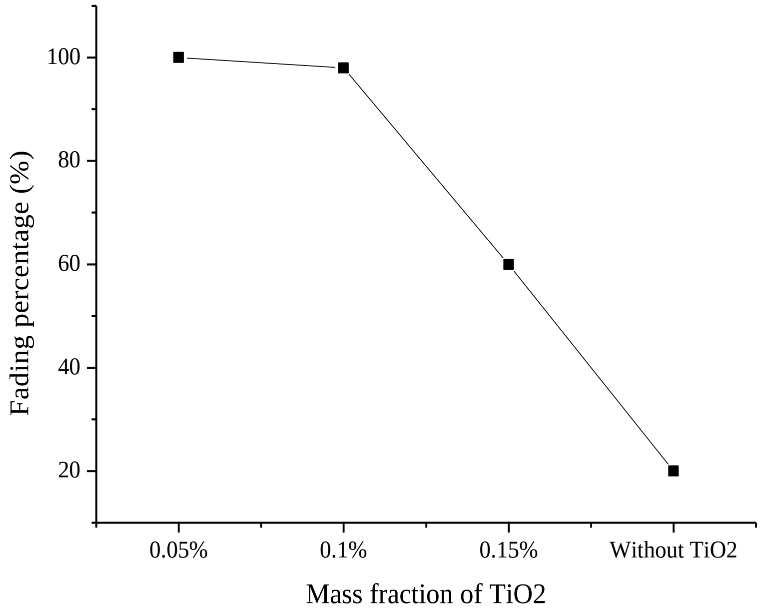

Figure. 7 Correlation curve between titanium dioxide content and the fading degree of methyl red

It can be seen from Figure 7 above that when the mass fraction of titanium dioxide is 0.1% and 0.15%, the methyl red solution on the ACP is almost completely eliminated, and when the mass fraction of titanium dioxide is 0.05%, the methyl red solution is partially removed. Methyl red on the uncoated ACP hardly fades, indicating that the coating in this study has self-cleaning properties. When the mass fraction of titanium dioxide is 0.1%, there is basically no difference in the degree of discoloration of the sample. Therefore, when preparing the coating, the mass fraction of TiO_2 can be set to 0.1%. Figure 8 below is the photocatalytic mechanism of TiO_2.

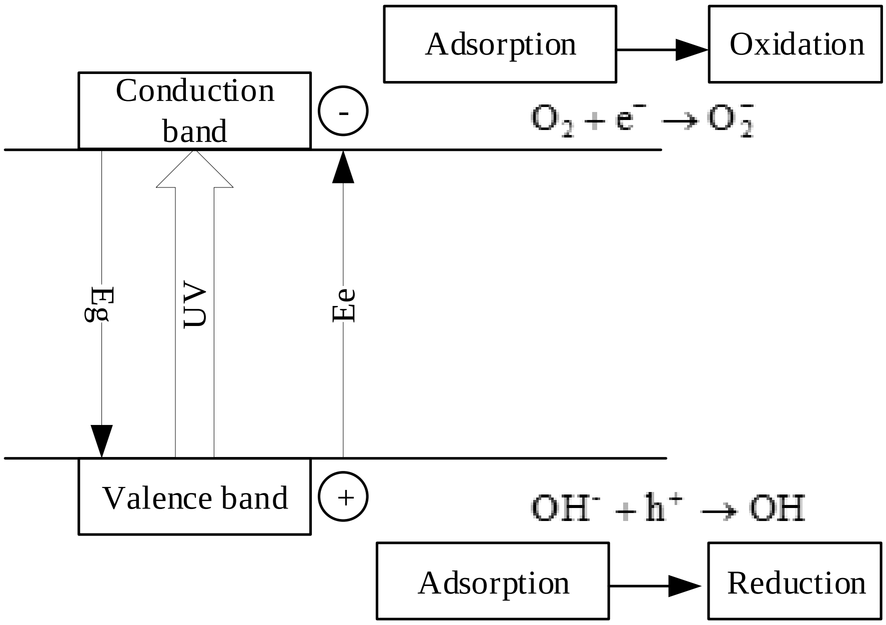

Figure. 8 Photocatalytic mechanism diagram of TiO_2

4 CONCLUSION

First, the preparation of ACP coating and the performance of the coating are studied in the article. Through the analysis of the ACP material, it is found that it is a safe and fireproof material and it is a third-generation curtain wall material with excellent performance, usually using fluorocarbon resin as the coating material; second, the preparation and performance of the fluorocarbon resin were analyzed. The nano-tin antimony oxide (ATO) and nano-titania (TiO_2) were added to the waterborne fluorocarbon resin to optimize the modification to generate a bio-functional nano coating. To further improve the properties of the coating, the modified waterborne fluorocarbon resin coating not only retains the metal feel of ACP, but also ensures the thermal insulation and self-cleaning functions of the coating; at last, through experiments, the modified coatings were analyzed for heat insulation, light transmission, and self-cleaning properties. It was found that when the adding quantity of ATO nanoparticles is within 2.5%, the waterborne fluorocarbon coating has the best light transmittance and thermal insulation performance. When adding TiO_2 with a mass fraction of 0.1%, the coating has excellent self-cleaning properties.

Due to the objective limitations, in this research process, only methyl red was selected to study the self-cleaning performance of the coating. At the same time, since this experiment was conducted in the laboratory, compared with the actual environment, there is still a certain difference. It is hoped that in the follow-up researches, the research scope and comprehensiveness of the ACP coating can be expanded to enhance the practical application of the research results.

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