Typical Inorganic Nanoparticles Used in Cosmetics

Jiayin Li *

School of Chemical Engineering, Changchun University of Technology, Changchun 130012, China

* Corresponding Author Email: 20211417@stu.ccut.edu.cn

Abstract. With the development of nanotechnology, there are more and more nanoparticles (NPs) of various kinds. Due to the new physical and chemical properties of nanoparticles, they are used in various industries, among which the cosmetics industry benefits a lot from NPs. Cosmetics mainly act on the skin, such as lotions, sunscreens, hydrating cosmetics, etc. Inorganic nanomaterials are used in a variety of cosmetics to improve the efficacy of cosmetics due to their unique physical and chemical properties. Most nanoparticles exhibit superior physical reflection or scattering effects, which can help enhance sunscreens while still stabilizing efficacy. There are pros and cons to enhancing the absorption capacity of nanoparticles, and it is necessary to control them within a safe and appropriate application range. This article mainly introduces inorganic nanoparticles such as titanium dioxide, zinc oxide, silicon dioxide, alumina, gold, silver, copper, hydroxyapatite, etc. Specifically, this article analyzes their basic information, their special effects and enhancing effects in related cosmetics, as well as the pros and cons of their absorption capacity and safety issues.

Keywords: Cosmetics, inorganic nanoparticles, titanium dioxide, gold.

1. Introduction

Nowadays, the cosmetics industry is developing rapidly, and people have an increasing demand for the effect of cosmetics. The introduction of NPs into cosmetics is an excellent way to achieve efficient improvement of cosmetics. Nanoscale cosmetics show some unique advantages over microscale cosmetics [1]. One of the most exciting aspects of nanoparticles is that their properties may differ very significantly from those of the corresponding bulk materials. Nanoparticles have a high surface area to efficiently carry active ingredients, as well as improve the absorption rate and action rate of active substances.

At the same time, the development of the cosmetics industry involves many disciplines such as materials, chemistry, biology, and medicine. Each inorganic nanoparticle has its own special physical and chemical properties that can provide a variety of options to meet the various needs of cosmetic development.

For inorganic nanoparticles, they have the advantages of low toxicity, and being hydrophilic, biocompatible, and highly stable. Nanoparticles have a high surface area to efficiently carry active ingredients, as well as improve the absorption rate and action rate of active substances. Each inorganic nanoparticle has its own special physical and chemical properties, which can provide a variety of options to meet the various needs of cosmetics development.

As is known to all, cosmetics are indispensable supplies for modern life, and people often use various cosmetics to clean, dress up, and change their appearance. The principle of action of cosmetics is that the effective active substance acts on the designated area by applying it to cleanse, soothe and calm, moisturize or protect the area. The addition of nanoparticles can ensure the stability and duration of the active substance or enhance the absorption and release of the active substance during the action stage.

Table 1. shows various cosmetic products regarding different types of NPs. Some of them are essential materials, while some are materials that can enhance the effects of this cosmetic action.

Inorganic materials used in these preparations are solids; they cannot deform, their solubility is generally very low, and they are unable to dissolve any material into their bulk. Some of them are made of porous aggregates of small elementary particles (nanoparticles) that may collapse upon shearing and possibly leave a few free elementary particles. Materials with a large specific area may adsorb large amounts of compounds at their surface [2].

Table 1. Applications of inorganic nanoparticles

Types of Nanomaterials	Cosmetics
Titanium dioxide	Suncreams, Toothpaste, Make-up products, etc.
Zinc oxide	Suncreams, etc.
Silica	Suncreams, Lipsticks, Liquid foundation, etc.
Aluminum oxide	Coating agents, Concealers, Face powders, Foundations, etc.
Gold	Anti-aging products, Lip care products, etc.
Silver	Deodorants, Suncreams, etc.
Copper	Eyeliner pencil, Colorant (anti-antibacterial capacity), etc.
Hydroxyapatite	Toothpaste, etc.

This article will introduce nano-metal oxides, metal nanoparticles and nano-hydroxyapatite, their specific applications in cosmetic products, and their effects on improving the efficacy of cosmetics. The advantages and disadvantages of each nanoparticle, as well as the current state of production, will also be analyzed. At the same time, the beneficial role of nanoparticles in enhancing absorption will be discussed.

2. Metallic Oxide

2.1. Titanium Dioxide

Titanium dioxide is often used in sunscreens because of its ability to block ultraviolet radiation from sunlight. Because its size is comparable to the wavelength of visible light, when light encounters titanium dioxide particles, they are scattered or refracted by the surface of the particles, reducing the light's ability to penetrate. Titanium dioxide also has a certain absorption capacity in the ultraviolet region and converts it into heat energy. Titanium dioxide provides good UV protection for use in sunscreens because of its high refractive index, its semiconductor properties to absorb ultraviolet light, and its ability to absorb ultraviolet light. However, for titanium dioxide to absorb UV rays, one would prefer it to reflect or scatter UV rays, because titanium dioxide may still cause damage to the skin after absorbing ultraviolet radiation, such as oxidative stress. Titanium dioxide, on the other hand, mainly reflects or scatters light, and has the advantages of high photostability, wide shielding range, chemical stability, and low toxicity. If the sun protection effect of titanium dioxide nanoparticles in sunscreen is to be improved, nano titanium dioxide can be used to change the surface properties of titanium dioxide at the same time to improve the blocking efficiency and dispersion of ultraviolet rays [3]. Due to the large bandgap (3.2 eV) of titanium dioxide, only three percent of the solar radiation can be utilized by it [4]. Therefore, people are also looking for ways to increase the utilization rate, and at the same time, they can increase the radiation blocking rate of nano titanium dioxide.

2.2. Zinc Oxide

Zinc oxide is also one of the commonly used inorganic sunscreens. The benefits of using zinc oxide in sunscreens are its ability to block UVA (320 nm-400 nm) and UVB (290 nm-320 nm) rays and its small size, which is transparent and odorless. Zinc oxide works in a similar way to titanium dioxide in sunscreens, both of which absorb or scatter light that is harmful to the skin. Zinc oxide is an N-type semiconductor, and the electrons in its valence band can accept the energy in the ultraviolet light and make a transition. Zinc oxide at the nanoscale has a significant advantage in scattering ultraviolet light, and when its size is smaller than the UV wavelength, the UV will be diverged in all directions, reducing the UV intensity. The benefits of zinc oxide in sizes as small as nanometers are increased cosmetic results and a stronger ability to disperse light. Regarding the safety of nano-zinc oxide, it is precisely because of the size of the nanometer, the smaller the particle size, the larger the specific surface area of the particle, which has the potential to cause nanotoxicological behavior [5].

2.3. Silica

Nano silica is made up of silicon and oxygen atoms bonded together by covalent bonds to form a three-dimensional network structure. This structure also gives it a higher specific surface area and porosity. This makes it an anti-caking agent and thickener in the cosmetics sector. At the same time, due to the hydrophilicity, good biocompatibility and low-cost synthesis of nano silica, it has become an important part of the cosmetic formulation [1]. The use of nano silica in lipsticks can enhance the texture and spreadability of lipsticks, which can cover lip lines well and make lips appear more youthful and hydrated. Silica nanoparticles can also reflect ultraviolet rays in sunscreens and have good stability, and will not decompose and discolor after being exposed to ultraviolet rays. Nano silica also plays an important role in hair coloring products, where it can be used as a dye to enter bleached hair fibers.

2.4. Aluminum Oxide

Nano alumina can exhibit a variety of physical properties, such as increasing the homogeneity, fullness and light scattering effect of cosmetics; On the other hand, nano alumina also has antibacterial, anti-inflammatory, and oil-absorbing effects, which can improve the moisturizing, sunscreen, and cleaning properties of cosmetics. Nano alumina diffuses light in concealer and remains transparent, so it can cover up facial imperfections well. In addition to the use of alumina nanoparticles in skin cosmetic care, they can also be used for tooth polishing and remineralization [1]. There are two methods for the preparation of nanoscale alumina. One is the mechanical method plus a series of chemical processes to remove impurities, and the other is the pyrolysis method using aluminum carbonate as the raw material.

3. Metal

3.1. Gold Nanoparticles

Gold nanoparticles come in a variety of shapes, including nano-cubes, nanospheres, nanorods, nano-shells, etc., and are used in products with different requirements. In addition to its high specific surface area properties, gold nanoparticles can better penetrate the deeper layers of the epidermal layer, allowing the accumulation and action of active ingredients in the skin. Gold nanoparticles can be used in wound healing, antibacteria, skin regeneration and other medical aspects. Chief among them is its antibacterial and antifungal properties, which are the most important and beneficial properties used in cosmeceutical products. As products that are in direct contact with the human body, most cosmetics have antibacterial ability, which is a particularly important part of cosmetics research and design. Gold nanoparticles also have an anti-aging effect, enhancing the firmness of the skin. At the same time, due to these properties, it is found in a variety of cosmetics, such as toothpaste, lipstick, oral cleanser, etc. Ginseng leaf extract studied by Jiménez-Pérez et al. shows that the P. ginseng leaves mediated gold nanoparticles (Pg AuNPs) have a cosmetic effect, can effectively scavenge free radicals little by little, are non-toxic to cells, and inhibit intracellular enzymes and melanin content, while improving moisturizing and whitening antioxidant properties [6]. Gold nanoparticles are also environmentally friendly materials. However, the cost of gold nanoparticles is extremely high, i.e., first, the price of gold itself is very high, and second, the means of preparation and production are not simple and cheap.

3.2. Silver Nanoparticles

Silver nanoparticles are similar to gold nanoparticles with antibacterial and antifungal properties, and silver nanoparticles can inhibit the growth of a variety of microorganisms, so they can exist as a preservative in cosmetics. Moreover, the strong stability of silver nanoparticles increases the shelf life of cosmetics. In addition, silver nanoparticles do not penetrate the skin and enter the human body and are non-toxic. At the same time, considering whether the particle size is related to the antibacterial

effect, the smaller the particle size, the higher the specific surface area, the better the antibacterial effect of silver nanoparticles [7]. And according to the size, shape and type of silver nanoparticles, they will exhibit different physical and chemical properties.

3.3. Copper Nanoparticles

Copper is one of the earliest metals used by human beings, and as early as ancient times, ancient people used copper in cosmetics. In cosmetics, copper can play a role in anti-aging, coloring, hair repair, etc. In addition to this, it also has antimicrobial, antioxidant and anti-cancer properties that are used in medicine [7]. For nanoscale copper materials, it also has a high specific surface area, which can make copper nanoparticles more closely contact and act with microorganisms, thereby improving antibacterial ability. Copper nanoparticles also have a property that is different from gold and silver is their coloring ability, so they are often used in colored cosmetics such as eyeshadow and lip gloss. However, the smaller the scale of copper nanoparticles, the stronger their ability to penetrate the skin, and even if copper is an essential mineral element in the human body, nanoscale copper entering the human body will still cause damage to human organs. Therefore, in the cosmetic industry, the utilization rate of copper nanoparticles is much lower than that of gold and silver nanoparticles [8].

4. Nano-Hydroxyapatite

Hydroxyapatite is mainly found in the bones and teeth of animals. Thus, through another perspective, hydroxyapatite is often used in osteoporosis therapy, children's bone development and cosmetic medical treatment. For nanohydroxyapatite, it is commonly used in oral dental care and cosmetics. According to research, nano-hydroxyapatite has been used to treat dentin hypersensitivity conditions and promote the remineralization of tooth enamel. And nano hydroxyapatite is harmless to human cells in oral care products [9]. Other cosmetic effects nano hydroxyapatite can play remains to be studied.

5. Conclusion

The research of cosmetic ingredients has developed rapidly, and there are many types of cosmetics involving nanoscale formulations. In particular, the absorption capacity of nanoparticles has a significant effect on the enhancement of the efficacy of some cosmetics. Just like nano-sized silica enhances the ability of sunscreens to absorb UV rays while keeping the ingredients stable, as well as the ability of nano-titanium dioxide and zinc oxide to reflect (scatter) UV rays. The hydrophilicity and biocompatibility of nanoscale silica make it ubiquitous in many cosmetic products, and the physical properties of nano-alumina are also outstanding in cosmetic applications, such as diffusing light when added to concealers to enhance concealment. It can improve the moisturizing ability of hydrating cream, and increase the cleaning ability of facial cleanser, its most characteristic physical properties are used in concealer, and it can also be used for dental care. Gold and silver nanoparticles are the main antibacterial and anti-inflammatory properties, which make them widely used in cosmeceutical products, and copper nanoparticles are often used in colored cosmetics due to their excellent tinting strength. Nanoparticles will be developed based on the functional needs of cosmetics and the safety of humans and the environment. Therefore, the absorption capacity of nanoparticles is not necessarily as strong as possible. For cosmetics such as hydration, anti-aging and anti-aging products, it is necessary to enhance the absorption within a certain range, and nanoparticles that will be harmful to human cells or the environment are not allowed to further strengthen their absorption, adsorption and other physical and chemical properties.

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