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The Preparation of Nano-Titanium Dioxide and Its Healthcare Effects in Cosmetics

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Abstract. Cosmetics are an integral part of daily life. Nowadays, cosmetics are endowed with more healthcare functions while meeting people's needs for beauty enhancement. Nano-titanium dioxide plays a crucial role in their formulation because of its antibacterial and anti-inflammatory properties. As a new type of nanomaterial, nano-titanium dioxide has excellent properties. This paper explores the properties, preparation methods, applications, and potential hazards associated with nano-titanium dioxide in cosmetics. The study highlights its strong ultraviolet (UV) shielding capabilities, which are used in sunscreen products. The nano-titanium dioxide has good dispersibility and weather resistance. The preparation methods included sol-gel, hydrothermal, vapor deposition, and oxide reduction methods. The paper further discusses the use of nano-titanium dioxide in various cosmetic products such as sunscreens, lotions, and gels. Despite its advantages, the paper also displays safety concerns related to skin exposure, inhalation, and oral intake of nano-titanium dioxide. The material poses certain risks, its beneficial properties make it a valuable component in the cosmetic industry. The nano-titanium dioxide significantly enhances the functionality of cosmetics. This work contributes to its widespread use in the future.

Keywords: Nano-Titanium Dioxide; Healthcare; Preparation Method; Antibacterial Properties; Cosmetics.

1. Introduction

Cosmetics have gradually become a must-have in many homes. Especially cosmetics with medical functions, on the basis of meeting the needs of people for beauty, also demonstrate healthcare benefits such as antibacterial and anti-inflammatory effects [1-4]. Sunscreen or lotion plays a vital role in face care. It is regarded as an important step in makeup. With the birth of healthcare demands for cosmetics, the use of new nano-materials to modify cosmetics has become the current research boom. One of the important nano-materials is nano-titanium dioxide.

Nano-materials exhibit nano scale (1-100nm) in one or more dimension. They may also be made up of basic units which are in nano scale. Nano-titanium dioxide with a chemical formula of TiO_2, is an inorganic compound. It is a white powdered amphoteric oxide without toxicity. It also display good opacity, whiteness and brightness. It is also considered as a good material for white pigment. There are three different crystal forms of titanium dioxide in nature which are anatase, rutile and plate titanium. Nano-titanium dioxide has a really important role in cosmetics.

In this work, nano-titanium dioxide is introduced. Its properties, preparation methods, safety concerns and applications are summarized.

2. Preparation

Nano-titanium dioxide has good properties, including UV shielding, dispersion, weather resistance and physical properties.

UV shielding is one of the main properties. Titanium dioxide has a strong ultraviolet shielding effect, which is widely used in cosmetics. As an ultraviolet shielding agent, it can effectively prevent the damage of ultraviolet rays. Secondly, nano-titanium dioxide is a white loose powder. It has good dispersibility and weather resistance, which makes it excellent in a variety of applications. Titanium

dioxide also has a lot of physical properties. It exhibits high dielectric constant. Among the commonly used white pigments, nano-titanium dioxide has the smallest relative density and the largest surface area. Meanwhile, it has the highest pigment volume. Rutile titanium dioxide has a has high thermal stability with a melting point of 1850^{o}C and a boiling point of is 3200 ± 300^{o}C.

2.1. Sol-Gel Method

Sol-gel method is a common method for preparing nano-titanium dioxide. The main steps include mixing titanate with solvents under acidic or alkaline conditions to form titanium sol. Then, the titanium sol is dried at high temperature to form a gel. Finally, by calcination process, nano-titanium dioxide is obtained. The nano-titanium dioxide prepared by this method has high specific surface area, good crystallinity and dispersibility. In addition, sol-gel method also includes hydrolysis method, ultrasonic atomization, and pyrolysis method. The key process of sol-gel method is preparing titanium oxide sol into titanium dioxide sol. In order to obtain the porous catalyst, gel is usually dried by calcination. When the solvent is removed, dry gel is prepared. In this way, nano-titanium dioxide is obtained.

2.2. Hydrothermal Method

Hydrothermal method is a feasible and effective method for preparing titania nanocrystals. The method offers several advantages, including simple operation, mild conditions, and low cost. It is also conducive to large-scale production and application. By carefully controlling key parameters such as reaction temperature, reaction time, and raw material concentration, titania nanocrystals with different morphologies and sizes can be successfully prepared. In addition, the nano-titanium dioxide prepared by hydrothermal method has good ultraviolet absorption capacity and excellent photocatalysis. It can be used as anti-ultraviolet and antibacterial finishing agent for fabrics.

2.3. Vapor Deposition Method

Vapor phase precipitation is a method for preparing nano-sized titanium dioxide under high temperature and high pressure. It involves heating the titanium raw material at high temperature, evaporating it into a gas state, and then transferring the gas titanium raw material to the reaction chambers, where it reacts with oxygen to produce nanoscale titanium dioxide. The method is suitable for the manufacture of high quality, high purity nano-titanium dioxide because the vapor phase method can control the composition and structure of the substance at the atomic or molecular level. Deposition method includes chemical deposition method and physical deposition method. This method typically involves the oxidation reaction of titanium inorganic salts, such as $TiCl_4$ or $TiOSO_4$. Alternatively, it can involve the reaction of titanium with organic alcohols or the reaction of oxygen with water vapor in the gas phase. These reactions lead to the hydrolysis of nanoparticles.

In addition, the particle size, morphology and crystallinity of nano-titanium dioxide can be adjusted by different reaction conditions. The change of the temperature, pressure, and reaction ratio can result in various products to meet specific application requirements. For example, the particle size of nano-titanium dioxide can be controlled by adjusting the reaction temperature and the partial pressure of titanium chloride. Increasing the partial pressure of titanium chloride helps to reduce the particle size of titanium dioxide. Nano-titanium dioxide produced by using this method exhibits high surface area and good dispersion. It is widely used in sunscreens.

2.4. Oxide Reduction Method

The oxide reduction method is a method of preparing nano-titanium dioxide by reducing titanium source with reducing agent. The titanium source, such as titanium oxide and titanium salt, is mixed with the reducing agent. The reducing agent here can be a substance that can reduce the titanium element in the titanium source, such as hydrogen, carbon and so on. Afterwards, the mixture is heated to cause the reduction reaction. In this process, reducing agent will reduce the titanium in the titanium source. At the same time. nano-titanium dioxide is produced. It is important to note that the specific

conditions and parameters of the oxide reduction method can vary. Factors such as temperature, pressure, reaction time, and the dosage of the reducing agent all depend on the titanium source and reducing agent. Therefore, in practical application, the experimental parameters need to be adjusted and optimized according to the specific situation.

3. Applications

The destruction of the atmospheric ozone layer increases the ultraviolet rays of sunlight to the ground, which seriously affects the living environment of human beings. The nano-titanium dioxide provides excellent sun protection. Ultraviolet light can be divided into UVA, UVB, and UVC regions according to wavelength. Titanium dioxide, for example, showed excellent absorption capacity in all three regions. Nano-titanium dioxide is non-toxic, tasteless, without irritation to the skin. In addition, it does not decompose or deteriorate. It exhibits good thermal stability. Therefore, it can be widely used in various cosmetics.

Nano-titanium dioxide toner showed extensive antibacterial activity. When the action time is 1h, the sterilization rate of Escherichia coli, Staphylococcus aureus, Pseudomonas aeruginosa could reach more than 99% [3]. While the bactericidal rate of Candida albicans could also reach up to 96.51%. The toner containing nano-titanium dioxide mainly absorbs UVB in the medium wave domain. With the increase of nano-titanium dioxide content, UV absorption capacity also increases. When the content exceeds 0.10%, in the wavelength range of 280 nm to 300 nm, medium-effect protection can be obtained.

Besides, nano-titanium dioxide is also added in the essential oil. Research shows that the essential oil contains borneol. Due to the interaction between nano-titanium dioxide and borneol, the essential oil has a strong light spectrum antibacterial effect.

Nano-titanium dioxide can be added to the gel to enhance the antibacterial properties. The addition of nano-titanium dioxide will not affect the rheological properties of the gel through appropriate methods. Adding too much nano-titanium dioxide would reduce the viscosity of the gel and produce white cotton coagulants. This indicates that nano-titanium dioxide is incompatible with carbomer. At the same time, gels containing nano-titanium dioxide have no antibacterial properties. Therefore, when adding nano-titanium dioxide to gel, it is important to explore the appropriate amount of addition. The gel, with the addition of nano-titanium dioxide, demonstrated good broad-spectrum antibacterial activity. The manufacturing process of this gel involves organic materials, which can promote the growth of coliform bacteria and Staphylococcus aureus. There is a certain competition between these bacteria, resulting in a slightly lower bactericidal rate compared to cosmetics like toner. When the content of nano-titanium dioxide is 0.4% and the action time is 5 hours, the bactericidal rate of these three bacteria can still reach more than 90%. Due to its own state, the adhesive has a greater effect of blocking ultraviolet light than cosmetics such as toner. It has a strong effect of blocking ultraviolet light, which is strengthened with the increase of nano-titanium dioxide content [5].

4. Toxicology

4.1. Skin Exposure

Nano-titanium dioxide is used in many sunscreen cosmetics because of its excellent UV protection ability, so its ability to enter the skin has raised concerns about human health. The properties, size and shape of nano-titanium dioxide were explored by optical and electron microscope analysis using three different application forms of nano-titanium dioxide. It is proved that nano-titanium dioxide is only present in the outermost layer of the skin and is not found in the deeper stratum corneum, the epidermis of the body and the actual cortex [6].

4.2. Inhalation Exposure

Due to its small particle size, nano-titanium dioxide can enter the body through the alveoli through osmosis or simple diffusion. Nichols, C.E et al. reported that inhalation of nano-titanium dioxide is associated with cardiac diastolic dysfunction and altered mitochondrial function [7].

4.3. Ora Intake

Oral intake is also one of the important ways for the human body to inhale nano-titanium dioxide particles. Nano-titanium dioxide is used as a traditional food additive in many foods, such as candy, oral icing and so on. Nanoparticles enter the body through the oral route. Oral ingestion of anatase-type nano-titanium dioxide particles can induce neuroinflammation. This may lead to neurotoxicity and pose potential health risks.

5. Conclusion

Nano-titanium dioxide played an really important role in cosmetics. This work mainly discussed about the properties, preparation methods, applications and hazards. It has a strong ultraviolet shielding effect, which is widely used in the cosmetics. Secondly, dispersibility and weather resistance are also good properties that are really important. It also has a lot of useful physical properties such as the electrical properties. For the preparation part of this work, it mainly displayed four of the main methods, including sol-gel, hydrothermal, vapor deposition and oxide reduction methods. This work especially talked about the applications in the cosmetics such as sunscreens, lotions or gel. At last, there are also a lot of safety hazards in the use of nano-titanium dioxide. It mainly discussed about skin exposure, inhalation exposure and oral intake. Nano-titanium dioxide is still a useful material in cosmetics due to the helpful properties. In conclusion, thanks to the good properties of nano-titanium dioxide, it has helped a lot in the industry of cosmetics. People benefit from the use of it in the cosmetics in their daily lives. It is worth studying how to better utilize the antibacterial effect of nano-titanium dioxide in cosmetics. and become a powerful supplement to medical care. In the future, nano-titanium dioxide will play a greater role in the field of healthcare.

References

[1] Paul H, Miller P L, Strathmann T J, Visible-light-mediated TiO2 photocatalysis of fluoroquinolone antibacterial agents, Environmental Science & Technology 41 (2007) 4720-4727.

[2] Baek S, Joo S H, Blackwelder P, Effects of coating materials on antibacterial properties of industrial and sunscreen-derived titanium-dioxide nanoparticles on Escherichia coli, Chemosphere 208 (2018) 196-206.

[3] He L, Xing L, Wen W, Effects of antiseptic and antibacterial ingredients in cosmetics on skin health from the perspective of skin micro-ecology, Detergent & Cosmetics 38 (2015) 10-13.

[4] Nichols CE, Shepherd DL, Hathaway QA, Reactive oxygen species damage drives cardiac and mitochondrial dysfunction following acute nano-titanium dioxide inhalation exposure, Nanotoxicology 12 (2018) 32-48.

[5] Grissa I, Guezguez S, Ezzi L, The effect of titanium dioxide nanoparticles on neuroinflammation response in rat brain, Environmental Science and Pollution Research 23 (2016) 20205-20213.

[6] PAÜCker F, Wendel V, Hohenberg H. The human stratum corneum layer: an effective barrier against dermal uptake of different forms of topically applied micronised titanium dioxide, Skin Pharmacology and Applied Skin Physiology, 14 (2001) 92-97.

[7] Nichols C, Shepherd D, Hathaway Q, Reactive oxygen species damage drives cardiac and mitochondrial dysfunction following acute nano-titanium dioxide inhalation exposure, Nanotoxicology 12 (2018) 32-48.