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Titanium dioxide nanoparticles synthesis methods and their application in coatings: A review

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Abstract
Today, the use of mineral pigments is very common in improving polymeric coatings properties and in creating nano composite coatings with optimal properties. Titanium dioxide is the most important white pigment used in coating industry, which is used for optimally disperse visible light. Titanium dioxide is present in two main crystalline structures of Anatase and rutile. Titanium dioxide rutile pigments are preferred over the better light scatter and durability than Anatase. Titanium dioxide is a good pigment because of its chemical resistance, photocatalytic properties, self-cleaning properties and also non-toxicity. In this article, we will introduce the different types of titanium dioxide nanoparticles, their photocatalytic performance, environmental issues, various methods of synthesis, and the properties of corrosion resistance of nano composite coatings.

Keywords: coating, nanoparticles, titanium dioxide, synthesis

Introduction
Organic coatings are commonly used for cheap, diverse applications and relative ease of use, and one of the cheapest corrosion control tools. But these coatings are vulnerable to various factors such as high corrosivity, ultraviolet radiation or mechanical shocks. One of the ways to improve the physical, mechanical, anti-corrosion and optical properties of these coatings is the use of mineral pigments [1, 2] about 9 years (due to luminosity and refractive index) Which expresses the amount of irregularity that the substance provides to the matrix (the uppermost of which is the most precious white pigment in products such as paints, coatings, adhesives, paper, cardboard, plastics, rubber, ink, textiles and knitwear, catalyst systems, ceramics, flooring parquet, Construction of roofs, accessories, pharmaceuticals, water purifiers, edible colors, automotive industry, etc. [4, 5]. When this pigment is combined with other colors, soft dough is obtained. Adding a small amount of titanium dioxide to some materials can improve the refractive index [6, 7].

Titanium dioxide in water, hydrochloric acid, dilute sulfuric acid and organic solvents are not soluble. Slowly dissolved in hydrofluoric acid and concentrated sulfuric acid. It is indissoluble in almost alkaline solutions [8, 9]. It is recommended for use in alkyds and latex paints for shiny and semi-shiny interior. This pigment is easily dispersed, provides a good gloss, and exhibits the greatest coating power in the presence of a wide range of transparent materials [11, 12]. Ultraviolet photons have high energy and can easily destroy objects, which usually occur through the loss of chemical bonds that are called photochemical degradation [13, 14].

Titanium dioxide is capable of absorbing ultraviolet light due to its photocatalytic properties and decreases its degradation effect. Application and performance of titanium dioxide is strongly influenced by the crystalline structure, shape and size of its particles. The three common crystalline structures are titanium dioxide, rutile, Anatase, and bruxite. The crystalline base units in all three phases are 6TiO octahedrons. The difference between these three phases is in the arrangement of these octahedrons. Thermodynamically, the rutile is the most stable titanium dioxide phase at normal pressure, and the other two phases are semi-stable phases. The Anatase is stable at normal temperatures, but when heated up to 559 Celsius is slowly turn into a rutile. When the particle size decreases to the nanometer range, the start-up temperature decrease in compare to mass state and the temperature range extends for deformation [15, 16, 17].

Rutile is a stable phase at high temperatures and in most activities it is possible to obtain a rutile to achieve titanium dioxide. Fuzzy rutile is a titanium dioxide that is most often considered, and as a semiconductor with a large amount of energy, it is very common in basic research as well as optical and electrical devices. However, Anatase phase at temperatures below 559 ° can be stable in powders, ceramics, natural or synthesized crystalline, thin films, etc. [18, 19, 20].

Photocatalytic activity of titanium dioxide

Titanium dioxide has a good restoring effect against UV, and it is very popular for its practical uses due to the advantages of non-toxicity, high chemical stability at high temperatures, and permanent resistance in the presence of UV. For example, the advancement of nanotechnology and technology to improve the performance of UV resistant films has created new ways of adding titanium dioxide. The precise mechanism of titanium dioxide as a UV restorer is not clear and researchers have different views on this issue. Some of them believe that this UV restoring or dispersal is due to its significant failure index, another group believe that this feature is due to semiconductor properties of this matter. Others claim that in a titanium dioxide mass, only particles with a nanometer size absorb UV rays and particles with larger sizes are less capable of doing so. According to different and often contradictory views on this issue, it seems that there is a need for more detailed studies on this issue.

Environmental issues

Since the use of titanium dioxide as a commercial product, no concern has been expressed about the risk to the health of consumers or other people. These facts are based on four major epidemiological studies that included more than 87000 workers in titanium dioxide industry in northern America as well as Europe, which showed no concern about the incidence of cancer or malicious effects on lungs [21, 22, 23].

Titanium dioxide has a high capacity for absorbing UV light. In addition, it is resistant to color variation in the presence of UV rays. The possibility of exposure to titanium dioxide particles is assumed to be very low, since titanium dioxide is usually imported into the matrix in a very limited way (such as the amount that is used in production of Colors and plastics), so the risk of exposure to inhaling this substance is not considered for all people [24, 25, 26].

Studies have shown that Titanium Dioxide particles (pigment or very fine) can not penetrate and damage the skin. In recent years, titanium dioxide has become more important as a photo catalyst. The photocatalytic activity of titanium dioxide is dependent on its crystalline structure, therefore, several studies have been carried out on these dependencies. It has recently been discovered that titanium dioxide composition of Anatase and rutile has more photocatalytic activity than Anatase or pure rutile [27, 28, 29].

Synthesis methods

Several methods have been developed for the synthesis of titanium dioxide nanoparticles, for example, by sol-gel, Hydrothermal and emulsion sedimentation Mechanochemical Thermal Radio Frequency Thermal Method, Steam chemical deposition method, Micro-mixing method [31, 32, 33, 34]. Although titanium dioxide nanoparticles have been successfully prepared by these methods, but more synthesized nanoparticles are inadequately crystalline in traditional ways and spread far apart each other [35, 36].

Production processes

Titanium dioxide pigments are produced in two commercial processes: sulfate and chloride. Both types of Anatase and rutile are produced by both methods. Chloride process becomes a dominant process, due to the fact that it produces better pigments and fewer emissions. The sulfate method was first used in 2043 for Anatase, and then in 2087 for rutile. In this process, ore consisted of titanium is dissolved in sulfuric acid and titanium, iron, and other metals sulfate solution is obtained. Then, titanium dioxide pigment is produced in the process of chemical reduction, purification, deposition, washing and calcination. The crystalline structure of Anatase or rutile is determined by nuclear and calcareous [37, 38].

Due to problems with cost and environment-friendly issues in sulfate method, most production capacity is currently in chloride method. Older production units that working by sulfate method must adhere to more stringent environmental requirements to improve their processes by recycling excess acids and burning metal sulfates to recover sulfur trioxide.

Resistance applications against corrosion

Titanium Dioxide Nano Pigments can increase coatings resistance to corrosion. Mahulikar works with his colleagues on the anti-corrosion properties of Nano-composite coatings based on epoxy-poly aniline and titanium dioxide. The results of immersion corrosion tests showed that corrosion resistance rises to an acceptable level in the presence of titanium dioxide nanoparticles [39]. Sheng and his colleagues studied corrosion resistance properties of titanium dioxide nanoparticles on a stainless-steel bed by using a sol-gel method. The electrochemical impedance spectroscopy showed an improvement in properties of corrosion resistance in the presence of Nano-titanium dioxide [40] In another study on anti-corrosion properties of nanocomposite coatings based on poly-aniline and Nano-titanium dioxide, the results showed remarkable improvements in properties of corrosion resistance in the presence of titanium dioxide nanoparticles [41]. Lens and his colleagues reviewed the anti-corrosion properties of polypirol-titanium dioxide nanocomposite coatings. The results of weight loss and saline tests showed an improvement in corrosion resistance in the presence of titanium oxide [42]. Improvement of anti-corrosion properties in the presence of titanium dioxide nanoparticles is due to the pigment's damping properties in the coating and, consequently, the reduction of ions transfers and electrolytes in the presence of nanoparticles. It should be noted that how the titanium nanoparticles are dispersed in polymer bed is very important. The accumulation of nanoparticles at one point greatly reduces the corrosion resistance properties of these coatings.

Conclusion

Mineral pigments play a special role in reducing corrosion. One of the most important and most practical white mineral pigment is titanium dioxide. This pigment has significant photocatalytic properties. Titanium dioxide pigments have three grid structures rutile, Anatase, and portico. In this regard, the crystalline structure of rutile is more stable than the other two. These pigments are used in organic coatings for various reasons such as high photocatalytic properties, self-cleaning properties, optimal anti-corrosion properties, and so on.

The photocatalytic properties of these pigments are reflected in their high energy bands, as well as the ability to restore these pigments. Resistance properties against corrosion are also due to the properties of pigmentation in their matrix in the presence of corrosive materials and electrolytes. According to the specific properties of this pigment, it is expected that in the future much more titanium dioxide powder will be used in various industries, including food, health and coatings industry.

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