

Review

Nanotechnology-Based Face Masks: Transforming the Cosmetics Landscape

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Abstract: The cosmetic market is constantly evolving and ever-changing, particularly with the introduction and incorporation of nanotechnology-based processes into cosmetics for the production of unique formulations with both aesthetic and therapeutic benefits. There is no doubt that nanotechnology is an emerging technology for cosmetic formulations. Among the numerous cosmetic items, incorporating nanomaterials has provided a greater scope and is commonly utilized in facial masks, hair products, antiaging creams, sunscreen creams, and lipsticks. In cosmetics, nanosized materials, including lipid crystals, liposomes, lipid NPs, inorganic nanocarriers, polymer nanocarriers, solid lipid nanocarriers (SLNs), nanostructured lipid carriers (NLCs), nanofibers, nanocrystals, and nanoemulsions, have become common ingredients. The implementation of nanotechnology in the formulation of face masks will improve its efficacy. Nanotechnology enhances the penetration of active ingredients used in the preparation of face masks, such as peel-off masks and sheet masks, which results in better effects. The emphasis of this review is mainly on the formulation of cosmetic face masks, in which the impact of nanotechnology has been demonstrated to improve the product performance on the skin.

Keywords: peel-off face mask; nanocarrier; cosmetics; nanocosmetics; skin care



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1. Introduction

The use of cosmetics predates written history. Nevertheless, they have such inextricable links to activities embedded in the double helix of humanity that we can safely assume that there exists a paleo cosmetology embedded in all our ancestral prototypes. Their use attracts lovers, intimidates enemies, masks aging effects, and compensates for exterior defects, both real and imagined [1]. Nanotechnology is a science that describes the investigation of materials on the atomic or molecular scale. Nanotechnology has the potential to produce breakthroughs and developments in delivery methods and formulations. NPs improve drug efficacy and topical delivery by improving drug solubility, and these NPs act as penetration enhancers [2]. Cosmetic compositions that utilize nanotechnology represent a relatively new yet highly promising area of exploration. The application of nanotechnology in cosmetics has been shown to address several limitations associated with traditional formulations. These limitations include poor bioavailability, inadequate skin penetration, short half-life, compromised quality, sensitivity of fragile skin, acne flare-ups, increased susceptibility to irritation, and the potential for allergic reactions. Furthermore, traditional remedies can exacerbate conditions such as photosensitivity, which may worsen

existing infections [3], while also adding extra positive features [4]. Regarding treating skin, hair, nails, lips, wrinkles, hyperpigmentation, and dandruff, there is little difference in the use of these methods. Nanocosmetics are preparations in which NPs are applied to the skin for beautifying, cleansing, and regenerative purposes. Nanocosmeceuticals are hybrids of cosmetics and drugs or active pharmaceutical agents used to enhance therapeutic effectiveness [5]. Nanocomposites using NPs as active ingredients have been found to improve product performance and consumer satisfaction when applied to a surface [6].

Nanomaterials have been found to improve product performance and customer satisfaction [7]. NPs such as zinc oxide, titanium oxide, silicon dioxide, alumina, calcium fluoride, silver, copper, solid-lipid NPs, nanogels, and nanopolymers have a vast range of applications in cosmetics [8]. By using nanotechnology, formulated face masks for cosmetics (skin acne, removing dead skin, beautifying purposes, etc.) and therapeutic purposes can be developed. Among the cosmetic treatments for skin restoration, facial masks are the most popular [9]. A facial mask is a paste-like material containing active ingredients such as vitamins, minerals, and fruit extracts. A sheet mask is a piece of fabric or cellulose-containing sheet in which NPs are incorporated to enhance the efficacy of the face mask. Four main types are available, namely (1) peel-off masks; (2) sheet masks; (3) hydrogels; and (4) rinse-off masks [9]. In this review article, we particularly focus on nanotechnology-based face masks used in cosmetics [10].

We have used different search engines, such as Scopus, PubMed, and Cochrane, to find relevant research and review articles for this review.

2. Role of Nanotechnology in Cosmetics

We live in a society where cosmetic products are evolving rapidly. As the globe has changed, so has nanotechnology, and cosmetics have grown more helpful to the environment. Nanotechnology involves engineering materials with dimensions between approximately 1 and 100 nm [7]. The surface size effect and quantum confinement effects provide advantages in that nanomaterials have excellent physiochemical properties and are widely used in the cosmetic industry because of their enhanced efficacy, filtration properties, high surface-volume ratio, and protective features [11]. Different nanomaterials, such as liposomes, solid lipid NPs, cubosomes, and dendrimers, have advanced properties for skin care [12]. The most significant component in this regard is nanoemulsion. They are commonly used in face masks. The design, development, production, characterization, and application of material devices and systems by controlling their shape and size at the nanometer scale are the two sides of nanotechnology [13,14]. The manipulation of materials at the atomic and molecular levels is known as nanotechnology. It has been a hot topic in many industries, especially in cosmetics and rejuvenation [15]. Nanotechnology has been used to create products that can repair damage at the cellular level, such as by repairing skin cells or even DNA. Technology also provides a new way for manufacturing to deliver ingredients to the skin [16]. The advantages and disadvantages are discussed in Figure 1.

As per E.U. Regulation no. 1223/2009 of the European Parliament and of the Council of 30 November 2009 on cosmetic products, the use of nanotechnology-based nanomaterials in cosmetic products may increase with further development in technology. To provide consumer safety, free circulation of goods, and legal clarity for businesses, a globally consistent definition of NPs is needed. In addition to its use in the cosmetic industry, FDA guidance can be useful for medical products, such as enhancing the bioavailability of drugs, and in foods, it can be useful for improving food packaging.

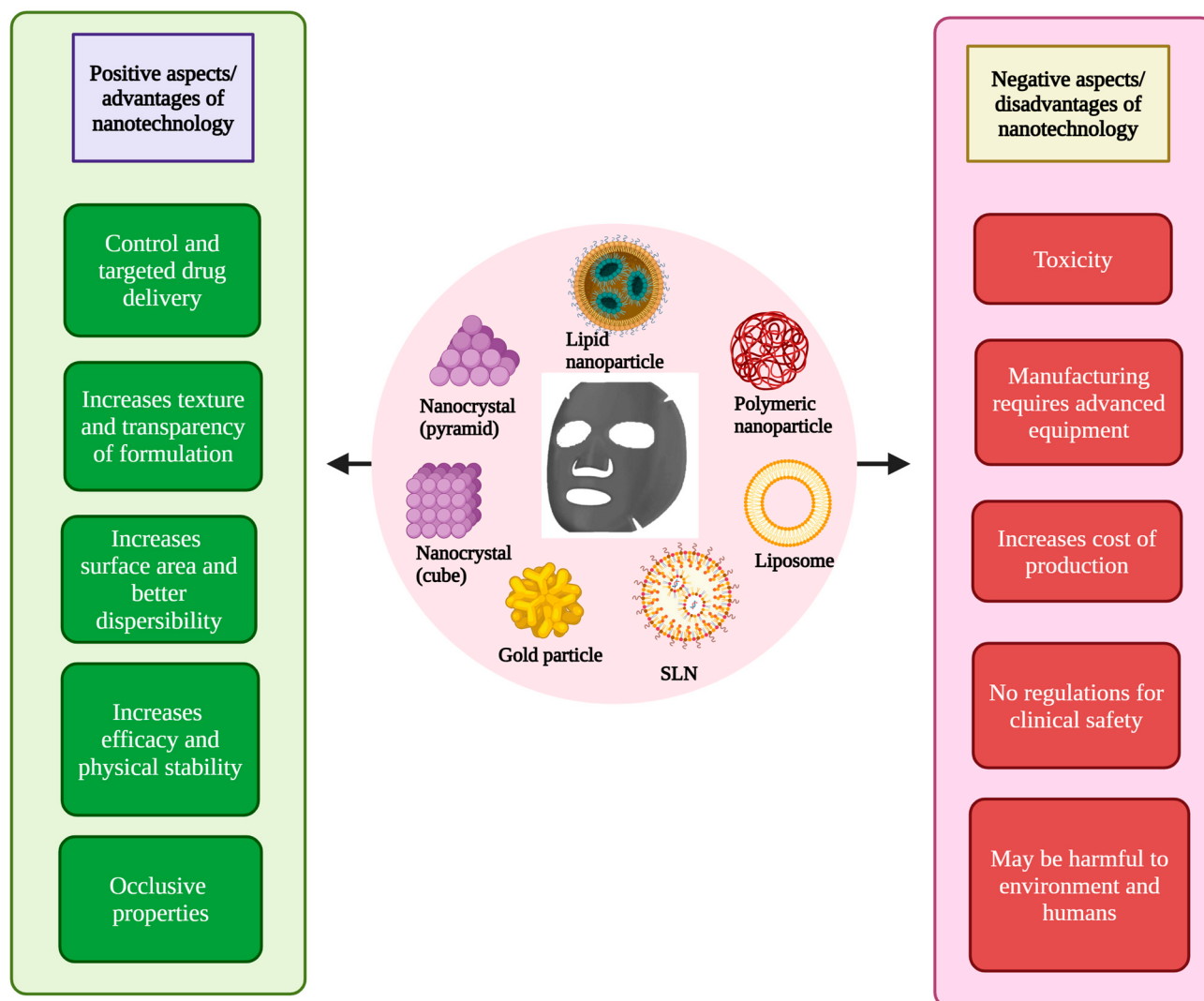


Figure 1. Positive aspects/advantages and negative aspects/disadvantages of nanotechnology in cosmetics. Various nanocarriers are shown in the figure. Positive aspects are highlighted in green, and negative aspects are highlighted in red.

Nail, hair, skin, and lip care conditions, such as dandruff, hair damage, wrinkles, hyperpigmentation, and photoaging, can now be treated with nanocosmeceuticals. These elements increase the efficacy of skin care formulas and the efficiency of sunscreen by enhancing UV protection [17]. Because they include extremely small particles, they increase the surface area, facilitating active chemical transmission into the skin. Occlusion improves permeability while also hydrating the skin, improving UV protection, the release of fragrance, finish quality, and prolonged duration of action to improve biocompatibility [18]. Nanocosmeceuticals have high entrapment efficacy and good sensorial properties, which increase their stability [19]. Liposomes have many positive effects, such as increasing the stability and efficiency of the product, reducing toxicity, and increasing the ease of penetration in the dermal layer [19]. Micelles are among the most recent areas used in cosmetics. Small micellar NPs with a larger surface area improve the efficacy of nanocomposites in cosmetics [20]. These agents do not penetrate directly into the skin and can be administered via NPs. For example, face masks contain vitamin C, an antioxidant that helps fight age-associated skin damage and is used to formulate antiaging face masks [20].

For a variety of effects, nanomaterials are employed in cosmetic goods. Their use, however, also creates significant security issues. Determining the types of nanomaterials

utilized, their stability, their propensity for skin absorption, their exposure route, and their formulation in cosmetic products can help alleviate some of these concerns [21]. Internationally, much work has been put into harmonizing methods to overcome the definitional challenges and safety concerns related to the use of NPs in cosmetic goods [22]. Nanotechnology has been used in the creation of cosmetics since ancient Egypt [20]. Nanotechnology has recently had a significant effect on the makeup industry. To control the biocompatibility of active components, the cosmetics industry has developed nanotechnology-based compounds in which the self-assembling properties of phospholipids are exploited [20]. The particles used in this field are usually less than 100 nm in size; it has a beneficial role in the skin, reducing the number of pores and making them less visible [19]. Fronza and collaborators defined nano-cosmos as a cosmetic formulation that carries active ingredients and other ingredients [19]. The application of nanotechnology in cosmetics is an emerging field with significant potential. Electrospinning is a technique used to produce nanofibers, yielding a variety of fiber sizes ranging from micrometers to nanometers. Gold nanoparticles (NPs) have been shown to reduce the appearance of wrinkles and enhance skin brightness. Facial masks often incorporate proteins, herbal ingredients, minerals, and other beneficial components [23]. Although they have several benefits, they possess limitations such as stability, selectivity, and cost, which affect clinical safety regulations. Small particles increase the surface area and improve bioavailability; however, smaller particles produce dose-dependent toxicity [24].

3. Role of Macromolecules in Cosmetics

New bio-based polymers and natural bioactive components are used in cosmetics, personal care, and biomedical products, which is a newly growing market. One of the most difficult issues is the use of surfactants in cosmetic products, which irritate the skin. Surfactants can attach with proteins to remove lipids from the surface of the skin and disorganize the liquid crystal structure of lipids that interact with living cells [25,26].

In recent years, a significant number of physiologically active compounds have been extracted, separated, and purified from various marine sources. There is a growing demand for bioactive compounds with unique activities across numerous industries. Thermoresponsive macromolecules have gained considerable importance in both academic and applied polymer science, as their properties can alter solution characteristics at specific temperatures [27].

Two major polymers, EP-AV1 and EP-AV2, were purified from the hot water extract of the *Porodaedalea pini murrill* fruiting body by 75% ethanol precipitation and are the polysaccharides mostly used in cosmetic formulations [28]. Moreover, methyl, ethyl, propyl, and butyl parabens react with a variety of nonionic macromolecules often found in cosmetics and pharmaceutical formulations [29].

A maximum molecular weight of 500 daltons, high lipophilicity, and specific polarity is required to penetrate the stratum corneum of the skin, increasing its therapeutic effectiveness [30]. Bacterial cellulose is a versatile biopolymer with superior material features, including high porosity and high water uptake. The application of bacterial cellulose in cosmetics, facial masks, scrubs, and personal cleansing formulations is important [31].

Many cosmetic elements contribute to the development of complex formations that improve the quality of beauty enhancement properties. Macromolecules containing allergens or precursors may play a crucial role in the prevention of disease. Macromolecules play a specific role in body washes. Polyvinylpyrrolidone (PVP) and hydrolyzed wheat protein (HWP) are macromolecules found in body washes that improve foaming properties. Its strongest property is that it can reduce skin irritation [32,33].

Fatty acid-containing oils have been utilized as components of cosmetic formulations, and unsaturated fatty acids found in phospholipids, fat, wax, and triglyceride oil, which are used as excipients in cosmetics, have been shown to have the best cosmetic function [34]. To decrease the formation of eczema or atopic dermatitis, high levels of linoleic acid and alpha-linolenic acid in oil are essential for skin care. This will restrict water loss. Oily wax has healing properties for skin irritation and is utilized for a variety of skin tolerances, protection, and cleansing products [35].

Polypeptides are included in skin care products because they are too large to absorb through the skin; they also improve skin barriers, reduce wrinkles, increase skin elasticity, and ease inflammation. However, some issues are associated with the use of macromolecules, such as decreased efficiency, excessive energy loss, low yield, low cost-effectiveness, and minimal selectivity [36,37].

Face masks are beauty products made up of facial mask products, and the beauty solutions closest to human skin have skin-friendly cosmetic and antibacterial functions [38,39]. According to one study, the amount of protein present in a face mask was determined. Protein is a macromolecule that is present in the face mask. The study was performed by using six samples of face masks. Protein was extracted from the samples via Tris-HCl buffer, and the protein content of each sample was determined. The results for the different samples varied. Here, the protein content was measured in g/L. Among the proteins, fibroblast growth factor (FGF), epidermal growth factor (EGF), and collagen are widely used [36].

4. Novel Nanocarriers

Many nanosystems or novel nanocarriers are commonly used in cosmetics, specifically in face mask formulations, to increase the stability and effectiveness of active ingredients [40]. The common characteristics of NPs, such as their permeability into the skin; stability and ability to carry lipophilic compounds; tolerability by the skin; uniformity of active pharmaceutical ingredients (APIs); and specificity to target novel NPs, such as lipid NPs, nanocrystals, solid-lipid NPs (SLNs), gold and silver particles, liposomes and polymeric nanocomponents, are used as novel nanocarriers in face masks [41]. SLNs and nanostructured lipid carriers (NLCs) are used as carriers and improve the penetration of active ingredients into the skin [42]. Other widely used nanocarriers with unique features are shown in Figure 2.

4.1. Currently Used Nanocarriers in Face Masks

4.1.1. Liposomes and Other Lipid-Based Nanocarriers

Liposomes are composed of a phospholipid bilayer surrounding an aqueous core that ranges in size from the microscale to the nanoscale. The core of liposomes encapsulates water-soluble compounds, whereas the hydrophobic domain entraps insoluble compounds [43]. It is a promising system for drug delivery [44]. Adult female acne (AFA) is thought to be caused by hyperandrogenism and decreased skin autophagy [45]. Gabriella Fabbrocini et al. tested a ready-to-use peel-off face mask comprising trehalose-loaded liposomes (as cutaneous autophagy activators) and myoinositol (an androgen inhibitor). It was used every other day for 60 days overnight to test whether it may improve AFA [46]. An open-label clinical study involving 40 AFA patients was designed to determine how facial masks affect lesion count, sebum production (as evaluated by the Sebutape method), and the Global Acne Grading System (GAGS) scale [47]. They also looked at changes in androgen and beclin-1 levels (an autophagy marker) in skin biopsy supernatants from the beginning through the conclusion of therapy. After the studies, they concluded that a ready-to-use peel-off face mask comprising trehalose-loaded liposomes and myoinositol

enhanced AFA aesthetic appearance by lowering cutaneous androgen levels and inducing skin autophagy [46]. Liposomes can deliver medications specifically to the skin structure because they have increased lipid solubility and function via fusion. It enhances hydration and water retention, allowing the medication to enter the skin structure more easily [48]. Because of its enhanced wettability and stronger attraction for a hair follicle, it alters how the medicine acts by entering the follicle. According to one study, medicines containing liposomes have a greater affinity of 6.95–2.30% than the extremely low affinity of 3.15–1.23% for the uncoated drug [49]. Compared with a nonencapsulated suspension, liposomes treated with Coenzyme Q10 increased liposomal accumulation (at least twofold) in vivo in rats, which reduced photoaging. The use of liposomes with terbinafine HCl prolonged drug retention in an in vivo study in rats [50]. Atopic dermatitis is a common disorder that can be cured by the use of liposomes with vitamin B12, which have protective effects on atopic dermatitis symptoms and can be used as a face mask to increase treatment efficacy [19]. In general, liposomes interact with their active ingredients and influence the release of the active material as cargo. The lipid component of liposomes is beneficial for improving the biocompatibility related to the lipid content present in formulations [51].

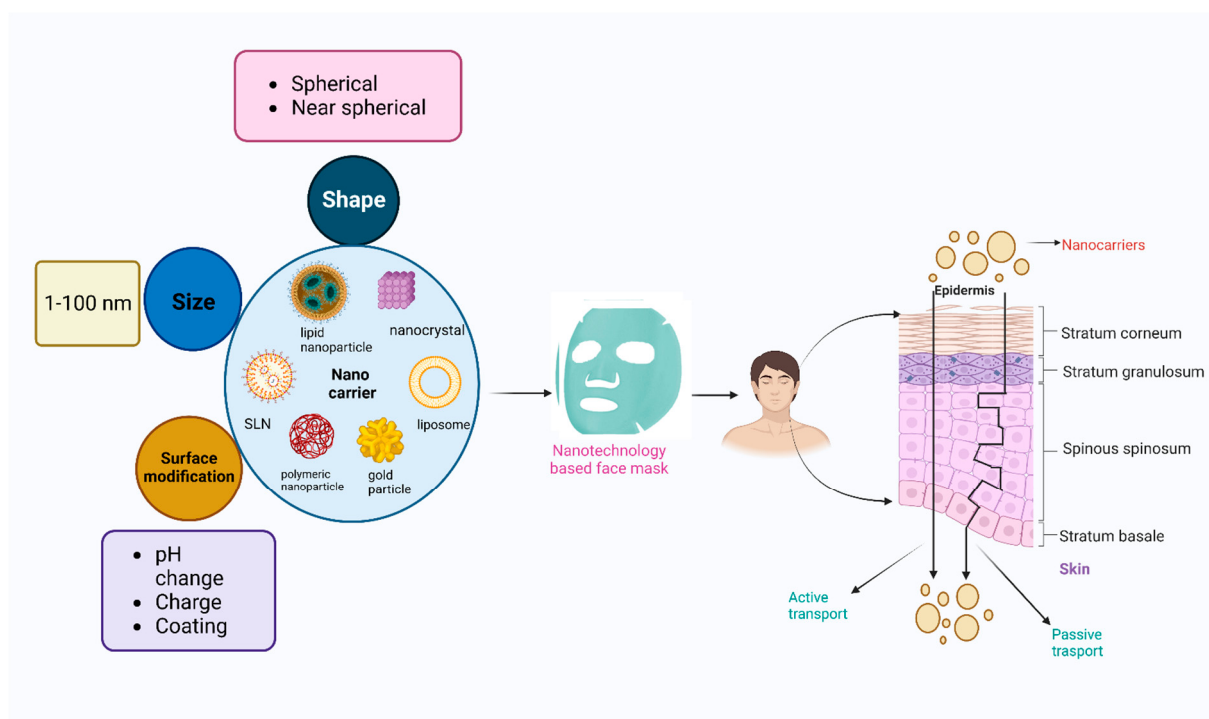


Figure 2. Nanocarriers for a face mask. Various nanocarriers are used in face masks, and their properties include size, shape, and surface tension. The active and passive transport of APIs by nanocarriers and the enhanced penetration of active ingredients by nanocarriers.

An icariin- β -CD inclusion complex was successfully produced, characterized, and tested in the laboratory for potential use as a biomedical material in the form of face masks and many cosmetic products. Many in vitro studies have shown that this complex provides antioxidant, antibacterial, drug release, and mechanical and physical strength to the formulation [52].

Lipid NPs, which are made up of liposomes and NPs of smaller sizes, interfere with the lipid bilayer of the skin and increase moisture. As a result, lipids are redistributed, increasing the drug's efficacy. Lipid nanocarriers exist in a variety of forms, including solid lipid NPs, nanostructured lipid carriers, nanocapsules, and liposomes. While NLCs have greater tensile properties as a particular action, SLNs have a regulated release of

the active components [19]. According to a study performed by Munster and colleagues, medicine coated with SLN seems to be more effective against acne than the uncoated version [53]. Owing to their complete biodegradability and biocompatible nature, lipid NPs can be considered 'nano-safe carriers' for the development of face masks [54]. Durah et al. formulated the antioxidant vitamin C-containing nanoparticle topical drug delivery system to reduce hyperpigmentation in the skin. The 3.5 and 7% concentrations of vitamin C in ethyl cellulose NPs were effective in treating hyperpigmentation [55].

Lipid-based lyotropic liquid crystals are thermodynamically stable nanostructures that have been used for potential drug delivery systems with the controlled release of drugs [56]. The medicine is effectively transported over the epidermal barrier by the crystals [57]. Because it holds onto moisture, which aids in the continuous release of the medicine in the skin, it has superior stability [58]. Corticosteroids (most widely used for skin treatment, such as antiaging and anti-wrinkle agents), clindamycin, mupirocin, and rifamycin are drugs used to treat skin infections that are transmitted into the skin with the help of liquid crystals [59]. Cyclopentasiloxane works as an emollient and lubricant and helps to soften the skin; however, it is not directly absorbed by the skin, so liquid crystals are used to increase the absorbance of this compound. So, we can incorporate it in face mask formulations to obtain the desired effect on the skin [60]. The interaction of a liquid crystal with its lipid components enhances lipid flow within the stratum corneum, allowing the liquid crystal to penetrate the cuticle [61]. In a trial, even a small number of liquid crystal formulations using water, oil, and surfactants were topically applied to mammalian skin, and epidermal thickening was observed; however, the application of skin medication had a perfect effect on lowering skin pigmentation and erasing age spots [62].

Nanostructured lipid carriers (NLCs) are employed as novel nanocarriers in cosmetic face masks. The initial lipid NPs were introduced as SLNs, and the second generation was enhanced as nanostructured lipid carriers (NLCs). NLCs and liposomes were first introduced on the market as cosmetic products [63]. NLC is an alternative to liposomes and emulsions as carrier systems. NLCs have several advantages for dermal cosmetic and pharmaceutical applications, such as drug targeting, regulated active release, occlusion, and the conditions that accompany them ease penetration and skin hydration [63]. Alzahabi et al. developed an NLC composed of prickly pear seed oil for the topical delivery of retinyl palmitate to evaluate the permeation of vitamin A in ex vivo studies using rat skin [64].

4.1.2. Gold and Silver NPs

Gold NPs (Au NPs) are inert and biocompatible inorganic NPs with sizes ranging from 1 to 120 nm and high monodispersity [65]. Strong antifungal and antibacterial capabilities are maintained by gold particles in addition to their excellent transport and conjugate-like behavior. According to a study on gold NPs, conjugating orange peel extract and tea tree extract with gold enhances their ability to diffuse while being resistant to absorption. They also looked at changes in androgen and beclin-1 levels (a sign of autophagy) in skin biopsy supernatants from the beginning through the conclusion of therapy [66]. Furthermore, these particles do not reach the blood circulation or the hypodermis. The facial masks were evaluated via various methods, such as electrospinning, Fourier transform infrared spectroscopy (FTIR spectroscopy), X-ray diffraction, and thermal analysis. They concluded that paper-like thin hydrogel face masks can provide various properties, such as antiaging, anti-wrinkle, and skin whitening [67]. Similarly to the previous study by Anahita Fathi-Azarbayjani, the team also researched novel vitamins and gold-loaded nanofiber face masks. Currently, premoistened face masks are available on the market, but they have developed a face mask that is wetted when applied to the skin, which increases the stability of the face mask. They concluded that a greater surface area–volume ratio of gold-loaded nanofibers

ensures maximum contact with the skin and helps to improve skin permeability to restore natural skin [68]. Due to its ability to enhance charge density and reduce fiber diameter, gold may play a significant role in this process. In comparison to the placebo (without gold nanoparticles), the presence of gold nanoparticles results in a slight separation of the skin layer, thereby increasing the efficiency of the active ingredient [68].

4.2. Future Prospects for the Use of Nanocarriers in Face Masks

4.2.1. Polymer Nanocarriers

Polymer nanocarriers are a type of nanocarrier made from biocompatible polymers, such as polymeric NPs, nanohydrogels, nanocapsules, polymeric micelles, and nanospheres [69]. The hydrophobic nucleus of a polymer micelle can be employed as a reservoir for insoluble medicines, increasing the concentration gradient of insoluble components in the stratum corneum and promoting their diffusion [70,71]. Additionally, a molecular structure such as a micelle enhances permeability while lowering surface tension [72]. Chitosan nanocarriers are natural polymeric nanocarriers to load drugs more effectively. Kim et al. developed retinol-loaded chitosan nanocarriers (size 50–200 nm) for the effective delivery of retinol in skin care formulation to reduce wrinkles and acne-prone skin [73].

4.2.2. Inorganic Nanocarriers

Inorganic compounds are consistently the preferred molecules for the pharmaceutical industry because of their high safety score, and aqueous and nontoxic nature. Zinc oxide and titanium dioxide are the two most often employed nanocarriers among the numerous metal complexes. TiO_2 and ZnO are frequently used in lotions to shield the skin from damaging UV radiation in addition to acting as nanocarriers [74]. The safety and effectiveness of the cosmetic sector are significantly influenced by the carriers, making the cosmetic formulation more effective in making skin more radiant, and protecting from harmful sun rays.

4.2.3. Solid Lipid Nanocarrier (SLN)

SLNs were the first lipid-based NPs discovered [75]. They range from 50 to 1000 nanometers in diameter and were invented in the 1990s. They are composed of solid lipids. Surfactants stabilize them at body temperature so that they remain solid at that temperature. Waxes, glycerides, triglycerides, steroids, and fatty acids are examples of lipid groups [76]. Owing to their enhanced penetration, they serve as effective transporters, protecting internal compounds from biodegradation by enzymes and transporting aesthetic components into the skin layer [77]. SLNs are commonly employed in cosmetic applications because they are nanoscopic, physiologically and chemically stable, and biodegradable. SLNs are classified into three categories based on their chemical structure and manufacturing technique. The three categories are drug-loaded shell, drug-loaded core, and homogeneous matrix. The occlusive characteristics of SLNs can aid in skin hydration. Because their fragrance is slowly supplied, they make ideal perfume and bug-repellent containers [78]. SLN used with vitamin A promotes occlusive effects and can be used in a face mask as an anti-wrinkle agent in the future [79].

4.2.4. Nanofibers

Nanofibers can be used in cancer diagnosis, drug delivery, tissue engineering, optical sensors, redox-flow barriers, and composite materials. They are generated from different polymers. A study on face masks containing collagen, retinoic acid, and ascorbic acid was carried out by Anahita Fathi-Azarbayjani et al. These authors developed and characterized the face masks via X-ray elemental analysis and field emission scanning electron microscopy (SEM) via human epidermis skin permeability of the nanofibers. They concluded that the stability of each ingredient was induced with the nanofiber medium. The permeability

of the nanofibers loaded with ascorbic acid and retinoic acid was enhanced, but there was no significant change in the skin permeability caused by gold because of the low concentration of gold [67,68]. Nanofibers are used for the transdermal delivery of nanogold in face masks. To generate gold NPs, a novel natural/nontoxic methodology utilizing orange peel and tea extracts is needed [67]. The Moia Elixirs CBDerma-Repair Nanofiber Mask is a biodegradable mask patented with nanofiber technology. To provide long-term hydration, smooth the skin, prevent wrinkles, improve elasticity, and protect the skin from sun damage, this treatment includes cannabis, vitamins C and E, hyaluronic acid, and PHA gluconolactone in nanofibers. A nanofiber face mask infused with cannabidiol is activated when it comes into contact with water and reportedly absorbs 97% of what is applied to the skin [80,81].

4.2.5. Nanocrystals

Nanocrystals are pure pharmaceutical particles that are stabilized by a surfactant or polymer, with the stabilizer serving as a key medium in nanocrystal-based formulations. Clusters of nanocrystals range in size from 10 to 400 nanometers [82]. Rutin nanocrystals were found to be 500 times more bioactive than a water-soluble rutin glycoside derivative [83]. It is a medication that is free of any protective coating [84]. Compounds such as flavonoids, beta-carotene, lutein, and many others can be effectively produced as nanocrystals, which are more potent than the individual forms [85,86]. Three flavonoids—rutin, hesperidin, and apigenin—have been studied by ARTcrystals, which concluded that in most trials, the nanoemulsion produced is more efficacious for therapeutic purposes than the control [87]. By incorporating such powerful ingredients in cosmetic face mask formulation, we can prepare more advanced and effective face masks. For more examples, refer to Table 1.

4.2.6. Nanoemulsions

Nanoemulsions are lipid-based pharmaceutical systems that can improve drug penetration through the skin. A nanoemulsion is an *o/w* emulsion with a mean droplet size of approximately 1 to 100 nanometers that is thermodynamically unstable. The inner oil phase allows lipophilic medicines to be solubilized, resulting in high encapsulation rates that are helpful for drug delivery. Microemulsions are adaptable choices for drug delivery over lipophilic barriers, and numerous synthetic and natural chemicals have been created via these delivery methods to increase bioactivity, transport, and stability. The most current relevant scientific studies reporting the potential of various delivery systems to increase the permeability of the cell membrane of medications with anticarcinogenic, anti-inflammatory, UV protection, and/or wound-healing actions are detailed below [88].

Table 1. Categories of various nanocarriers and their examples.

Category	Examples	Ref.
UV filters	• Inorganic NPs (ZnO NPs and TiO₂ NPs); • Nanocrystals of organic filters; • Nanodiamonds; • Ivy NPs.	[19,89]
Bioactive molecules	• Nanocrystals.	[19,90]
Antiaging and moisturizing nanomaterials	• Liposomes contain unsaturated phospholipids; • Liposomes made of saturated phospholipids; • Gold NPs; • Copper NPs; • SLNs and NLCs; • Fullerenes.	[19,91]

Table 1. Cont.

Category	Examples	Ref.
Antibacterial and antifungal agents	• Gold NPs; • Silver NPs.	[19,92]
Cleansing agents	• Micelles and nanoemulsions.	[19,93]
Other uses	• Silica NPs.	[19,94]

5. Active Ingredients

5.1. Retinol (Vit-A)

The most prevalent circulating form of vitamin A must be converted into active retinoic acid to exert biological effects. These compounds are commonly utilized as ingredients in over-the-counter (OTC) cosmetic skincare products and are not classified as prescription medications. Numerous researchers have conducted studies examining the safety and efficacy of retinol. This section describes several of these studies to enhance understanding. Tucker-Samaras et al. concluded that [95] the effects of retinoic acid and retinol on the skin have been studied, and they have been shown to increase the expression of skin function-related genes and proteins [96]. Retinoic acid has an antiaging effect by increasing epidermal thickness and upregulating the expression of genes encoding collagen type 1 and collagen type 3, with a corresponding increase in procollagen protein expression, and it inhibits the UV induction of matrix metalloproteinases [63]. Retinol is also effective in treating acne, reducing wrinkles, and increasing skin protection against UV radiation. Similarly, it can also be incorporated into a welding matrix of a peel-off mask, sheet masks, and rinse-off masks. This phenomenon needs to be further evaluated as a part of research on the use of nanotechnology in cosmetics [97].

5.2. Ascorbic Acid (Vit-C)

Vitamin C plays an active role as an antioxidant and eliminates reactive oxygen species (ROS). Because of its ability to scavenge free radicals and eliminate oxidative compounds, L-ascorbic acid is widely employed in cosmetic and dermatological products. However, it is chemically unstable and readily oxidized, and sometimes, it causes skin irritation [98]. Topical vitamin C increases the mRNA levels of collagens 1 and 3 and processing enzymes in the human body. It improves wound healing and reduces facial wrinkles. It enhances the density of dermal papillae through the mechanism of angiogenesis [99]. Ascorbic acid and other unstable active ingredients in cosmetic face masks currently sold may undergo oxidation due to the presence of aqueous fluid. The anti-wrinkle nanofiber face mask presented in the study by Anahita Fathi-Azarbayjani et al. contains collagen, retinoic acid, ascorbic acid, and gold nanoparticles (NPs). These masks enhance product stability because they are only wetted upon application to the skin [68]. When the mask is soaked, the substance gradually dissolves and releases the active ingredients, allowing for maximum skin penetration. Furthermore, the nanofiber mask has a high surface-volume ratio to ensure maximum contact with the skin surface, which aids in skin permeation and skin health restoration [68].

5.3. Carotenoids

Carotenoids, among the most well-known natural antioxidants, have been the subject of extensive research for many years. Beta-carotene is the primary carotenoid and a fat-soluble plant pigment found in various foods, bacteria, and chlorophyll-containing plants [100]. The skin benefits of this robust carotenoid include its potent antioxidant properties, which assist in neutralizing environmental free radicals [101]. Due to its po-

tential protective effects against UV light-induced damage, beta-carotene is frequently incorporated into skincare products. Consequently, products infused with beta-carotene may help reduce oxidative stress and enhance the overall appearance of the skin [102]. Clinical research has demonstrated that carotenoids are effective against premature skin aging caused by oxidative stress. It is used as a face mask, particularly for dry skin, because it softens and protects the skin while also containing lycopene [103].

5.4. Vitamin E (Tocopherol)

There are eight types of tocopherols (vitamin E), among which gamma-tocopherol levels are the highest in human skin [104]. Vitamin E acts as an antioxidant, and its nonantioxidant function can protect the integrity of tissues. It is a lipid-soluble nonenzymatic anti-inflammatory agent that protects the skin from adverse effects such as oxidative stress and scavenges free oxygen radicals. In vivo animal studies have shown that vitamin E is photoprotective and antiphotaging [105]. Additionally, it inhibits the production of Pg E2 and nitric oxide and prevents sunburn, UV-induced lipid peroxidation, and edema. Most antiaging cosmetics contain 0.5–1% vitamin E. Vitamin E is the most widely incorporated material in various face masks, such as peel-out masks, sheet masks, and rinse-off masks [106].

5.5. Coenzyme Q10 (Ubiquinone)

Coenzyme Q10 or ubiquinone is effective in the treatment of damaged skin because it acts as an active carrier of electrons in skin respiration [107]. CoQ10 is a nonenzymatic agent that can stimulate the repair process as a natural antioxidant; it removes damaged biomolecules before they accumulate and alters cell metabolism or skin viability [108]. A clinical trial has demonstrated that Coenzyme Q10 (CoQ10) exhibits greater efficacy when combined with other elements, including vitamins A, C, E, D, and B6, as well as amino acids. The application of a face mask containing CoQ10 has been shown to elevate the levels of quinone on the skin's surface and enhance the energy metabolism of skin cells. Similarly to other active ingredients, CoQ10 can provide additional benefits when incorporated into face mask formulations [107].

6. Skin Barriers and the Role of NPs in Resolving Skin Barrier Properties

The skin serves as the outermost layer of the body. Due to its extensive surface area and greater accessibility, the absorption and penetration of drugs occur primarily through the dermis. The epidermis, which has a thickness ranging from 100 to 150 μm , is composed of corneocytes, keratinocytes, and various other cell types [109]. The epidermis contributes to the skin's barrier function through tight junctions, adherens junctions, cytoskeletal elements, and desmosomes. These corneocytes assemble into the so-called "brick and mortar" model, influencing molecular diffusion across the skin. Two primary routes of absorption through this layer are probable. Although geometrically longer, the intracellular pathway through corneocytes or intercellular spaces within the lipid matrix appears preferential, offering channel-like structures and increased diffusivity [110]. NPs have the qualities of better skin permeation, optical transparency, high solubilization, and greater stability. NPs are thermostable and have a stable dispersion system because they are used in transdermal and topical drug delivery systems. This route bypasses the hepatic first-pass effect, reduces adverse reactions, and increases the therapeutic effect [2]. NPs have been explored for many drug delivery systems, but skin penetration provides better results for biological systems. NPs are useful for different treatments. The integrity of human skin is critical for preventing infection. As a barrier to infection, skin integrity can compromise the development of acute and chronic wounds. The skin, a multifunctional organ, has significant biochemical and

physical features that impact its microbiology. These characteristics include a slightly acidic pH and high phosphorus and lipid content in the cell membrane, which consists of two components: a hydrophobic tail and a hydrophilic head. The properties of the skin not only favor the colonization of certain beneficial microorganisms but also enhance biofilm formation by these organisms [111].

Despite the presence of transbarrier channels, the skin is refractive to the majority of molecules, especially hydrophilic compounds. It is crucial to maintain this protective barrier even after piercing the skin surface for transdermal medicine administration when dealing with cutaneous bacteria [112]. Mechanical abraders, local energy dischargers, or other hard, sharp items can pierce a limited number of relatively broad breaches in the skin barrier, allowing transiently modest medication amounts and even enormous molecules to flow through [113]. Microscopic ballistic droplets or particles also introduce modest quantities of medication into the top skin via the $\geq 10^6$ cm² holes they generate.

The penetration of NPs through the skin was evaluated via multiphoton microscopy. Nanoparticle absorbance is affected by the microstructure of the stratum corneum and its tortuous aqueous and lipidic channels. An experimental study on the penetration of four models of gold NPs with diameters of 6 nm and 15 nm, which differ in surface polarity and vehicle nature, through human skin was conducted [114]. Rats were utilized to investigate the dispersion features of AuNPs of various sizes, including 22 ± 3 , 105 ± 11 , and 186 ± 20 nm. The AuNPs were examined both in vitro and in vivo, with skin from the hind paw extracted via a diffusion chamber. Compared with the 105 and 186 nm particles, the extracted skin segments were exposed to 22 nm AuNPs for just 3 h. According to the findings of this experimental study, thick skin increases nanoparticle penetration and serves as a depot for the release of AuNPs into the circulatory system [115]. The observations in this study were performed via multiphoton laser scanning microscopy. Using a two-photon excitation microscope or an inverted confocal microscope, fluorescence images were captured. Some physiochemical factors can affect the penetration of NPs through the skin. The size and surface polarity of AuNPs and the physical state of the dispersion of NPs are considered for the absorbance of any NPs through the SC [114].

Zinc oxide (ZnO) is utilized as a nanoparticle in various therapeutic applications; however, it can exhibit toxicity if absorbed into systemic circulations. Following the topical application of several ZnO nanoparticle products, multiphoton tomography with fluorescence lifetime imaging microscopy (MPT-FLIM) was employed to simultaneously investigate the penetration of ZnO nanoparticles and potential metabolic alterations within the viable epidermis of human volunteers. ZnO nanoparticles are absorbed by the stratum granulosum of the epidermis, particularly in areas adjacent to furrows, but not to a significant extent, allowing for therapeutic effects. To elucidate the mechanism and cytotoxicity of ZnO nanoparticles, in vitro experiments were conducted. The release of extracellular lactate dehydrogenase and decreased cell viability indicate increased oxidative stress, which leads to damage in lung cells [116]. Nanosomes and other types of liposomes help to restore skin barrier protection. Lecithin is commonly used and contains 10% to 20% phosphatidylcholine. This phenomenon is associated with increased cell compatibility and increased nonantigenic properties [117]. Nanosomes can easily penetrate the skin via topical use because of their small size. Nanosomes contain encapsulated and mobilized water- and oil-soluble materials. This not only provides a wide variety of encapsulated ingredients to cells but also works to help cells create their building blocks [118].

The penetration of all the NPs depends on the rate of absorbance and the shape of the NPs. However, if penetration occurs via the follicular route, this does not occur since they all aggregate in the follicular pores at the same time before being absorbed through the dermis [19]. The experiment was carried out on mice, which have a greater density of

follicles than humans. Depending on the cause of the intracellular pathway in humans, the human population is ethnic, and the body part is considered where the topical NPs are applied. NPs might, thus, travel through the SC, epidermal, and collagen/muscle-filled dermal layers [109].

7. Application of Nanoparticle-Based Face Masks

The fields of nanoscience and nanotechnology are rapidly expanding. The development and application of nanoparticle and nanoparticle-based formulations in cosmetics and cosmeceuticals are increasing daily. Nanosized materials, such as cubosomes, nanocrystals, inorganic nanoparticles, nanopolymers, liposomes, nanodots, dendrimers, and nanoemulsions, are widely utilized as ingredients in the cosmetic industry. Due to their small particle size and unique characteristics, nanoparticles are employed in the manufacturing of cosmetic products to enhance their efficacy and bioavailability [19].

Face masks contain active ingredients and moisturizing agents that help to hydrate, moisturize, dry, or exfoliate the skin, allowing ingredients to penetrate the skin for a short time. Adding NPs as ingredients to the face mask alters its properties and improves its efficiency to provide better effects. NPs are applicable for formulating a face mask because of their increased chemical reactivity, improved solubility, increased surface area, and dispersibility. Face masks, such as clay masks, gel masks, peel-off masks, cream masks, and sheet masks containing NPs, are currently used. Nanomaterials are defined as having a size range of 1–100 nm, a high surface area, ideal characteristics, and a variety of NPs that apply to the formulation of face masks [119].

NPs can be used in face masks (cosmetics) to improve UV protection, deeper skin penetration, long-lasting benefits, and product quality and efficacy. Because without UV protection, UV A and UVB are harmful to us, and they can penetrate the skin and damage it. NPs such as inorganic NPs, nanofillers, nanocrystals, nanodiamonds, zinc oxide, and titanium oxide particles are broadly employed in the range of 30–150 nm. Inorganic particles are coated and then used as NPs to prevent long-term toxicity and skin damage. Nanodiamonds are excellent UVB filters that overcome toxicity [19]. Silver- and gold-like inorganic NPs with broad-spectrum activity and stability can be used for stable face mask preparation. Gold is more applicable than silver because it is more colloiddally stable. Liposomes, copper, and phospholipids are stable upon preparation, have skin protective functions, and are involved in dermal regeneration, so they are used to remove dead skin. The bioactive ingredients of NPs increase the dissolution rate and improve the product texture [120].

The formulation of the peel-off mask incorporates silver nanoparticles (NPs) as antibacterial agents. Silver particles are combined with polyvinyl alcohol, sodium alginate, and hydroxyethyl cellulose. Scanning electron microscopy reveals that the diameter of the silver nanoparticles ranges from 26 to 51 nm [121]. Antibacterial activity is shown by a reduction in the growth of various bacteria, and after freeze-thaw stability studies, AgNP peel-off mask formulations are used in a face mask. Similarly, gold NPs have also been used for preparing peel mask formulations [122]. First, we will assess the efficacy of gold nanoparticles (NPs). Following this evaluation, we expect to observe their antibacterial and anti-colloidal properties, which would enable their application in various fields. Additionally, zinc-containing nanofibers serve as effective antibacterial agents. When integrated with polyvinyl alcohol (PVA) nanofibers, these zinc nanofibers enhance swelling properties and exhibit antimicrobial activity. Consequently, this combination may be utilized in anti-acne face masks while preventing ZnO particles from penetrating the stratum corneum (SC) layer of the skin [123].

Liposome-containing face masks applied to the skin deeply penetrate the SC. The activity of epidermal phospholipases produces osmolytes, which limit water loss. When lipid- or surfactant-based NPs are applied topically as a face mask, they attach to the skin surface

and produce a film that inhibits water loss [124]. Glyceryl stearate, cetyl palmitate, glyceryltrimyristate, glyceryl behenate, and beeswax are used as solid lipid NPs. Owing to their small size and strong adhesive properties, they form an invisible thin layer on the skin surface. Compared with a normal mask, it can be as effective as a face mask by maintaining the hydration of the skin for a longer time. However, owing to their smaller size, they are not visible [125].

Niosomes, transfersomes, and ethosomes represent various types of nanocarriers (NPs). Notably, niosomes exhibit stability during storage, which enhances the shelf life of facial masks. Additionally, transfersomes improve the deformability of bilayers, enabling deeper penetration into skin layers, and thereby facilitating the effective treatment of acne [126]. At those times, maintaining the release properties of the nanoparticles (NPs) can lead to enhanced effects. Gold nanoparticles are employed in devices that measure the differences in dielectric constants between water and other substances. The dielectric constant of the subcutaneous layer is influenced by the water content in the skin. Utilizing this device allows for the assessment of the skin's hydration state [127].

Copper stimulates collagen and elastin production and fibroblast proliferation; it prevents skin aging via dermal regeneration and reduces wrinkles. The skin contains a sebaceous gland on the surface, and surfactant impairs function by solubilizing the oily components of the skin and helping to remove them [128]. Surfactants can interact with lipid particles, leading to the formation of microemulsions that effectively remove dirt from the skin without compromising the skin barrier. It has been suggested that nanocrystals, along with other nanoparticles (NPs), are highly effective in enhancing the efficacy of face masks. The various applications and effects of NPs in face masks are illustrated in Figure 3 [84].

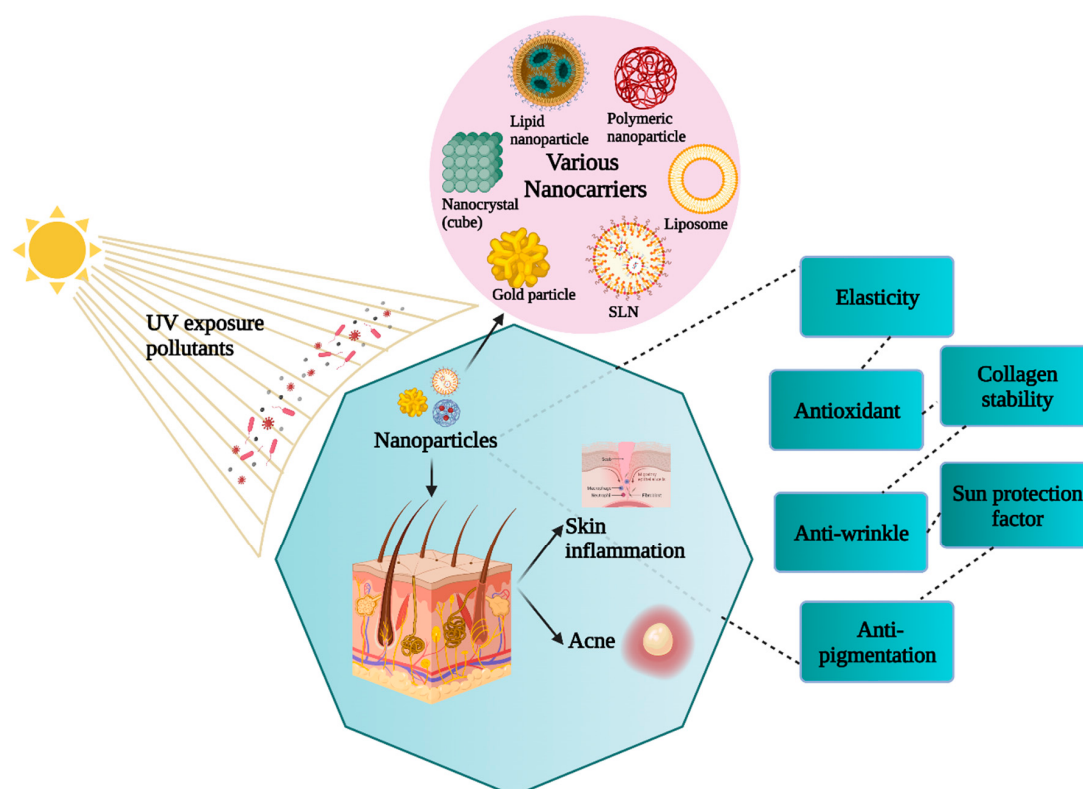


Figure 3. Applications and effects of NPs used in face masks. The application of NPs under various conditions, such as acne and skin inflammation, is shown in the figure. In addition, they also provide effects such as elasticity, antioxidants, anti-wrinkle, anti-pigmentation, collagen stability, and sun protection.

The nanonization of bioactive agents has proven valuable in addressing challenges including limited solubility, instability, and reduced efficacy, thereby improving the overall performance and delivery of active ingredients. Nanoparticle (NP)-enhanced face masks exhibit enhanced stability, facilitating broader application and commercial potential.

8. Advantages of Nanoparticle-Based Face Masks

In the context of NPs and nanocarrier-based drug delivery from a cosmetic perspective, NPs are highly preferred due to their numerous advantages. The incorporation of NPs into cosmetics offers benefits such as enhanced efficiency, improved transparency, protection of active ingredients, high bioavailability, unique textures, and increased consumer compliance. NPs, including silver-, gold-, silica-, zinc-, titanium-, and carbon-based materials used in face masks, provide more significant advantages compared to traditional face mask sheets.

Occasionally, zinc (Zn) and titanium dioxide (TiO₂) are coated with silica and aluminum oxide to enhance their dispersion and efficacy. NPs like silver and gold exhibit superior germicidal and antibacterial properties, making them more effective than conventional face masks. Additionally, lipid NPs, inorganic NPs, and dendritic polymers such as nanocrystals have gained popularity in the skincare industry due to their beneficial properties [129]. Refer to Table 2.

Table 2. Various properties of NPs and their advantages.

Nanoparticle	Property	Advantage	Reference
Gold	Anti-wrinkle Anti-pro radical Antioxidant	Gold particles act as anti-inflammatory and antioxidants by preventing oxidation, reducing acne and wrinkles, and helping to remove dead skin.	[130]
Silver	Antibacterial	Silver is extremely good at sterilizing and aids in the reduction in skin pore size and the treatment of acne. The antibacterial properties are due to the high reflectivity of silver.	[131]
Lipid nanoparticle	Antiaging As moisturizer	Liposomes have the capacity for sustained release, so it is beneficial to deliver active ingredients at the right time, which gives long-lasting effects.	[132]
Zinc oxide(coated)	Antibacterial	Coated zinc particles avoid direct skin contact, increasing their margin of safety. It adsorbs the protein on the nanoparticle surface, which may improve its bioavailability.	[133]
Titanium oxide (SiO ₂ = Al ₂ O ₃ coated)	Antibiotic Antimicrobial	Because particles are only penetrated into the surface layer of the stratum corneum and are not penetrated deeply, adverse effects such as itching are avoided.	[134]
Silica	Antibacterial Antiaging	Improving product texture and providing a matt finish to the face mask.	[135]
Nanosphere and nanocapsule	Synthetic polymers act as antioxidants	Nanocapsules are reservoirs consisting of a liquid core encapsulated by a surfactant or coating that facilitates the sustained release of a drug. In contrast, nanospheres are polymeric matrices that store multiple active substances. It is the polymeric matrix that plays a crucial role in enhancing the properties of face masks that incorporate nanoparticles.	[136]
Nanofiber	High retardancy and antibacterial properties	It provides a high surface area to volume ratio, increases the pore size and permeability of active ingredients, and reduces the thickness of the mask.	[137]

Compared with other normal face masks, NPs increase product value through contact between sensitive agents and the skin and controlled timely release. Along with producing a longer effect, they also contain moisturizing agents that help to maintain skin moisture because our drug or active ingredients are released slowly. The concentrations of agents and additives are reduced to achieve therapeutic efficacy via the use of NPs. It accumulates the drug in infected tissue and prevents acne and inflammation by producing desirable effects [138]. They increase self-life and hence greater product satisfaction. Some NPs are not absorbed, and they remain at the top of the skin to prevent itching. Owing to their relatively high efficacy, very small amounts of NPs are needed to increase the effectiveness of normal face masks. They increase the strength and rigidity while improving the texture of the skin [139]. These products have longer shelf-lives. This provides better UV protection and a faster onset of action than a normal face mask. They also improve the solubility of lipid NPs and are highly effective; moreover, they may mix with the lipid bilayer in cell membranes, allowing substances that would otherwise be unable to enter the cellular level to be delivered. Lipids in the SC moisturize and reduce the dryness of the skin [140]. Silver-containing masks are extremely good at sterilization and aid in reducing the pore size of the skin. The fundamental advantage of NPs is their high substantivity, which prevents them from being washed away easily [141].

Compared to conventional face masks, nanocarriers (NPs) possess larger surface areas and enhanced potential for drug delivery. Due to their low surface tension, these nanocarriers can be easily wetted and applied, facilitated by the presence of liposomes. This characteristic minimizes water loss from the transepidermal tissue of the skin. Furthermore, NPs enhance the solubility of active ingredients through their combination with these carriers. Additionally, they provide protection for active ingredients against hydrolytic and enzymatic degradation [82]. Nanopolymers with a relatively high loading capacity prevent burst release. The prevention of drugs during preparation and expulsion reduces the cytotoxicity of hazardous molecules [63].

9. Challenges

The extensive application of nanoparticles (NPs) in cosmetics can be attributed to their chemical reactivity, solubility, transparency, and color, which enhance the appeal of nanomaterials for the cosmetics and personal care industries. Nanomaterials incorporate various types of NPs, including liposomes, nanotubes, fullerenes, quantum dots, dendrimers, and nanosilver and nanogold particles. The ability of NPs to penetrate the skin is influenced by multiple factors, leading to challenges and risks associated with their route of administration and exposure. There is a potential for NPs to inadvertently induce cytotoxicity and pose physical and environmental risks [142].

Minghong Wu and colleagues at Shanghai University reported that ZnO NPs produce neurotoxicity and harm or kill brain stem cells in mice [143]. ZnO NPs are widely used in sunscreens. Other NPs also induce cytometry and apoptosis, which cause alterations in cell morphology [144]. However, until now, no case studies from the published literature have been found to overcome this cytotoxicity and assess the method of nanoparticle interactions [145].

Carbon fullerene nanoparticles (NPs), commonly found in moisturizers and certain facial creams, have been associated with genotoxicity and neurotoxicity. Fullerenes exhibit carcinogenic properties towards vascular endothelial cells. The toxic effects are manifested through mechanisms such as DNA damage, autophagy, inflammatory responses, and necrosis [146].

Environmental risk is also considered a major factor. NP exposure occurs through the release of NPs into water, air, and soil during manufacturing, usage, and disposal. These

nanomaterials eliminate microbes that play important roles in the ecosystem and help to treat wastewater [147]. Occupational risk is a significant consideration in nanomaterial manufacturing. Several cleaning and maintenance practices within research, production, and handling facilities are hypothesized to contribute to the potential adverse health effects of nanoparticles (NPs). Furthermore, increased production volumes correlate with a greater probability of consumer exposure to these materials [148].

Some negative aspects of using nanotechnology in the formulation of face masks can lead to significant issues. These negative aspects are illustrated in Figure 1. For instance, the increased risk of toxicity associated with smaller particle sizes can result in reactivity that poses harmful effects to both humans and the environment. Notably, there is currently no regulation governing clinical safety for these formulations. Additionally, unwanted side effects may arise, and the production costs for such formulations tend to be prohibitively high.

10. Future Prospects

Nanotechnology is currently employed in the manufacturing of cosmetics; however, technological advancements in omics sciences are poised to significantly impact the future of the industry. Big data analysis and machine learning techniques now allow for the assessment of cellular and tissue responses to specific cosmetic formulations and bioactive compounds. The concept of “cosmeceuticals”, where cosmetic items prevent or treat disease, is well established. Nanotechnology, a promising and revolutionary field, can improve drug delivery and is valued across various sectors, including cosmetics and cosmeceuticals. The use of nanoparticles (NPs) in cosmetic products is increasingly common, offering potential benefits such as enhanced skin penetration [7]. Nanotechnology represents a recent advancement in novel drug delivery, addressing customer concerns regarding product penetrability. This technology aids in protection, moisturization, and wrinkle reduction, and facilitates the manufacturing of NPs using advanced techniques. Consequently, nanomaterial products are gaining traction in the market. Cosmetics companies were the early adopters of nanotechnology in product development [149].

The formulation of cosmetic ingredients has consistently posed challenges due to the dependency of active ingredient release on both the selectivity of the skin barrier and the carrier system. The epidermis serves as the primary barrier within the skin, making it difficult for many active ingredients to penetrate. Various innovative strategies have been developed to effectively deliver dermal formulations to the desired depths within the skin, including nanoemulsions, nanogels, liposomes, aquasomes, niosomes, dendrimers, and fullerenes. Nanobiotechnology can play a crucial role in creating sustainable and healthy cosmetics for two main reasons. First, nanotechnology has the potential to produce biomimetic particles that can transport natural metabolites to specific cellular targets, which is essential for achieving the desired benefits. Additionally, the structural characteristics of nanoparticles—including size, shape, composition, and surface charge—can be modified to enhance their efficacy in transcutaneous penetration across different epidermal and dermal layers. Second, biotechnology contributes to the development of excipients utilized in cosmetic formulations [150].

11. Conclusions

The integration of nanotechnology into cosmetic face masks represents a transformative advancement in the cosmetics landscape, offering enhanced efficacy and user experience. These innovative masks leverage nanofibers and NPs to improve active ingredient delivery, ensuring that beneficial compounds penetrate the skin more effectively while maintaining stability and reducing the risk of irritation. Nanotechnology not only enhances

the performance of cosmetic masks by providing superior filtration and antimicrobial properties but also addresses common issues associated with traditional masks, such as ingredient degradation and uneven application. Furthermore, ongoing research into the safety and environmental impact of nanomaterials will be crucial as the industry continues to evolve. As consumer awareness increases, the demand for effective, safe, and sustainable cosmetic solutions will likely drive further innovation in this field.

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