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REVIEW PAPER

Nanomaterials: Applications and challenges in the cosmetics sector

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Abstract

As nanomaterials are being continuously used in the health sector, the cosmetic sector is believed to be the most advanced for using nanoparticles in their products. In order to increase the effectiveness of cosmetic goods, the cosmetic industry is profoundly exploring nanomaterials. Liposomes, dendrimers, nano-emulsions, etc. are examples of nanomaterials that are now common constituents in the cosmetic industry. This article highlights the applications and challenges of nanomaterials in the cosmetics sector. Nanoparticle-based cosmetics have expanded the possibilities of nano cosmetics use to treat dispersed hyperpigmentation, dehydrated, and wrinkled skin diseases that are related to aging. It offers excellent opportunities for both business and academic research. On the other side, there are a lot of safety-related issues that are always getting more attention. That's why it is necessary to discuss both applications as well as the challenges of applying nanotechnology to cosmetics. Based on all the applications as well as the challenges, it can be concluded that nanomaterials used in cosmetics have substantial health advantages and are helpful, however, they must be sensitively described to ensure their safe usage and total removal from the body. As a result, nano cosmetics products must be produced and marketed with the utmost regard for both the environment and consumer health.

Keywords: *Nano Cosmetics; Nano-emulsions; Nano Pigments; Nano-somes; Nanostructured Lipid Carriers.*

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INTRODUCTION

" A woman without paint is like food without salt," said the Roman philosopher Plautus. The significance of cosmetics since ancient times is evident. Although nanoscale materials have been utilized in cosmetics for ages, current nanoscience and nanotechnology are relatively recent. Women's nails were colored hundreds of years ago by silver and gold particles of varying sizes. In the Middle Ages, a liquid mixture with gold powder was utilized as an anti-aging treatment. Researchers in ancient Egypt, Greece, and Rome used nanotechnology in hair dye preparations more than 4,000 years ago. [1] The idea of nanotechnology first emerged in 1959 across a variety of scientific disciplines, including biology, physics, chemistry, and engineering [2].

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Although nanotechnology keeps gaining attention in the human resources and healthcare sectors, the cosmetics industry is regarded to be the most advanced in incorporating nanoparticles into its products. According to a market survey conducted by the Woodrow Wilson Project on Emerging Nanotechnology, more than 1600 products had been developed by October 2013. The primary category, which accounts for about 50% of the share, is health and personnel care. Between 2006 and 2013, the number of cosmetic nanotechnology products surged by about 516% [3].

Numerous factors contribute to the widespread use of nanomaterials in the cosmetics industry. Cosmetic formulas with improved performance, retention, alluring aesthetics, and most importantly safety have been developed in

response to the enormous growth in customer demand [4, 5]. Permanent stability and good formulation, dispersion at the point of application are primary benefits of applying nanoparticles to cosmetic products. Their high surface-to-volume ratio is the cause of, which facilitates improved skin penetration, nanoparticles are increasingly being used in cosmetic formulations [6–10]. The ability of nanoparticles to act as UV filters has led to the development of sunscreen-compatible nanoparticles. In 1987, Christian Dior developed Capture TM, a liposome-infused anti-aging cream [11]. Later, several cosmetic firms began incorporating nanoparticles into their cosmetic formulas. L'Oréal S. A [12] cosmetics published numbers of patents for nanoparticles applications in cosmetics. Dendrimers, cubosomes, and nano emulsions are some examples of nanoparticles applications in cosmetics formulations and productions.

Cosmetic manufacturers utilize chemicals with nanoscale modifications to improve ultra violet (UV) protection, quality of color and finish, etc. Due of their changed properties, such as color, visibility, solubility, and chemical reactivity, nanoparticles are appealing to the cosmetics and personal care industries [13]. According to the cosmetics industry, skin can absorb smaller particles more easily and heal damage more quickly and effectively [14]. The primary advantages of nano- cosmetics include their stability due to the encapsulation of cosmetic chemicals within nanoparticles, aesthetically pleasing products, and excellent UV protection.

The mineral nanoparticles TiO_2 (titanium dioxide) and ZnO (zinc oxide) are useful UV filters because they can scatter and reflect visible solar energy while simultaneously absorbing UV radiation. These qualities make them a popular ingredient in sunscreens. Body firming lotion, bronzer, exfoliating scrubs, eyeliners, styling gels, and more are additional examples of nano-cosmetic items available on the market. Fullerenes serve as cages for active compounds in cosmetic products. They may be taken in transdermal, or through the skin. Some fullerenes, particularly carbon-based ones, may be dangerous to breathe in and may oxidize some cells.

Nano-systems have made it possible for cosmetic agents to be delivered more effectively, have achieved their stated goals, and have lessened cosmetic concerns like signs of ageing, spots, pigmentation, imperfections, balding, uneven complexions, and many more. They also impart attractiveness and give off an overall good appeal.

APPLICATIONS

COSMETICS USING NANOMATERIALS

Making numerous types of unique products for the nano cosmetics industry is one of the most fascinating uses of nanotechnology. An adult uses approximately nine cosmetics every day on average [15]. A cosmetic is any substance other than soap used to clean, enhance, or otherwise change the appearance of the human body by rubbing, pouring, sprinkling, or spraying it. Numerous different personal care products are included in cosmetics. Different categories can be used to categorize cosmetics according to where on the body they are used like skin-care cosmetics, hair-care products, cosmetics for the face such as foundation, lipstick, and mascara, nail care items such as nail polish remover, ultraviolet (UV) light-screening items such as sunscreens, and fragrance products including cologne, deodorants, aftershaves, and perfumes etc. (Fig. 1a, 1b) [16, 17].

NANOEMULSIONS

Nano emulsions, a relatively new category of biphasic systems, have received attention as a promising vehicle for the targeted, secure, and the active substances delivered effectively to skin [18]. They are essentially non-equilibrium systems made up of two immiscible liquids, such as water and oil, which are distributed into one another as submicron droplets and stabilized by surfactants. Because nano emulsions create droplets in the submicron size range, they are known as "ultrafine emulsions." They have a distinctive blue dazzling tinge due to their radii, which range from 10 to 100 nm. Although Brownian motion prevents coagulation, they are significantly more stable against it because they are at a phase transition. Nano emulsion has advantages over microemulsion, such as requiring a low surfactant concentration (for nano emulsion, 5–10% is enough against 20–25% for microemulsion). Nano emulsions are preferable to other carriers due to their greater sensory qualities, particularly moisturizing power [19]. Hydration is a key factor which affects skin permeability. Wet wipes have only recently been made with emulsion-based

(a) (b)

Fig. 1. Nanocosmetics [16]. (a) http://tinaounds2016.blogspot.in, and, (b) https://www.nanotechia.org

materials. These wet wipes are infused with nano emulsions [20]. Skin permeability is significantly influenced by emulsion composition, globule charge, and surfactants [21]. Skin naturally contains lipids including palmitic acid and ceramide 3. It has been proven that including these lipids and cholesterol greatly improves the skin's moisture and suppleness. The convention of nano emulsions in cosmetic products has expanded due to their small particle sizes, which will undoubtedly aid in improving skin penetration, hydration, fluidity, and a glossy coating on the skin as well as the infiltration of active chemicals via the skin. Nano emulsions enhances penetration even more [22].

An oil-in-water nano emulsion using non-ionic surfactants, emulsifiers, and consistency-increasing agents is described by Jean *et al.* For hair care, the newly created nano emulsion is perfect. This solution also continuously nourishes tissues, smoothen the skin, and improves absorption when applied topically [23]. On the basis of at least one non-ionic lipid, the formulation includes a naturally amphiphilic lipid component. The lipid is liquid at a temperature of less than 45 °C. It is more stable than those having an amphiphilic lipid phase composed of phosphoglycerates, water, and oil [24]. The manufacture of nano emulsion at a reasonable cost is a major hurdle. Nano emulsion preparation requires a considerable energy input. High pressure homogenizers are an example of a mechanical device that is very expensive, uses a lot of energy, and is challenging to maintain. Low-energy manufacturing techniques are existed; however, they are unsuccessful when used on an industrial scale. The sunscreen product line Kores Red Vine Hair also employs nano emulsions [25, 26]. Basically, these are used in sprayable form.

In order to create a nano emulsion, a macroemulsion must first be created, and only then can it be transformed into a nano emulsion. Some processes used to create nano emulsions include micro fluidization, bubble bursting at an oil/water interface, the Fryd and Mason evaporative ripening process, and high-pressure homogenization (HPH) [27–29]. Numerous products, such as sunscreen, deodorant, hair conditioners, and hair serums, contain nano emulsions [30]. Nano emulsions are frequently employed in cosmeceuticals including lotions, shampoo, nail polish, and hair conditioners as a medium for the regulated delivery of biologically active chemicals [31]. For example, the $500 skin caviar intensive ampoule treatment from La Prairie uses this technique to more quickly transfer active ingredients to the skin's site of action in order to achieve the product's stated goals of reducing uneven skin pigmentation and erasing lines and wrinkles.

The majorities of nano emulsions are stable and have a texture that is so fine that they may be applied with a spray. To improve skin penetration, chemicals are nano emulsified or encapsulated during the manufacturing of skin creams. Nano emulsions are frequently employed in cosmeceuticals such lotions, shampoo, nail polish, and hair conditioners as a medium for the regulated delivery of biologically active substances [31]. The companies that make these products assert that nano emulsions can deliver helpful substances in high concentrations deep into the skin. The ingredients utilized in their preparation are safe to use and GRAS (Generally Recognized as Safe) -certified materials.

Nanotechnology-based mini emulsions smaller than 1 mm (millimeter) crystals are known as nanocrystals. They are aggregation "clusters" that include tens of thousands to a few hundred atoms. These aggregates usually have sizes between 10 and 400 nm. Drugs that are poorly soluble in water can also be transformed into nanocrystals and utilized in cosmetics to boost their ability to permeate the skin. In 2007, JUVENA and La Prairie

became the first cosmetics on the market with the goal of lowering trans epidermal water loss, enhancing skin defense, and enhancing active ingredient penetration. For skin care, moisturizing, and anti-aging products, it might be useful. It's beneficial to add a nice skin sensation to skin care products[32].

NANOSOMES

Essentially, nanosomes are self-assembling nanostructures that enclose active or biologically active components within vesicles. When applied, the active chemicals either come into touch with the skin and unleash their effects immediately or deeply penetrate the skin like liposomes, niosomes etc.

Liposomes are concentric bilayer vesicles that are generally recognized as safe (GRAS) items. A phospholipid bilayer made of either synthetic or naturally occurring phospholipids, entirely encapsulates the water volume in liposomes (Fig. 2a). The lipids in liposomes shield the active chemicals from UV light, extending the shelf life of the products [33]. Micro fluidization and sonication techniques can be used to create nanoliposomes and liposomes. Extrusion was the initial method of liposome production. Liposomes provide UV protection for the skin, hair, and nails as well. Because liposomes include the phosphatidylcholine type of phospholipid, which has softening and conditioning qualities, these can be employed in a variety of shampoos and conditioners.

They are typically created in an aquatic environment with the proper lipid-to-water ratio in the presence of thermal energy from cholesterol and natural phospholipids. The phospholipids, whether saturated or unsaturated, are non-toxic. Unsaturated fats, such as the phosphatidyl choline that occurs naturally in eggs, are less stable but more permeable. The saturated ones, such as dipalmitoyl phosphatidyl choline, have lengthy acyl chains that form hard, impenetrable bilayer structures [34]. These can capture both hydrophilic and hydrophobic cosmetic components.

The very first liposomal cosmetic to enter the market was the anti-aging lotion "Capture," which Dior unveiled in 1987. Additionally, they have

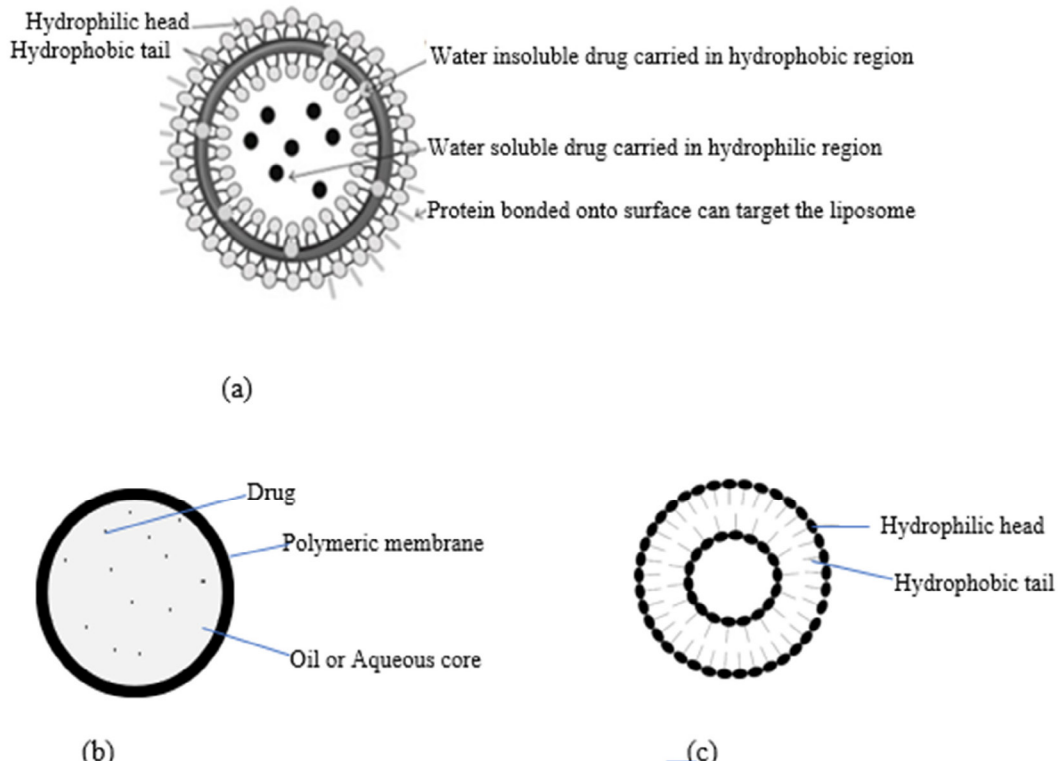

Fig. 2. Several kinds of nanoparticles, (a) A liposome with an aqueous interior surrounded by a phospholipid bilayer; (b) niosome and its internal synthetic surfactant surrounding drug, (c) A nano capsule with various drug-loading techniques [35].

been applied to the management of hair loss. A vasodilator called minoxidil is the main component in hair loss-prevention treatments like Regaine. The first study on liposomes was published in 1963 by Bangham, and early in the 1980s, In other article, Mezei and Gulase kharam discussed how well liposomes distribute topical medications [36, 37]. Liposomes have been combined with a variety of active ingredients, including carotenoids, lycopene, CoQ10, and vitamins A, E, and K as well as antioxidants. When dissolved in water, this improves their physical and chemical stability, which is used to make skin epidermis renew. Since lipid soluble compounds like cholesterol and ceramides are normally present in healthy skin tissue and are therefore simple to incorporate into liposomes, they have long been utilized in topically applied skin creams to encourage skin hydration and generate softer, smoother skin.

Costs associated with production and developments are still being held back by issues with liposome stability, sterilization, and insufficient drug loading capacity. Due to these limitations, vesicular structures such as transferosomes, ethosomes, niosomes, cerasomes, etc. have been developed that resemble regular liposomes in some ways but differ in others. Transfersomes, sometimes referred to as elastic vesicles, have the potential to pass through the epidermal barrier. Cerasomes utilize the same lipids found in the skin's outer layer, but ethosomes are distinctive vesicles generated with a high quantity of alcohol and phospholipid.

Niosomes are basically non-ionic surfactant-based nano-vesicles that self-assemble, either with or without the addition of lipids or cholesterol. In order to make uneven surfaces, a variety of chemicals, such as cholesterol and non-ionic surfactants, are used [38]. The ether injection approach, the film method, the Handjani-Vila sonication method, the reverse-phase evaporation method, and the heating method are the most used techniques for making niosomes. These vesicles can be unilamellar or multilamellar, and they can contain solutes in aqueous solutions as well as the membrane created when surfactant molecules form a bilayer [39, 40]. Proniosomes are utilized in conjunction with niosome to provide better medication delivery systems [41]. The characteristics of niosomes are similar to those of liposomes, however they are more flexible and stable [42].In addition to being utilized for aesthetic purposes, they were also employed in a range of other industries, such as the food and pharmaceutical industries [43]. A number of variables, such as structure, surfactant type, drug type that is encapsulated, and temperature, can affect the formation of niosome [44].

The aqueous solution in the system is encircled by a self-assembled surfactant bilayer (Fig. 2b). Functional cosmetic ingredients can be dispersed in aqueous medium inside the niosomes, and discharged at specific locations (targeted delivery) or on a set rate (controlled delivery). Lipophilic and hydrophilic medicines are contained in the membrane bilayer and the watery centre of niosomes, respectively. The advantages of niosomes over liposomes have led to a focus on them, including their higher chemical stability of surfactant than phospholipid, lack of need for particular preparation or storage conditions, lack of purity issues, and low manufacturing costs [45]. Niosomes have several benefits, including the capacity to raise the stability of medications that are entrapped in them, improve the bioavailability of substances that are not well absorbed, and improve skin penetration [46]. There has been research on numerous medications and cosmetics as topical vesicular carriers using these niosomes. Because they can have been lengthen the components' occupancy times in the stratum corneum and epidermis. Also decrease systemic absorption and beneficial in the topical distribution of active compounds [47].

NANOCAPSULES

The various components are encapsulated using the polymeric nano capsule solutions, which can be applied directly to the skin. Poly-L-lactic acid (PLA) is biodegradable aliphatic polyester derived from lactic acid formed by bacterial fermentation of glucose-rich substances. In the body, the polymer PLA breaks down into lactic acid monomers, making it biocompatible and biodegradable[48]. As part of the Calvin cycle, the liver converts lactic acid into glucose, a typical transitory outcome of anaerobic breath. When it happens, the body starts using glucose as fuel. As a result, using PLA nanoparticles is safe and doesn't cause any substantial harm. By nano precipitating poly-l-lactic acid, it is possible to create stable nano capsules with dimensions of 115 nm. These nano capsules are filled with aromatic chemicals that release fragrance continuously. Because of

their biocompatibility, these nano capsules are used in a variety of deodorants.

Chitosan is a fibrous and natural polysaccharide polymer. The scavenger found ordinary biopolymer chitin which was incompletely N-deacetylated to produce chitosan, a changed normal sugar polymer. Jasmine essence trapped in the chitosan could release the scent over time [49]. Several techniques have been used to create nano capsules, including chemical vapor condensation, and mini emulsion polymerization etc. Several patents owned by L'Oreal, Unilever, and The Dow Chemical Company cover the use of nano capsules in hair care, skincare products, and professional nail products [50, 51]. The nano capsules carry the anti-oxidants that are effective in anti-aging cosmetic compositions [52].

The polymeric nanoparticles known as nano capsules have a hollow interior where desired materials can be loaded and kept safe from the outside environment (Fig. 2c). L'Oreal, a French business with a nanotechnology patent in the US, has used polymer nano capsules to transport retinol to the skin's deeper layers [53]. Nano capsules are submicroscopic particles with an aqueous or oleic core encased in a polymeric shell. According to research, nano capsules work better than conventional emulsions at preventing UV filter octyl methoxycinnamate from penetrating pig skin [54]. Both hydrophobic and hydrophilic types of carriers can be trapped in these nano capsules. Proteins, polymers, and biomolecules can be bonded to the surfaces of nano capsules. These nano capsules are naturally biodegradable, biocompatible, and stable in aqueous environments [55–60]. The dimensions of the particles are influenced by the polymers attached with nano capsules. These particles break down into carbon dioxide (CO_2) and water since they are biocompatible by nature. These items can leave the body through excretion.

NANOPIGMENTS

The most stable and inert class of nanomaterials are nano pigments, and they are among the most complex and labile carriers of cosmetic compounds. Although nano pigments are frequently employed in sunscreens and widely recognized as UV rays' blockers, they have a wide range of other applications. Other uncommon uses include using them as components in moisturizers, gold facial masks, and cosmetic soaps. For the purpose of proving their safety, many research on toxicity both in vivo and in vitro, including those on genotoxicity, photo-genotoxicity, general toxicity, cytotoxicity, etc., have been conducted [61]. Numerous in vivo and ex vivo toxicity tests have shown that nanoparticles are completely safe for human use and do not possess any negative properties. However, some investigations on insoluble particles discourse because that tiny, ultra-fine particle might cause oxidative cell damage and are genotoxic.

In order to improve the visual appeal of biological surfaces, Maitra P. *et al.* patented formulations in 2014 that combine a pigment and an effective number of nanoparticles in a vehicle with a film forming. When used on a biological surface like the face, the innovative compositions minimize the appearance of facial age indicators such as actinic-aging, photo-aging, and hormonal-aging. This is accomplished by increasing light transmittance and optical blurring. Pigment particles of diameters between 100 nanometers and 2 microns are employed to improve light absorption and decrease reflection when the wavelength of visible light is less than this value. The composition might be made up of a mix of colors with various refractive indices or just one pigment, depending on the version. Zirconium oxide, cerium oxide, and titanium dioxide were included in addition to inorganic (titanium dioxide) and organic (barium, strontium, and calcium) colors. In a weight ratio ranging from 10.0:1.0 to roughly 1.0:10.0, pigments are combined with nanoparticles made of fumed silica, polymeric and metal oxides nanoparticles. The novel mixes are either topical or intended for use on certain organs [62]. There is proof that insoluble nanoparticles were present in hair follicles, where they remained until they could be removed by washing. Concerns over the likelihood of inorganic pigments particularly titanium dioxide passing through skin have been very prevalent. However, numerous investigations have demonstrated that neither zinc oxide nor titanium dioxide can pass through skin.

Due to their enhanced stability as a result of technical improvements, silver nanoparticles are being employed more frequently for their antibacterial and preservation qualities[63–66]. The oldest antibacterial agent in conventional medicine is silver and its derivatives, but since silver compounds progressively precipitate in

cosmetics, they are not suitable as a preservative [67]. Silver ion, a univalent positive ion (Ag^+) present in the formulation, is responsible for its antibacterial properties. Additionally, it has been found that combining silver with platinum promotes the oxidation of Ag to Ag^+, increasing silver's antibacterial action. The top three manufacturers of commercial and consumer goods using silver nanoparticles are Korea, China, and the United States [68]. According to Kokura S. et al.'s 2010 study, silver nanoparticles can remain stable for longer periods of time without experiencing physical instability, such as sedimentation. They were largely preserved by their resistance to germs and fungi. Silver nanoparticles at concentrations between 0.00 and 0.02 ppm (part per million) under Ultra Violet B (UVB) radiation did not affect human keratinocytes in any way. They had no influence whatsoever on the UVB-induced cell death either. In a study, silver nanoparticles were used as bioactive components in alcohol-free mouthwashes to lower the incidence of oral infections in cancer patients who had impaired immune systems. High antimicrobial effects have been observed to exist at low concentrations of ethanol because it irritates sensitive or inflamed mucosa (30,000 g/ml) [69]. In a manner similar to this, Bong Hyun Jung *et al.* patented a cosmetic pigment compound in 2008 that included gold or silver nanoparticles. The researchers produced a range of colors for use in lipsticks and other color cosmetics by combining silver and gold nanoparticles with yellow and red colors, respectively [70].

Some producers of underarm deodorants currently make the promise that the silver in their products will offer up to 24 hours of germ prevention. 12% of all nanoparticles used worldwide in cosmetics are nano-silver [71]. Since it has been demonstrated that silver nanoparticles may stop the growth of dermatophytes such *Staphylococcus aureus*, *Vibrio cholerae*, *Pseudomonas aeruginosa*, *Syphilis typhus*, and *Escherichia coli*, they may be efficient anti-infective agents [72, 73]. Similar research has been done significantly on its variants to take advantage of its special antibacterial and antifungal properties [74]. Published research suggests that the antibacterial action of silver nanoparticles may be caused by the generation of silver ions. On the other hand, gold nanoparticles could be used in cosmetics because of their special capabilities for loading and unloading medications and ease of manufacturing. According to reports, toothpaste that effectively clean the mouth and other commercial personal care items have been infused with nano gold [75].

According to research by French scientist Dr. Philippe Walter and his team that was published in ACS (American Chemical Society) Nano Communications, human hair produces luminescent gold nanoparticles [76]. It required dipping white hairs into a gold-infused solution. These dipped hairs initially changed color to a pale yellow before deepening to a rich brown hue. The researchers used an electron microscope to demonstrate that the nanoparticles were developing in the core substance of the hair cortex. The color lasted over multiple washings. Similar to nano silver, nanosized gold has been incorporated into toothpaste and is said to be extremely effective at killing oral bacteria. Silver nanoparticles, are also found present in many personal care products, including shampoo, shower gel, toothpastes and acne treatments. This is strongly related to the silver nanoparticles' antibacterial capabilities. Because of their potent antibacterial and antifungal qualities, gold and silver nanoparticles are commonly used in cosmeceutical products. According to one study, an ointment with silver nanoparticles has antibacterial properties and has the potential to treat skin lesions and irritation [77].

DENDRIMERS

These enormous, branched chain, star-like molecules with nanometer-scale dimensions can only be explained by a primary structure, an inner dendritic architecture, and an exterior surface with functional surface groups [78]. One of the first dendrimers made synthetically was the Newkome dendrimer in 1985. A divergent or convergent method can be used to synthesize dendrimers. The divergent method of synthesis starts with the dendrimer core and then incorporates the exterior building blocks. The second method, however, incorporates the reverse as a divergent strategy, where the beginning material for the synthesis is the outside material that becomes the dendrimer's outermost arm [79–81] (Fig. 3a).

Organic compounds called "dendrimers" have a semi-polymeric tree-like structure [82]. According to a cosmetic composition protected by the carbosiloxane dendrimer patent, the skin and/or hair can benefit from its good moisture resilience, sebum

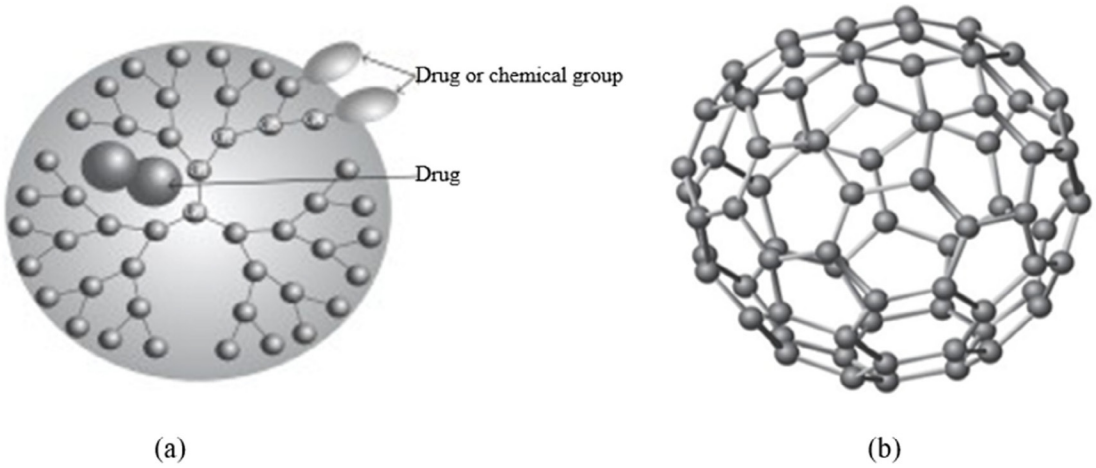

Fig. 3. (a) Dendrimer and its various drug-loading techniques, and (b) fullerene [17, 35].

rigidity, lustre, tactile sensation, and/or adhesive properties [83]. Drug transport, genetic transfection, catalysts, energy harvesting, photoactivity, rheology modification, molecular mass and size determination, and nano science and technology are only a few of the recent uses for dendrimers.

NANOCARBON MATERIALS

They have excellent electrical, thermal, and structural qualities due to their high aspect ratio and chemical makeup, which enables their extensive application. Fullerene and carbon nanotubes are two newly emerging uses for carbon nanoparticles. There are other carbon allotropes besides diamond and graphite, which are the most common ones. Nanocrystalline diamond, one of the most thoroughly studied substances, is a future application of nanotechnology. UV protection occurs in accordance with the nanodiamond's size and any functional molecules. Sung, C.M., was granted a patent for a sunscreen formulation using functionalized nanodiamonds in 2013. In one embodiment, nanodiamonds are dispersed in a volatile carrier and evaporate to leave a nanodiamond residue [84].

Carbon nanotubes (CNTs), are hollow and have lengths of about 10 s of microns, weigh relatively little, and range in size from 0.7 to 50 nm [85]. CNTs, carbon nanoparticles, and CNTs based on peptides are used in cosmetic formulations. CNTs that have undergone chemical modification are used to color eyebrows, eyelashes, and hair [86] Additionally, nickel vanadate, boron nitride, and halloysite clay nanotubes are used in hair care products. The production of carbon nanotubes has also been done using electrochemical anodization and chemical vapor deposition (CVD) [87, 88]. The high availability of nano clay nanotubes in nature, their low toxicity, and their low cost account for their high demand in hair care products [89–91]. Its usage in biosensors, medical equipment, and cancer treatment is motivated by its dimensional and chemical compatibility. Numerous hair coloring products use the graphene-based nanomaterials. Products with color are created by attaching various polymers to the nanoparticles. This polymer and nanomaterial combination results in the development of very resistant hair colors, making shampooing challenging.

Fullerenes have three-dimensional spherical nanostructures made up of odd-numbered carbon rings [92, 93]. These structures resemble cages (Fig. 3b). These structures have a three-dimensional spherical shape because of the odd-numbered carbon rings (such as the Pentagon and Heptagon) that make up their construction [94]. As a result, these structures are often referred to as fullerenes or "Bucky Balls." Since fullerenes are insoluble in aqueous solutions, their extreme hydrophobicity initially restricted their utilization. The surface modifications has enhanced fullerenes' water solubility and growing interest in their possible medical applications [95].

It is reported that fullerenes can be produced by vaporizing a carbon source, by vaporizing carbon using a laser in an inert atmosphere, by heating graphite with an electric arc, by irradiating polycyclic hydrocarbons (PAHs) with laser light,

and by heating graphite with a resistive arc [96, 97]. Fullerenes have the ability to neutralize free radicals and shield cells from apoptosis. Fullerenes are a great ingredient in anti-aging cosmetic products because of their antioxidant qualities. Fullerene-C60 (Lipo-Fullerene), which has anti-wrinkle characteristics, is employed as a potential ingredient [98–100].

Kato S investigated the radical oxygen species (ROS) during the in vitro defense of fullerene-C60 derivatives against TiO_2-photocatalyzed in HaCaT keratinocytes and discovered that pretreatment with polyvinylpyrrolidone-entrapped fullerene-C60 reduced intracellular ROS, cell membrane-lipid peroxidation, and improved cell survival [101]. Fullerene gel decreased the severity of acne vulgaris by reducing neutrophil infiltration and sebum production while increasing the water content of the skin [102]. Due to their significant scavenging activities against radical oxygen species, they may be used in the development of skin-rejuvenation cosmeceutical formulations [98]. Free radicals can be scavenged by carbon fullerenes, which can also renew the skin. They are typically hydrophobic and challenging to saturate, but when bound to other molecules like surfactants, they become soluble and can be used in a variety of cosmetic compositions. The keratinocytes are capable of being shielded from UVB-induced harm by the carboxy- fullerenes. They perform well as lubricants in moisturizers to encourage skin regeneration and as antioxidants to neutralize free radicals. One commercial product that comprises buckyball is the anti-aging cosmeceutical Zelens Fullerene C-60 night moisturizer, which has been shown to have strong antioxidant properties [17]. It has been used into some quite pricey face lotions. The purpose is to profit from its ability to act as a powerful free radical scavenger.

NANO LIPID CARRIERS (NLC)

Hydrophobic nature of the solid lipid nanocarriers (SLN), makes them useful in preventing skin drying and preserve its moisture. These nanoparticles are therefore more effective carriers, non-toxic, and have superior skin penetration. Instead of deeper skin penetration, these nanoparticles can release the active ingredients. Chemicals for sunscreen, anti-acne, and anti-aging are typically carried by SLN and NLC(Nano lipid carriers) [103–105]. For aesthetic applications, SLN and NLCs exhibit a number of advantageous characteristics, providing improved skin hydration, occlusion, and regulated active ingredient release. These are regarded as a “nano safe” carrier system since they are constructed of biodegradable and physiological lipids, which have remarkably high tolerance and little cytotoxicity. Other popular techniques for their synthesis include solvent emulsification-evaporation, solvent emulsification diffusion, high shear homogenization, and/or ultrasonication [106–108]. The NLCs in cosmetic goods are greater than SLNs due to their strong absorption and stability. The skin can be penetrated more effectively by these lipid nanoparticles. The translucent lipid particles enhance the appearance of cosmetics. Nano repair cream, which initially came on the market in 2005, contained these lipid particles. Skin penetration was improved by NLCs in Dr. Rimpler GmbH’s moisturizer [109, 110].

Some authors refer to them as an oil-in-water emulsion that has solidified [111]. SLN are susceptible to changing into polymorphic forms under unfavorable storage conditions. This might cause differences in the release or non-release of any medications or cosmetic components they contain [112].They are greasy lipid droplets that are stabilized by surfactants and solid at body temperature. They have been shown to boost the bioactive chemicals’ absorption into the stratum corneum and can be used for the regulated release of cosmetic components over an extended period of time. Additionally, they can prevent the enclosing materials from degrading. Their UV-resistant properties were also identified in them and improved by including and testing a molecular sunscreen. UV blockage was enhanced when the UV absorber 3,4,5-trimethoxybenzoylchitin was added to SLNs [113]. The Dr. Kurt Richter Laboratorium GmbH in Berlin, Germany, manufactured Nano Repair Q10 cream and Nano Repair Q10 serum, which were both released on the cosmetic market in October 2005 and demonstrated the effectiveness of lipid nanoparticles in the anti-aging sector [114]. Skin hydration was observed to increase by 31% after 4 weeks in an in vivo research when 4% SLNs were added to a regular cream [115]

NANOCOSMETICS SUBSTANCES IN MARKET

There are number of examples of nano cosmetics substances (Table.1.) [17, 116–119]. Nanotechnology-based skin care products are also

available from Bionova. According to Chantecaille Nano Gold Energizing Cream, "moisturizing, antioxidant, and anti-inflammatory silk microfibre are bonded to 24-karat gold nanoparticles." In order to protect the skin and enhance look, Leorex Hypoallergenic Anti-Wrinkle Nano-Booster is said to "produce a silica nanoparticles network, which straightens and supports the skin matrix," and that "the nano particles scavenge free radicals and pollutants." Additionally, it creates a hypoallergenic anti-wrinkle nano formula for the neck and decollate. According to Purelogicol Instant Lip Plumper, it uses "the revolutionary MVS LIPSTM nano-technology." According to Rosactive Biomixyl, an advanced anti-wrinkle collagen therapy "stimulates the natural collagen production without requiring exogenous collagen." relying on nano-sized proteins.

Salcura Zeoderm Skin Repair System states that Zeoderm plus "is a unique blend of nano minerals and important nutrients, suited for adults and children who may be prone to dry and itchy skin symptoms like eczema, psoriasis, dermatitis, and skin allergies." According to the

Table 1. Various cosmeceuticals on the market that use nanotechnology [17].

Product	Proposed	Manufacturer	Marketing claims
Hydra Flash Bronzer Daily Face moisturizer	Moisturizer	Lancôme	Nanocapsules of pure vitamin E provide powerful antioxidant protection. A light touch of self-tanner ensures a natural, healthy glowing skin.
Hydra Zen Cream	Moisturizer	Lancôme	Containing Nanoencapsulated Triceramides, Hydra Zen helps restore perfect comfort and softness and renew skin's healthy look. Protected from signs of daily stress and fully hydrated, your skin is beautifully soft and smooth all day long.
Nano-In Hand and Nail Moisturizing Serum and Foot Moisturizing Serum	Moisturizer	Nano-Infinity Nanotech	Fine crystals of ZnO nanoparticles will go straight into skin tissue to prevent hand and nails from being hurt and restore skin health
Lancôme Renergie Microlift	Antiwrinkle	Lancôme	Formulated with colloidal silica and soy protein nanoparticles to provide the closest possible face-lift effect.
RevitaLift Anti-Wrinkle and Firming Face and Neck Contour Cream	Antiwrinkle	L'Oreal	The Revitalift formula is enriched with Pro-Retinol A, a powerful antiwrinkle agent, which is encapsulated in nanosomes. Nanosomes penetrate deep into the epidermis to work at the heart of wrinkles.
Revitalift Double Lifting	Antiwrinkle	L'Oreal	It contains nanosomes of Pro-Retinol A. RevitaLift Double Lifting is a unique dual-action treatment that instantly retightens skin and effectively fights wrinkles.

Continued Table 1. Various cosmeceuticals on the market that use nanotechnology [17].

Product	Proposed use	Manufacturer	Marketing claims
Eye Tender	Antiwrinkle	Kara Vita	It contains nanospheres, delivers 13 bioactives including proven, wrinkle-reducing peptides to stimulate fibroblasts, build collagen, brighten skin, and reduce inflammation for a younger, healthier appearance.
Eye Contour Nanolift	Antiwrinkle Antiaging	Euoko	It is based on nanocapsules technology. Lifting nanocapsules join seven other immediate and long-term fighters of fine lines, wrinkles, and puffiness. It provides instant and long-term smoothness, gives the eye area more radiance, and diminishes the appearance of dark circles and puffiness.
Soleil Soft-Touch Anti-Wrinkle Sun Cream SPF 15	Antiwrinkle sunscreen	Lancôme	It contains vitamin nanocapsules which help to preserve skin's youth effectively. SPF 15 offers optimal protection against the sun. It contains exclusive ingredients to guarantee a long-lasting effect.
Nano Gold Firming Treatment	Antiaging	Chantecaille	Infinitely small nanoparticles of pure gold are bound to silk microfibers to firm and tone skin, while delivering incredible anti-inflammatory, healing, and age defying power.
Nanosphere Plus	Antiaging	DermaSwiss	A stem cells revolutionary antiaging therapy Nanosphere Plus serum has been specially formulated to allow natural stem cells to preserve and protect skin cells. Using the cells from a rare Swiss apple (Uttwiler Spatlauber), Nanosphere Plus protects longevity and combats chronological aging.
Zelens Fullerene C-60 Night Cream	Antiaging	Zelens	Fullerene C-60 is a naturally occurring microscopic form of carbon which was found to have remarkable antioxidant properties.
Clearly It! Complexion Mist	Antiacne	Kara Vita	This nanosphere technology-based product tackles acne conditions and balances sebum production. Nanosphere time-released bioactives stimulate capillary activity for all-day detoxifying results.
DiorSnow Pure UV Base SPF 50	Sunscreen	Dior	Contains nano-UV filters for ultraprotection against the damaging effects of UVA and UVB rays.

Continued Table 1. Various cosmeceuticals on the market that use nanotechnology [17].

Product	Proposed use	Manufacturer	Marketing claims
Soleil Instant Cooling Sun Spritz SPF 15	Sun protection spray	Lancôme	Contains vitamin nanocapsule. Instant cooling sun spray SPF 15 immediately offers a sensation of freshness. SPF 15 provides optimal protection against the sun.
Fresh As A Daisy Body Lotion	Body lotion	Kara Vita	This lotion uses nanospheres to quickly penetrate, moisturize, and nourish all types of skin.
Cosil Nano Beauty Soap	Cleanser	Natural Korea	Silver nanoparticles are highly effective as disinfectant and guarantee protection of skin.
CosilWhitening Mask	Face mask	Natural Korea	Made with nanocolloidal silver used for the effect of getting rid of germs from your face, compressing pores, soothing the skin condition, and keeping your skin radiant and soft.
Nanorama—Nano Gold Mask Pack	Face mask	LEXON NanoTech	It contains pure nanosized gold that is highly effective in penetrating small pores and disinfecting skin, helps to reduce pore size, and prevents and treats acne. It is well known that nanogold is very effective disinfectants.
Primordiale Optimum Lip	Lip treatment	Lancôme	Delivers 100% botanically pure vitamin E via nanocapsule technology to reduce lip bleeding and feathering due to fine lines and wrinkles.
Lip Tender	Lip moisturizer	Kara Vita	Ten bioactive ingredients are precisely calculated to work within lyphazomes, delivering a 4-in-1formula and bringing long-lasting hydration for fast and dramatic lip repair.
Nano Cyclic Cleanser Silver	Cleanser	Nano Cyclic	Cyclic cleanser is a scientifically balanced blend of nanosilver and natural ingredients. It kills harmful bacteria and fungi, treats acne, exfoliates dead skin on all parts of the body, diminishes age spots, deodorizes the body, and fights wrinkles.
LifePak Nano	Face gel	Pharmanex	LifePak Nano is a nutritional antiaging program formulated to nourish and protect cells, tissues, and organs in the body with the specific purpose of guarding against the ravages of aging. Nanoencapsulation increases bioavailability coenzyme Q10 by 5–10 times.

manufacturer of the hand Kit, "thermo-active Nano Exfoliating technology delivers strong dermabrasive characteristics without creating long-lasting redness or harming the skin." In order to moisturize the skin, Tracie Martyn Shakti Resculpting Body Cream says it "uses nanotechnology to release natural black currant lipids deep into the skin." According to St Herb Nano Breast Cream, which claims to combine "nanotechnology and the venerable Thai herb, Pueraria Mirifica," nanosomes "expand the cellular substructure and development of the lobules and alveoli of the breasts," resulting in breasts that are larger, ranging from one to three cups.

Nanoclusters TM, "nanoclusters to give your hair a healthy shine," are used in the Nanoceuticals Citrus Mint Shampoo and Conditioner from RBC Life Science. In the world of cosmetics, Serge Lutens Blusher's Nano Dispersion technology "creates an incredibly fine and light powder with amazing properties like great elasticity, extreme softness, and light diffusion." L'Oreal Revitalift Double Lifting anti-wrinkle cream contains pro-retinol A nanosomes and is the company's "first double-action cream that quickly firms the skin and minimizes the appearance of wrinkles." Lancôme Hydra Zen Cream "renews skin's healthy appearance with nano encapsulated Triceramides." Korea produces and markets Ace Silver Plus Nano silver toothpaste. According to reports, Ace Silver Plus Nano silver toothpaste is the first "re-mineralizing" toothpaste ever created, enhancing dental health by encouraging natural healing.

CURRENT STATUS & FUTURE OPPORTUNITIES

Researchers must carefully examine the solubility and bio-persistence of the nanomaterials because this field of technology is still quite young. Titanium dioxide, zinc oxide, and aluminum oxide are the three nano pigments that are most frequently employed in cosmetics. Nano-aluminum oxide is used in mineral foundations and concealers to mask wrinkles since it diffuses and softens light's focus. Nano-titanium dioxide is used to block the sun's UV radiation. Titanium dioxide is white and opaque as a bigger particle. However, titanium dioxide turns transparent at the nanoscale. Iron oxide nanoparticles are employed as pigments. Present-day face masks used in salons and beauty clinics sometimes contain gold nanoparticles. It is thought to operate by increasing blood flow, skin suppleness, and preventing wrinkles forming. Additionally, they have no adverse effects on human skin [120–122]. The National Institute for Occupational Safety and Health (NIOSH) conducted a study in 2005 that revealed trace amounts of breathed TiO_2 to be an unlikely contributor to human cancer.

A precisely designed nanoparticle to cover the uneven sections may open new vistas, particularly after plastic surgery for the aesthetic appeal of biological components. The release of nanomaterials driven by a skin pH gradient is another fascinating area. The combination of proteins and enzymes is also gaining interest due to their exceptional capacity to suck water into the horny layers of skin. Nanomaterials are extensively used in the cosmetics sector for a variety of functions, including UV filters and preservatives. According to tests on non-cytotoxic nanoparticle concentrations, silver nano particles (AgNPs) made from fenugreek leaves had the least amount of cytotoxicity against HaCaT cells when they were present in solutions at a concentration of 250 g/mL [123]. AgNPs produced from Albizia lebbeck flowers were biocompatible with the cell lines A549, as shown by the nanoparticles' biocompatibility at doses ranging from 2 g per ml to 50 g per ml [124]. The biocompatibility of nanoparticles was demonstrated by the fact that normal cell lines, glial cell lines, and breast cancer cell lines were unaffected by iron oxide nanoparticles at concentrations of 0.1–10 g/mL [125].

CHALLENGES

Nanomaterials have been harmful to human tissue and cell cultures, increasing oxidative stress and cell death. These have the ability to cause cytotoxicity, cancer, and pulmonary fibrosis [126]. Despite an extensive literature, we remain unaware of the nanomaterials' capacity to enter the dermis, and that's what makes them dangerous. However, it appears from the research sources that particular situations and distinctive traits, including its small size, assist the assimilation of nanomaterials, which creates major challenges[127]. Nanoparticles that have been topically administered may not necessarily cause harm by penetrating the dermis. Dror Cohen *et al.* (2013) proposed that soluble ions are generated when copper oxide (CuO) nanoparticles interact with the surrounding acidic environment. The skin of a person can be easily penetrated

by these soluble ions[128]. Some observations were made, after conducting research on skin organ cultivation. Titanium dioxide molecules have recently been found to be safe and non-carcinogenic according to results of a mice medium-term skin carcinogenesis bioassay. There was no evidence of any activity that could have resulted in skin cancer after dermal injection in mice [129] . According to the Scientific Committee on Consumer Safety, nanoparticles employed as UV filters in sunscreens at a concentration of under 25% are safe to use. According to this discussion, there is currently a lack of information regarding the toxic effects of nanomaterials, especially those utilized in cosmetics.

Numerous studies have revealed that the carbon fullerenes used in some face creams and moisturizers now have the potential to harm fish brains, have bactericidal qualities and destroy water fleas [130, 131] . In a study by Dhawan et al., the author revealed that there is a high link between genotoxic response and fullerene concentration, indicating that stable aqueous suspensions of colloidal C60 fullerenes have shown genotoxicity [132].It has even been discovered that fullerenes are harmful to vascular endothelial cells [133].

CONCLUSION

The most important technological advance of the twenty-first century is nanotechnology, and it offers excellent opportunities for both business and academic research. High technological and financial expectations have been raised by the quick uptake and implementation of nanotechnology in cosmetics, but they have also raised concerns about new threats to consumer health and safety. As a result, nanotechnology-based cosmeceutical products must be produced and marketed with the utmost regard for both the environment and consumer health.

Based on all above applications and challenges, it can be concluded that nanoparticles used in cosmetics have substantial health advantages and are useful, however, they must be sensitively described to assure their safe usage and total removal from the body. At their core, cosmetics must be both genuinely effective and secure. The cost factor is also a big hindrance to the market of nano cosmetics.

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CONFLICT OF INTEREST

The authors confirm that there is no conflict of interest in this article content.

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