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Review Article

NANOPARTICLES IN COSMETIC SCIENCE: A REVIEW

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Abstract: This review article is intended for the development of nanoparticles in cosmetics and the application of the nanoparticles in the cosmetic industry. The development of nanotechnology is going on at a steady pace for past few decades. The science of controlling molecules, atoms, particles in the nanoscale is called Nanotechnology, which is 80,00 times thinner than the diameter of a human's hair. The world nanotechnology market size was valued USD 1.76 billion in 2020, and is forecasted to grow at a compound annual growth rate (CAGR) of 36.4 % from 2021 to 2030. Almost every cosmetic product is having nanoparticles as their constituents. The applications of nanotechnology in cosmetic products are called Nano-cosmetics. Nano-cosmeceuticals are utilized to fight against wrinkles, hyperpigmentation and dandruff. Nanotechnology offers various novel nanocarriers such as solid lipid nanoparticles, micro-emulsion, nano-vesicles, liposomes, fullerenes, nano-somes, nanostructured lipid carrier, nano-emulsions and nanospheres that act as transporters in order to eliminate the problems linkedto conventional dosage form. These nanocarriers prevent cosmetic agents from degradation, leakage, ultraviolet radiations and stability problems and hence increase the formulation efficacy, skin penetration and controlled delivery of active ingredients. On the contrary, the use of nanoparticles in cosmetic products can raise safety concerns and can cause environmental and health issues. Agencies like USA Food and Drug Administration, European commission ECHA, Nanotech in Brazil implemented laws for continuous testing and transparency based on researchesin order to ensure safety, effectiveness, quality of the cosmetic products containing nanoparticles. Food and Drug Administration(FDA) in the United States will be in charge of consumer products that include nanoparticles in cosmetics, food and pharmaceutical products.

Keywords: Nanoparticles, Cosmetics

Dr. Jaishree Vaijanathappa M. Pharm. Ph. D, Professor and Head, Faculty of Life Sciences, Mauritius. She Experienced in Teaching and Research and strong sense of academic integrity. The output of her research work are several international and national indexed publications and two patents. Organized several conferences, seminars and Faculty Development Programs. Supervised around 35 Postgraduate students and few PhD students. Received Senior Research Fellowship 2007- 2008 Oct (ICMR) and Best Poster Award in One Day Symposium on Future Directions of NMR Research Centre, Indian Institute of Sciences, Bangalore on 25th August 2007.

Dedication: This work is dedicated to Dr. P.D. Gupta on his 85th birthday.

INTRODUCTION

Cosmeticscience is the application or use of pharmaceutical chemistry methods or procedures in the development of cosmetics. The importance of beauty in human affairs has long appreciated by people and helps in career development and ultimate achievement. Throughout history till the modern times, different forms of cosmetics and toiletries have been used by both men and women to improve health, scent and appearance. Cosmetics are mostly available in the form of creams, lipsticks, perfumes, foundations, nail polishes, hair sprays, shampoos and hand sanitizer. The cosmetics industry is one of the most proliferated industries across the globe and nanoparticles are being used in cosmetic products for various effects. Furthermore, the recent Covid-19 pandemic had a great impact on the cosmetic industry and the consumers are changing their perspectives towards a more clean and natural products thus increasing the demand of safer and transparent cosmetic products [1,2] The global nanoparticle titanium dioxide market was valued at $ 9.7 billion in 2020, and is expected to reach $17.3 billion in 2030, growing a CAGR of 6.1% from 2021 to 2030 hence encouraging the use of nanoparticles in cosmetic products especially sun care and anti-aging products as it enhances the product quality and efficacy [3]. Nanoparticles are helping to formulate safer products and to reduce the use of toxins.

Nanoparticles can adjust certain properties of cosmetic products including color, stability, transparency, solubility, long-lasting effects, stability and chemical reactivity [4]. Till date, regulatory agencies have not yet established a definition for nanoparticles. The nanoparticles are considered as the ultrafine particles in the size of nanometer order. "Nano" is a prefix indicating the minus ninth power of ten, namely one billionth and the numerical "nano" is a Greek word which means dwarf. Nanoparticles are in the size range of 1 to 100 nm (nanometer) or in the three digits range of nanometer from 1 nm (nanometer) to 1 µm (micro-meter). Nanoparticles are referred as nanomaterials. According to Cosmos Standard, nanomaterial is defined as "an insoluble or bio persistent and intentionally manufactured material with one or more external dimensions, or an internal structure, on the scale from 1 to 100 nm." Nanoparticles are obtained from nature for instance from blood borne proteins and lipids, carbon and minerals like silver and gold. Nanoparticles has been used since the first century B.C. in Egypt, where Queen Cleopatra is said to have used masks made up of gold nanoparticles to maintain fair skin complexion. In 1986, the technology of liposomes and niosomes which are currently used as delivery vehicles in cosmetics were formulated by the L'Oréal group for Lancôme, and "Capture®" was designed by LVMH under the Dior brand [5]. Other personal care industries and some independent research institutes are using nanoparticles to create new formulations for broaderbeauty care products.

In modern times, nanoparticles are employed in cosmetics as active ingredients and novel nanocarriers providing a better UV protection, deeper skin penetration, easy repairing skin damage, increasing stability, solubility, shell-life and quality. Cosmetics containing nanoparticles are called nano-cosmetics.However, research has found some alarming problems when nanoparticles are included in cosmetics, it starts to destroy important micro-organisms in the environment and human health. The presence of high reactivity of nanoparticles because of high surface to volume ratio increasing the level of toxicity. Relatively small number of nanoparticles should be inserted into cosmetic product since large amount can lead to an increased entry of nanoparticles in the skin and affects the human cells. The USA Food and Drug Administration plays an important role in monitoring the use of nanoparticles and the use of nanoscale materials in cosmetics.[6] The review article focuses on the benefits and the negative impacts of nanoparticles in cosmetic science along with the uses and types of nanoparticles mainly used in the cosmetic industry. Application of nanoparticles and nanoparticles interaction with the skin surface are highlighted.

The types of nanoparticles used in cosmetic science: There is no single type of nanoparticle. Nanoparticles in cosmetics can differ according to composition, particle size, shape, surface coatings and strength of particle bonds [7].

- Zero-dimensional nanoparticles are all dimensions (x,y,z) are at nanoscale for instance the dimensions should not exceed 100 nm. Nanospheres, nanoclusters, graphene quantum dots, gold nanoparticles and fullerenes are examples of zero dimensional nanoparticles.

- One dimensional nanoparticles (1D) are when two dimensions (x,y) are at nanoscale and one dimensional remains large that is outside the nanoscale and electron is allowed to move along this dimension. The examples that follow one-dimensional nanoparticles include polymeric nanofibers, self-assembled structures, nanotubes (carbon and metallic), gold nanowires and metal nanorods (ceramic crystals).
- Two dimensional nanoparticles (2D) are nanoparticles that contain two dimensions outside the nanoscale. Two dimensions stay long and electron is allowed to move along the same two directions. Those are graphene sheets, layered nanomaterials nanofilms, nano-wells, nano-coatings, liposome, polycrystalline, dendrimer and nanolayers.
- Three- dimensional nanoparticles (3D) are particles that are not restricted to nanoscale in any dimension therefore the electron is allowed to pass in all three directions (x, y, z). The nanoparticles that are three dimensional are nanopowders, bulk nanomaterials and multi layered nanotubes (polycrystals).

Moreover, nanoparticles can also be classified as:

- Carbon based nanoparticles : they are primarily-composed of carbon such as graphene, fullerene, CNTs, carbon dots, diamond and bucky balls.
- Inorganic based nanoparticles: metal based inorganic nanomaterials are silver, gold, aluminium, cadmium, copper, iron, lead and zinc. Metal oxide based include titanium dioxide, iron oxide, cerium oxide, zinc oxide and silicone dioxide.
- Organic based nanoparticles dendrimers, cyclodextrin, liposome and micelle.
- Composite based nanoparticles are complicated structures like a metal organic framework and bulk type materials such as nanosized clays which are incorporated in products in order to increase thermal barrier and mechanical properties.
- Dendrimers are repeated branches molecules. They are nanosized polymers made up of repeated branched molecules. The surface of a dendrimer has many chains ends, which enables it to perform chemical functions. They are utilized in drug delivery.
- Metallic based nanoparticles are made of metals and its derivatives and they possess specialized optoelectrical properties. Nanoparticlesof alkali and noble metals(gold, silver, copper and other metals).
- Ceramics based nanoparticles are made of materials produced by high temperature firing of inorganic, non-metallic rocks and minerals. They can be in the form of amorphous, polycrystalline, dense or hollow forms. They undergo reactions such as catalysis, photocatalysis and photo degradation of dyes.
- Semi-conductor based nanoparticles are substances with electrical properties such as a good conductor (metal) and a good insulator (non-metal). These materials show immense importance in photocatalysis, photo optics and electronic equipment.
- Polymeric-based nanoparticles are organic-based nanoparticles namely nanospheres or nano-capsules. They help in the synthesis of lipid nanoparticles and act as drug carriers and delivery.

Types of nanoparticles mainly used in cosmetic science:

Nano-emulsions: Nano-emulsions are one of the most advanced nanoparticles used for cosmetics formulation. Nano-emulsions are thermodynamically unstable system containing mixture of two or more immiscible liquids which is stabilized using an emulsifying agent. Nano-emulsions are biphasic systems composed of oil and aqueous phase, and one or more emulsifying agents. Nano- emulsions are in the size range of 50 to 1000 nm. They are non-vesicular nanoparticles.Emulsification and solubilization technologies are used in various care cosmetics products such as skin lotions, shampoos, deodorants and creams. When changing the sequence of pressure in the process of mixing water and oil, it enables the controlling of the size of emulsified particles from 1 to 10 mm to several tens of nanometers. Nano-emulsions synthesis is a two-step process where a macro-emulsion is primarily prepared and then converted to a nano-emulsion in a second step. The nano-emulsions synthesis is classified into high-low energy methods namely micro fluidization, high-pressure homogenization and so on.There are two main types of manufacturing nano-emulsions namely surface chemical methods and mechanical methods. Although the dispersion methods such as the phase-transfer emulsification method [8], the hydrophilic-lipophilic balance temperature emulsification method [9], the D-phase emulsification method [10], the amino acid gel emulsification method [11] and the aggregation [12] methods are used. Moreover, an emulsifying machine having a large shear force is required to get an emulsion with small particle diameters. Mechanical forces such as shear force, shock force, cavitation force, frictional force and compression force can be obtained in crushing and rotating equipment such as mills, low-speed stirring machine, high-speed shear stirring machine, high pressure homogenizer, ultrasonic emulsifying machine and static machine. Even in a formulation that include the same oil as white opalescence cream, by changing the emulsified particles into nanoparticles by applying pressure as depicted as water [13].

When nano-emulsions are applied to the skin, there is a feeling of smoothness and high penetration to the surface of the skin and thereby increasing the skin hydration. Nano-emulsions are used in cosmetic science to provide the products with a prolonged shelf life, better texture, high surface area, good stability and less viscosity. Nano-emulsions can be formulated into foams, creams, lotions, sprays and liquids. They do not show difficulties such as sedimentation, coalescence, creaming and flocculation. Nano-emulsions are so small particles that they can be sprayed on and are able to rise the content of nourishing oil, and to preserve the transparency and lightness of the formula. Pure Ology, a company which began experimenting with nano-emulsions in 2000 and started to create a product line especially developed for color treated hair. They are considered safe and are mostly being used in sunscreens, shampoos, hair serum and nail enamels as they improve the fluidity with a lustrous film with active ingredients through the skin (Fig. 1). Other nano-emulsions technologies have been developed for various effects including sun protection, anti-wrinkling and anti-aging of the skin [14,15].

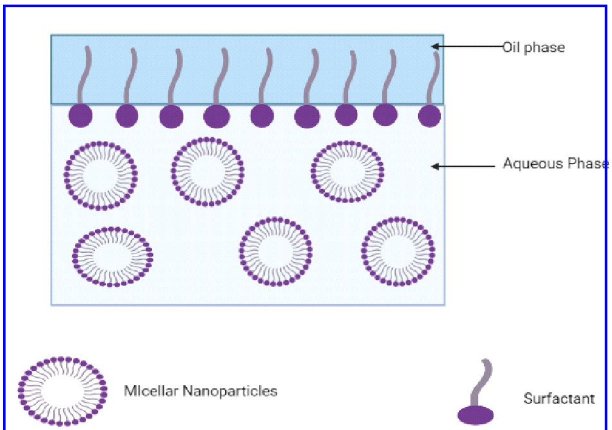


Fig. 1: A diagram showing micellar nanoparticles formation in a nano-emulsion system

Nano-liposomes: Nano-liposomes are vesicular structures with an aqueous core surrounded by a hydrophobic lipid bilayer, created by the extrusion of phospholipids and cholesterol in the presence of heat energy. The phospholipids are GRAS (generally recognized as safe) ingredients, hence can minimize the potential adverse effects. The phospholipids could be unsaturated or saturated. However, the unsaturated phospholipids for instance egg phosphatidyl choline are less stable but more permeable [16]. The first method involved in the synthesis of nano-liposomes was extrusion.Nano-liposomes are presently synthesized by sonication method and Micro-fluidization method [17]. These liposomes act as vehicles to deliver enclosed desired molecules into the skin therefore enhancing penetration of nanoparticles in skin and improving skin hydration, texture, reducing wrinkles and fine lines [18]. Nano-liposomes' size is in the range of 25 - few hundred microns.Nano-liposomes are used in the cosmetic science since they have several advantages such as non-toxic, biodegradable, flexibility, reduce the exposure of sensitive tissues to toxic ingredients thus an easy and safe delivery as they can trap cosmetic ingredients, releasing their contents at the localized area. Nano-liposomes have aided antioxidants, lipid molecules, vitamins like A, E, C to deliver into the epidermis of the skin improving the stability of the product. Especial care should be taken while incorporating nano-liposomes into cosmetic products as they have certain drawbacks for example low solubility, short shelf-life, production cost is high and phospholipid can undergo oxidation and hydrolysis reaction. The first nano-liposomes cosmetic product was an anti-aging cream 'Capture' launched by Dior in 1986[19]. Nano-liposomes are mostly being used in shampoos, sunscreens and creams [20].

Niosomes: Niosomes are non-ionic surfactants-based vesicles that have a similar structure to that of phospholipid vesicles like liposomes. They are considered as vesicular delivery systems. They can be used to encapsulate aqueous solutes and act as drug and cosmetic carriers. They are formed by self-assembly of non-ionic surfactants with or without cholesterol in aqueous medium. Non-ionic surfactants can be from a mix of polysorbate 80 and tween 20 together with an optimum level of cholesterol [21,22]. Niosomes size range can be from 100-2000 nm. Niosomes are synthesized from the method of ether injection method, thin-film hydration technique and reverse-phase evaporation technique [23,24]. Niosomes are used in cosmetic science as they increase product effectiveness, improve bioavailability, increasing stability and penetration into the epidermis of the skin thus they can be considered as drug delivery vehicles. Other advantages are because they are stable, osmotically active, non-toxic and biodegradable. The banes of using niosomes are as they provide insufficient drug loading capacity, leakage of entrapped drug, leads to aggregation and are expensive. Moisturizing creams and lotions, skin whitening creams, anti-wrinkle creams, shampoos and conditions have been formulated through noisome since past few years. [25,26]

Dendrimers: Dendrimers are monodispersed, unimolecular, multivalent macromolecules. The word "dendrimers'' is derived from a Greek word ''dendron'' which means "tree". They are family of nanosized, highly branched three-dimensional molecules and are in the size range of 2-20 nm. In 1985, the synthesis of polyamidoamine (PAMAM) dendrimer was a turning point. In 1985, Newkome dendrimers were one of the first artificially synthesized dendrimers. The characterization of dendritic polymers are spectroscopy methods, scattering techniques, electrical techniques, chromatographic techniques, microscopy and rheology. Dendrimers are synthesized by divergent method and convergent method [27,28]. Dendrimers have properties like mono-dispersity, polyvalence, stability, nanoscale size and shape, viscosity, high aqueous solubility, high solubility in non-polar solutions, low compressibility, non-crystalline and have low glass temperature therefore making them suitable in delivering ingredients in or through the skin. Dendrimers play an important role in cosmetic science as they are biocompatible, readily react due to its nanostructure, degradation can be controlled as well as molecular weight and size, these benefits increase the use of dendrimers in the cosmetic industry.Dendrimers have been used in various cosmetic products such as sun care products, shampoos, anti-care creams and hair styling materials [29,30]. The cosmetic companies such as Dow Chemical Company, L'Oreal, Revlon, and Unilever, have registered patents on dendrimer-dependent cosmetic preparations for various applications for skin, nail, and hair care products.

Solid Lipid Nanoparticles: Solid lipid nanoparticles (SLN) were evolved at the beginning of the 1990 s as an alternative carrier system to emulsions, liposomes and polymeric nanoparticles.[31]. They are sub-micron colloidal carriers ranging from 50-1000 nm, which are composed of a physiological lipid dispersed in water or in aqueous surfactant solution. They are non-vesicular nanoparticles. Solid lipid nanoparticles were discovered by Gasco and Muller in 1991 and were initially designed to overcome the disadvantages associated with liquid state of the oil droplets.These nanoparticles are made up of solid lipids form the oil phase and are well known as solidified oil-in-water emulsion. They are manufactured from solvent-emulsification evaporation technique, high pressure homogenization, high speed homogenization and micro-emulsion technique [34]. The utilization of solid lipid nanoparticles made absorption of these nanoparticles easy during topical applications. Being hydrophobic in nature, the particles help in protecting the skin from hydration thus maintaining the moisture content of the skin. Henceforth, solid lipid nanoparticles usage increased through times as they enhanced skin penetration, controlled the formation of occlusive layer, stability lowering drug leakages and are non-toxic and biocompatible. The drawbacks of implementing solid lipid nanoparticles are mostly due to poor drug loading capacity, relatively high-water content of the dispersions, low capacity to load hydrophilic drugs due to partitioning effects during the production process and lastly, drug expulsion after polymeric transition during storage [32-35]. Solid lipid nanoparticles have shown UV-resistant properties, especially when (SLN) 3,4,5-trimethox ybenoylchitin was incorporated and tested [36]. Consequently, solid lipid particles can form an occlusive adhesive film on the skin surface and acts as good UV absorbers reducing toxicity of ingredients added in the formulation of the products thus making them a salient nanoparticle in the cosmetic science (Table 1).

Table 1: Advantages of Polymeric Nanoparticles against Solid Liquid Nanoparticles

Polymeric Nanoparticles	Solid Liquid Nanoparticles
Residual contamination	A void residual contamination
Can result in toxicity problems	No toxicity problems
Expensive production and lack of large-scale production method.	Cheap and unexpensive methods are available
Absence of suitable sterilization method	Presence of suitable sterilization method
Not stable as solid lipid nanoparticles	Solid liquid nanoparticels' formulation stable for even three years have been developed.

Nanostructured Lipid Carriers (NLC): Nanostructured lipid carriers are second-generation of solid lipid nanoparticles and are attracting attention as novel nanocarriers for cosmetics use. They fall into the category of non-vesicular nanoparticles. Nanostructured lipid carriers(NLC) are composed of a binary mixture of solid lipid and a spatially different liquid lipid as a hybrid carrier. In NLC the oil phase is a blend of liquid and solid lipids. Their average size is between 10-500 nm. NLC contains a mixture of blended solid liquid (long chain) with liquid lipid (short chain), preferably in a ratio of 70:30 to 99.9:0.1. NLC manufacturing techniques are high-pressure homogenization, micro-emulsion technique, phase inversion, solvent emulsification evaporation technique and solvent diffusion method [34]. The boons of having nanostructured lipid carriers in cosmetic science are because they are physically stable, have low level of toxicity and cytotoxicity, have higher drug loading capacity, higher water content in dispersions, ease of preparation and scale-up, and extended release of drug. Some common examples of NLC are mostly solid lipids (Beeswax, Stearic acid), liquid lipids (castor oil, olive oil, palm oil, oleic acid, cetiolV), emulsifying agents which is absorbed at interfaces and lowers interfacial tension therefore enhancing colloidal stability by decreasing either or both the rates of aggregation (Tween 80, Plaronic F68, Polaxamer 188 and Phospolipon 90G) [37-41]. In addition, NLC act as UV blockers thus help to protect the skin from ultraviolet radiation of the sun, lowering the risk of skin cancer. Nano-structured lipid carriers (NLCs) are applied to encapsulate UV filters with pumpkin and kenaf seed oils and avobenzone. Kenaf seed oil-NLC is selected as the best formulation for UV filters encapsulation. With spherical amorphous NLC structure, it shows high entrapment efficiency for the UV filters and antioxidant activities. Results indicate that kenaf seed oil absorbing capacity is high and remains physically stable upon 12 weeks of storage period [42]. Furthermore, nanostructured lipid carriers are encouraged to utilized them in cosmetic products since they increase in skin occlusion and adhesiveness to the skin, they help in repairing stratum corneum layer of the skin and they increase skin hydration and elasticity. They also enhanced skin permeation, drug targeting and chemical stability of chemically labile compounds [37,38]. Minoxidil loaded NLC based hydrogel formulation is a drug widely used for the treatment of alopecia. NLC systems with good perspective are being marketed successfully due to low cost, regulatory excipient status and their good qualification and validation. For instance, Nano-Lipid Restore CLR® developed by Chemisches Laboratorium Dr. Kurt Richter, Germany and distributed by Pharmacos India whereby the white or yellow liquid NLC dispersion containing black current seed oil, as liquid lipid. This oil is rich in omega-3 and omega-6 fatty acids which are designed for regenerative care of dry, scaly, rough and old skin, restoring the skin barrier and reducing trans-epidermal water loss(TEWL). Besides, the NLC technology is able to safeguard the fatty acids against oxidation and permits a controlled release of the incorporated black current seed oil. Other constituents of this dispersion include carnauba wax as solid-lipid, decyl glucoside as a surfactant and water as a solvent. Nano-Lipid Restore CLR® is a semi-finished product used in the cosmetic product line IOPE® from Amore Pacific, South Korea. Moreover, other products containing NLC are in the market such as Nanorepair Q10® (cream and serum) and Nanovital Q10® (cream) from Cutanova® (Dr.Rimpler, Germany) and Surmer® from Isabelle Lancray (France) [43].

Both NLC and SLN (solid lipid nanoparticles) are acting as topical vehicles for perfumes, fragrances and repellents because of prolonged release of perfume has the advantage of making a once- a-day application with extended effect over several hours. This demonstration was done by comparing a SLN or NLC with an oil in water emulsions. In the first hours, similar release of perfume from outer layers of the particles. However, during the remaining 10 hours, the release from SLN was lengthen. After 6 hours, 100 % of perfume was liberated from emulsion compared to SLN only 75% was released. Eventually, this property can be excellent in the delivery of insect repellents to be applied onto the skin [44,45].

Nano-capsules: Nano-capsules are nano-vesicles systems that exhibit a typical core-shell structure in which a polymeric membrane surrounds and encapsulates a liquid core (oil). They are considered as polymeric nanoparticles and is an advanced technique of nanotechnology [46]. Nanoencapsulation involves forming drug loaded particles with diameters ranging from 1 to 1000 nm. Nano-capsules are prepared by Nano-precipitation method, Emulsion- diffusion method, Double- emulsification method, Emulsion-coacervation method and Polymer-coating method [49]. The main use of nano-capsules in cosmetic science are to prevent undesirable side effects, increase drug bioavailability, lowering drug degradation upon administration and act as nanoparticles carriers that can be targeted to specific cells and locations within the body. Nano-capsules are used in cosmetics for protection of ingredients, minimizing unwanted body odors and remove incompatibility issues between formulation components [46]. One of the first nano-capsule based products available in the market was anti-wrinkle lotion with vitamin A nano-capsules that gradually discharge the active through time. L'Oréal marketed Primordiale Intense and Hydra Zen Serum using nano-capsules to encapsulate various active ingredients [50]. The advantages of using nano-capsules are higher dose loading, greater protection from degradation during storage and after administration, increase bioavailability of product, control and sustain release of particles at the localized site. Nano-capsule suspensions can be directly applied on the skin. The degree of skin penetration of an ingredient depends on the raw materials like surfactant and polymers inserted into cosmetics [47]. Some of the disadvantages using nano-capsules in cosmetics are cytotoxicity, limited target abilities and prolonged use of poly vinyl alcohol as a detergent cause toxicity and irritation. Nano-capsules particles like stabilized poly-lactic acid with a diameter of approximately 115 nm were prepared through nanoprecipitation, and a sustained liberation of perfume, by entrapping molecules in a polymeric nano-carrier was achieved. Henceforth, nano-capsules play an essential role in the formulation of fragrances, perfumes and deodorant [48]. Additionally, the application of nano-capsules has diminished the penetration of UV filter octyl methoxycinnamate in skin over customary mixtures. Nano-capsules were tested as sunscreen carriers for octyl methoxy-cinnamate (OMC) produced from polymer PCL, octyl salicylate, and benzophenone-3. They created a protective layer on the surface of the skin and decelerated the permeation of the actives in sunscreen to the applicable layer. Octyl methoxycinnamate (OMC) was encapsulated in cellulose acetate phthalate nano-capsules and octyl methoxycinnamate (OMC) was encapsulated in cellulose acetate phthalate nano-capsules and its penetration in the SC was compared to nano-emulsion. Nano-capsules were not effective in delivering OMC as opposed to encapsulation of benzophenone-3 were more effective [50].

Nanospheres: Nanospheres are solid polymeric particles and matrix type structure in which a drug or an active ingredient is dispersed. Nanospheres are manufactured by solvo-thermal routes where charged metallic copper powder and carbon tetrachloride are placed into a teflon-lined cylindrical stainless-steel autoclave sealed, heated up to 200 °C within 30 min, and maintained at 200 °C for 2 hours in an oven, then are cooled, the product collected are then treated with nitric acid for 20 hours under ambient conditions stirring. The product recovered by filtration, washed with deionized water dried at 60 °C for 10 hours. The nanospheres are in the size range of 10 to 200 nm. They are amorphous, crystalline in nature, biodegradable and non-biodegradable [51]. Biodegradable nanospheres consists of gelatin nanospheres, modified starch nanospheres, and albumin nanospheres and nonbiodegradable nanospheres are for example polylactic acid, which is the only approved polymer. The incorporation of nanospheres in cosmetic science bring certain benefits such as they reduce toxicity, controlled release, site specific targeting and allow easy penetration in skin. Nanospheres play a significant role in cosmetic science as they enable deep and precise delivery of active ingredients into the epidermis of the skin. Most common cosmetics products having nanospheres are anti-aging, anti-acne, anti-wrinkle and moisturizing creams [52,53].

Nanocrystals: Nanocrystals are the substance in which a drug or an active ingredient is combined with a polymer. They are pure solid particles with a mean diameter below 1000 nm. The term nanocrystals implya crystalline state of discrete particles, but depending on the production method they can also be partially or completely amorphous. They do not contain of any matrix material. They are formed by decreasing the particle size, causing an increase in solubility of the drug. Nanocrystals are formed by precipitation method or size reduction techniques. The advantages of using nanocrystals in cosmetic formulation are that they enhanced bioavailability, suitable for administration by all routes and increased solubility [54,55]. A cosmetic company named Juvena produced nanocrystals formulation of rutin, an antioxidant, Juvedical®, in 2000. A study has shown that the original rutin molecule is 500 times more bioactive in contrast to the water-soluble form, rutin glycoside. This study between rutin nanocrystal and rutin glycoside was based on its sun protective factor. [56,57].

Gold nanoparticles and silver nanoparticles: Global gold nanoparticles consumption is projected to reach over 20,000 kilo grams by 2022 [58]. Gold nanoparticles are also known as colloidal gold and their size range are from 5 nm to 400 nm [59]. The properties of gold nanoparticles consisted of having optical properties like plasmon resonance, provide microscopic probes for the study of cancerous cells, are stable and chemically inert, biocompatible and have high stability due gold sulfur bond [59]. During ancient time, Queen Cleopatra who reigned in the first century B.C is believed to have used gold masks to maintain a fair and young complexion. Ancient Chinese masseurs used the glittering powder to decrease wrinkles and to maintain smooth skin. Gold nanoparticles cosmetic care are exorbitant in price, while considering their benefits it covered this disadvantage. Moreover, the advantages of incorporating gold nanoparticles are that they reduced wrinkles, acne spots and fine lines and helped in stimulation of skin cells. They are also used to slow down collagen depletion, in treating inflammation and skin ulcers, in increasing skin hydration and glow and help to reduce hyperpigmentation [64]. Gold nanoparticles have both anti-bacterial and anti-inflammatory properties, when applied on the skin, it retards cell degradation from free radicals hence increasing oxygen penetration and blood flow, which reduces inflammations. When increased blood flow, gold nanoparticles help to retain moisture. This helped to rise hydration reduces skin dryness which imparts a glossy effect on the skin [64]. A vivo studies has shown that gold nanoparticles together with collagen will demonstrate high wound closure percentage, decreased inflammatory response and increased granulation tissue formation [65]. Besides, gold nanoparticles have anti-aging effects thus can improve skin texture, elasticity and firmness. They are suitable for treating acne, sun-damaged and sensitive skin (Fig. 2).

Silver nanoparticles are also termed as colloidal silver or nano silver. "The global silver nanoparticles market was at USD 1.8 billion in 2019, and is projected to reach USD 4.1 billion by 2027, growing at a CAGR

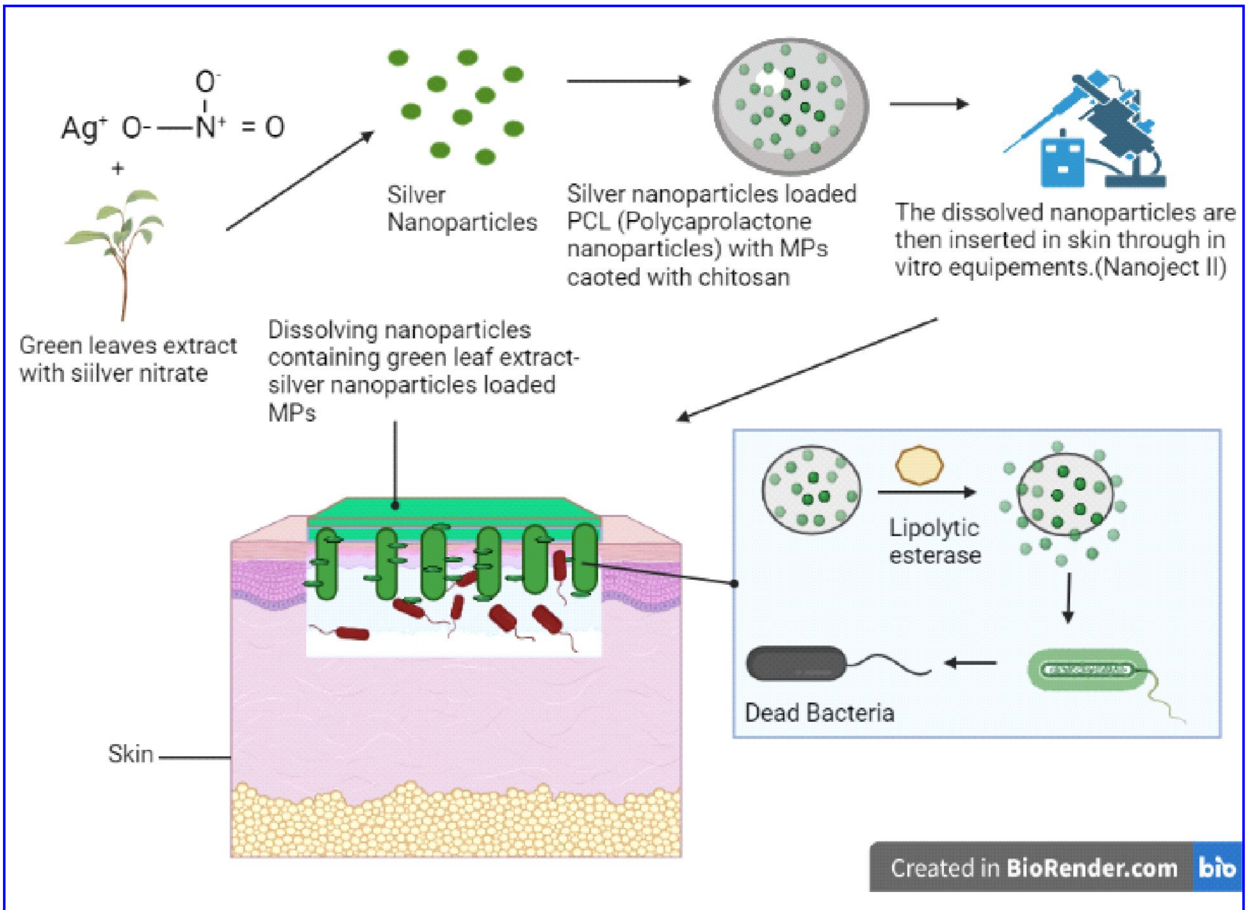


Fig. 2: A diagram illustrating the reactions of silver nanoparticles when it permeated into skin.

of 15.7 % from 2020 to 2027" [61]. Silver nanoparticles are most commonly in toothpastes, shampoos and anti-acne creams. The properties of silver nanoparticles comprised of having a higher ability of water absorbance, having high electric and heat conductivity and inhibit the virus from attaching with host therefore making them anti-infective agents active against infectious organisms such as Vibrio cholerae, Pseudomonas aeruginosa, Syphilis typhus, and Staphylococcus aureus [60-63]. The cons of both gold and silver nanoparticles are the instability of the particles, impurity, biologically harmful, recycling and disposal and long-term cytotoxicity (Fig. 2).

Fullerenes and buckyballs: Fullerenes are closed hollow cages consisting of carbon atoms interconnected in pentagonal and hexagonal rings. Each carbon atom on the cage surface is bonded to three carbon neighbors therefore is sp^2 hybridized. C60 is most studied fullerene due to its availability, high symmetry and low cost. C_{60} is known as buckminsterfullerene and also by buckyballs. Buckyballs are 1 nm in diameter. They are made up of odd numbered carbon atoms arranged as rings so that it resemble the shape of a football. Fullerenes increase solubility in organic solvents and also enhances its processability. Due to its powerful antioxidant, they react readily and at a higher rate with free radicals, which can often lead to cell damage or death. They behave like a "radical sponge" so as it can sponge-up and neutralize 20 or more free radicals per fullerene molecule. Fullerenes possess a novel ability of selectively entering oxidation-damage cerebral endothelial cells rather than normal endothelial cells and then protect them from apoptosis. They improve skin absorption and helps to reduce fine lines, wrinkles, acne, open come-dons (blackhead) and dark-spots caused by oxidation of cells. A best example of cosmetic product having fullerene in the formulation is the UV Whitening cream wherein it contains Fullerene RS™, a patented Nobel Prize technology, which is a superior radical scavenger with unparallel anti-oxidation effect that remove free radicals and inhibits UVA-Induced melanin formation [66,67].

Cubosomes: Cubosomes are self- assembled nanostructured particles formed by aqueous lipid and surfactant systems. They have high heat stability, and are thermodynamically stable and capable of carrying hydrophilic and hydrophobic molecules. The purpose adding cubosomes in cosmetic science are as they are relatively simple method of preparation, high drug payloads due to high internal surface area and cubic crystalline structures. Other advantages include good biodegradability of lipids, capacity of encapsulating hydrophilic, hydrophobic and amphiphilic substances, targeted release and controlled release of bioactive agent, they remain stable almost at any dilution level because of the relative insolubility of cubic phase forming lipid in water and can be thermodynamically stable for long period of time. Large scale production is sometimes difficult because of high viscosity. Cubosomes can be manufactured by top-down technique and bottom-up technique (Liquid Cubosomes Precursors and powder Cubosomes Precursors) [68]. Cubosomes are used in personal care products such as skin care, hair care and antiperspirants. The cubic phase has been shown to provide a vehicle for several in vivo delivery routes, including depot, transdermal, muco-adhesion and ophthalmic. It increases the penetration of macro molecules. They are used in melanoma cancer therapy. Companies like L'Oreal and Niveaare trying to use cubosome particles as oil in water emulsion stabilizers and pollutant absorbents in cosmetics products [69].

Hydrogels: Hydrogels are water swollen polymeric materials that maintain a three-dimensional structure. They are classified as natural, synthetic or hybrid hydrogels based according to the nature of crosslinking. They are used in cosmetic science to maintain a significant effect on the efficacy of the products and to minimize drug degradation. Hydrogels are further used in preventing harmful side-effects and to increase drug bioavailability and drug delivery. The polyvinyl alcohol route prepared optically clear hydrogels containing 80-90% water but these hydrogels did not show mechanical properties necessary for use in contact lenses [70].

Nano-Hydroxyapatite: Nano- Hydroxyapatite (nano- HAp) is a cosmetic ingredient used as abrasive, bulking and emulsion stabilizing in the nano uncoated form, mostly used in oral cosmetic products, such as toothpastes, tooth whiteners and mouth-washes. It is commonly used up to a concentration of 10% in these oral care products. On October 16th 2015, the SCCS published an opinion on the safety of hydroxyapatite in its nano form and mentioned that nano hydroxyapatite can be absorbed and enter into the cells therefore for the safety, nano-hydroxyapatite's concentration is used only up to 10 %. It is utilized for remineralization and in case of hypersensitivity. It is a biomaterial for use in prosthetic application due to its similarity in size and chemical composition with human hard tissues. It has properties like biocompatibility, bioactivity, osteo-conductivity and non-toxicity and on- inflammatory nature [72,73,74].

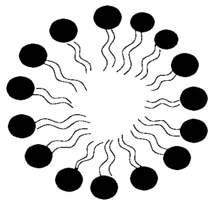
Nanotubes: Carbon nanotube (buckytube) is an allotrope of carbon that is graphite, in which carbon atom have sp^2 hybridized state. Nanotubes are cylindrical fullerenes. Configurationally it is two-dimensional graphene sheet rolled up with continuous unbroken hexagonal mesh into cylindrical tube. Diameters of carbon nanotubes have ranging from 2 nm to 55 nm. They have a very broad range of electronic, thermal and structural properties. Some properties are high surface area, excellent chemical stability, rich electronic poly aromatic structure, small size, high surface to volume ratio and are not soluble in aqueous solutions because they have highly hydrophobic. Carbon nanotubes are used as antioxidant in nature therefore are used to preserve drugs formulations prone to oxidation. Their antioxidant property is used in anti-aging cosmetics and with zinc oxide as sunscreen dermatological to prevent oxidation of important skin components [75,76]. Nanotubes have been implemented in various hair coloring agents which then result in the formation of strong resistant hair dyes, thus cannot be washed easily with shampoos. Peptide- based carbon nanotubes are synthesized by integrating a hair-binding peptide on the surface of the nanotube, increase the affinity to hair by covalent bonding [77,78].

Microsponge: The Micro-sponge technology was developed by Won in 1987. Micro-sponge is a distinctive technology which is composed of micro-porous beads to control the release of topical agents. The size of the micro-sponges ranges from 5 - 300 nm. It is loaded with active agent having properties like inertness with monomer, adequate stability in contact with polymerization catalyst and process, immiscibility or slight solubility in water. Micro-sponge is being used in cosmetic science and its formulation provides extended release with reduced irritation and improved patient compliance. These are stable and self-sterilizing capacity as nanoparticles are very small in size where bacteria cannot penetrate. Application of micro-sponge technology is involved in oral cosmetics such as to sustain the release of volatile ingredients, thus increasing the duration of the 'fresh feel' in toothpastes or mouthwashes. Micro-sponges are able to entrap color and make them last long, thus may be found in color cosmetics like lipsticks, lip rouge and eye shadows. Marketed formulation using micro-sponge technology include dermatological products which can absorb large quantities of excess skin oil, maintaining a smooth feel of skin. Micro-sponges mostly are available in cleansers, conditioners, lotions, moisturizers, deodorants, shaving creams , lipstick, makeup, powders, and eye shadows; which offers several advantages, including improved physical and chemical stability, greater available concentrations, controlled release of the active ingredients, reduced skin irritation and sensitization, and unique tactile qualities [79,80]. Retinol is a pure form of vitamin A which has shown a remarkable ability to maintain the young appearance of skin and help to reduce irritation. However, it becomes unstable when mixed with other ingredients [79].

Graphene and diamond: As moisture increases, graphite stops acting as a lubricant hence graphite is converted into graphene. They are carbon nanoparticles. Graphene is a mixture of crumpled graphene and non-crumpled graphene. They first put graphene in paraffin wax, then make a wax graphene composite, then they melt the wax and dispersed it in water which becomes an emulsion. The waxes help the wax droplet get to where they want and then evaporate the water away and then the wax fills all gaps in crack, graphene coat the surface the bits that oil cannot reach and stay there in use and it needs to work. Graphene acts as a wax. Moreover, Argon National laboratory in America made nano-diamonds which are tiny microscopic ball-bearing and wrap many sheets of graphene. Nano-diamonds are produced by adding graphite and wrap it in trinitrotoluene and then put it into a chamber and set it off. They eliminate friction between two surfactants.

Micelles: Micelles are inorganic and organic nanoparticles that arise in mixtures of amphiphilic colloids (amphiphiles or surface-active agents which are characterized by having two distinct regions of opposing solution affinities within the same molecule or ion). Aggregation occurs at a narrow range and aggregates may contain 50 or more monomers, are called micelles. The concentration of monomer at which micelles form is termed the critical micelle concentration (CMC). At a certain CMC level, surface active agents begin to rearrange themselves and this reaction creates small, spherical micelles having both lipophilic and hydrophilic properties. Below the CMC, the concentration of amphiphile undergoing adsorption of air – water interface increases as the total concentration of amphiphile is raised (Fig. 3).

Fig. 3: A picture of micelle



Micelles are used in cleansing products such as shampoos, soaps, face and body wash and tonics. They are used for the purpose of removing makeup, surface grime (layer of dirt on skin) and secretions of the skin from the face and throat respectively.

Mesoporous silica nanoparticles: Mesoporous silica nanoparticles play an important role in cosmetic science and for drug delivery, due to distinctive properties such as their hydrophilic surface. It is an effective treatment for several skin diseases by controlling the sustained release of cosmetic ingredients or drugs to the skin and also enhancing penetration ingredients into the skin. They are mostly used for skin cancer therapy, transcut-aneous vaccination, and gene delivery. Silicon dioxide nanoparticles act as carriers for drugs having low solubility, and therefore improving product safety, stability and performance (cosmetics and toiletries).

Titanium dioxide and zinc oxide nanoparticles: Titanium dioxide (TiO2) and zinc oxide (ZnO)are fine white powders that occurs naturally. They are mostly used in a vast of personal care products, including sunscreens (UV filter), pressed powders, and loose powders. Both titanium dioxide and zinc oxide powders consist of primary particles that have crystalline structures held by atomic or molecular bonding. The size of primary particles is determined by the process conditions when titanium dioxide or zinc oxide crystals are formed. The primary particles tend to bind to form secondary particles because of their high surface energy (van der Waals forces of attraction and hydrogen bonding) and strong electrostatic forces of attraction between surface hydroxyl groups. They are UV- resistant and is used to increase the sun protection factor of sunscreen products.The E.U. was the first scientific response on the safe use of titanium dioxide nanoparticles as a UV-filter at a maximum concentration of 25% in cosmetic products was adopted 24 October 2000 by the SCCNFP. They are incorporated in color cosmetics such as eye shadow, blush, loose and pressed powders. Some safety concerns have been raised concerning the use of cosmetics products such as it is acausative agent for cancer as astudy which was conducted by International Agency for Research on cancer on those animals who were exposed to titanium dioxide nanoparticles and the result is that they obtained lung cancers. Another concern is that both titanium dioxide and zinc oxide nanoparticles penetrate deeply into the skin (epidermis, dermis) therefore causing cell damage of skin (safe cosmetics organizations).

Application of nanoparticles in cosmetic science:

Skin products (UV filters and sunscreens): Today, sunscreens contain insoluble nanoparticles like titanium dioxide or zinc oxide which disperse ultraviolet more effectively than larger particles. The nano-sized particles are used in sunscreen as a substitute to existing chemical UV absorbers, such as p- aminobenzoic acid and benzophenones, which can cause sensitivity reactions in individuals. One most common ingredient in broad spectrum sunscreens, which protect the skin from UVA and UVB rays, is avobenzone, which can make a greasy film upon application to the skin. Another common sunscreen ingredient, titanium dioxide requires an oily mixture to dissolve, a white residue can be apparent on the skin upon application.Titanium dioxide is one of the largest industrial production down to 25nm. Sunscreen formulations with nanoparticles of titanium dioxide are less greasy, transparent, less smelly and aesthetically appealing while the chalky white residue on the skin observed after using larger particle size is absent with nanosized counterparts. However, when these active ingredients in sunscreens are converted into nanoparticles, they can be suspended in less greasy formulations which seem to vanish on the skin and do not leave a greasy and sticky residue while retaining their ability to block UVA and UVB light. These nanoparticles scatter UV light thereby preventing its harmful effect on the skin [80,81]. Nanoparticles are more efficient than larger particle sized as they coat the skin more tightly and evenly than their counterparts. Sunscreens that use nano-particles generated by ivy plantsare more effective than oxide nanoparticles in blocking ultraviolet rays. Research has revealed that these ivy nanoparticles are more effective; about four times better, than metallic oxide nanoparticles in blocking ultraviolet rays [82]. A good example is Sunforgettable® powder containing titanium dioxide nanoparticles a product from Colorescience [82,83].

Moisturizing and anti-aging products: Skin aging is a biological process which is irreversible, progre-ssive loss of homeostasis capacity, genetically determined program and partly from both endogenous and exogenous factors and occur at cellular level. Skin aging is characterized by loss of elasticity, wrinkles and uneven pigmentation, less sebum, loss of moisture, less nutrition transfer into epidermis, loss of melanin and decrease in vascular responsiveness. Chemical pollutants, ultraviolet and infrared irradia-tions, abrasion, stress have also contributed to aging. Furthermore, when properly engineered, nanoparticles may be able to topically deliver retinoids, antioxidants and drugs such as botulinum toxin or growth factors for rejuvenation of the skin in the future. Vitamin C which is incorporated into the formulation of anti-aging products acts as antioxidant that helps to fight age related skin damage which works best below the top layer of skin. Vitamin C also aids in the synthesis of collagen which help in rejuvenation and wrinkle reversal effect of skin. In the bulk form, vitamin C is not very stable and is difficult to penetrate the skin. However, in future formulations, nanotechnology may increase the stability of vitamin C and enhance its ability to penetrate the skin. Vitamin C has been in cosmetic for its photoprotective action, ability to destroy free radicals and oxidizing agents. It can also encourage collagen synthesis and suppress the pigmentation of the skin. Vitamin C is chemically unstable, and can be oxidized very easily henceforth more stable derivatives like ascorbyl palmitate, ascorbyl tetrais-opalmitate, and magnesium ascorbyl phosphate formulated as an emulsion are extensively used in pharmaceutical industry. Actually, gold facial masks are being used in beauty clinics and saloons. It works by improving the blood circulation, skin elasticity and thereby revitalizes the skin and also reduces the formation of wrinkles. When gold is converted into gold nanoparticles called nano-shells has been shown to be a useful treatment for melanoma in animal studies [82,83]. Skin permeation studies demonstrate that spherical gold nanoparticles are not inherently toxic to human skin cell. In addition, retinoic acid can be used in treatment of acne and helps in promoting the repair of skin damaged by ultraviolet and can decrease wrinkles caused by photo-aging.Topical paralytic agents like alpha-aminobutyric acid, are being used to relax muscles of facial expression. Botullinum toxin has been stabilized and encapsulated in a form that allows penetration of the skin and apparent effacement of rhytides in early clinical trials. Moreover, nanoparticles of hyaluronic acid can penetrate the skin making topical application possible without the need of an injection. Skin creams are made up of proteins derived from stem cells to prevent aging of the skin. These proteins are encapsu-lated in liposomes nanoparticles which merge with the membrane of skin cells to allow delivery of the proteins. Liposomes composed of unsaturated phospholipids which tend to split after application on skin, this property allows them to penetrate deeply into the epidermis of skin, exerting a moisturizing effect. [84]. Certain products are claimed to alter the conditions that characterize aging giving elasticity, firmness and rigidity to aging skin. The first liposomal cosmetic product to appear on the market was anti-aging cream 'Capture' launched by Dior in 1986. "Hydrazen cream, made up of nano-capsules of triceramides, a product of Lancôme claims to restore perfect comfort, and softness to skin giving it prolonged protection from daily stress. Vinosun® Anti-Aging Suncare, a product from Caudalie in Paris, France, combines nanosized UV filters and antioxidants for rejuvenating ageing skin and Plentitude Revitalift® from L'oreal also incorporates nanoparticles and is used as an anti-wrinkle cream" [83]. More companies for example Lifeline skin care company uses proteins enclosed in liposomes nanoparticles into anti-aging creams. Nanoparticles of copper are used in cosmetics in order to regenerate the dermis (synthesis of collagen and elastin production) thus help in treatment of skin aging [85].

When water is lost from stratum corneum readily compared to it has received from lower layers of skin, the skin becomes dehydrated. Additionally, the outer layer of epidermis is termed as stratum corneum which primarily consists of Natural Moisturizing Factor (NMF) and whenwater naturally binds to Natural Moisturizing Factor and it is this water binding is linked to skin hydration.The dehydrated skin loses its flexibility and becomes dry and rough. Therefore, moisturizers are used to retain water or moisture and plasticizes the stratum corneum, preventing them from becoming dry, scaly and breaking away of the surface skin. Almost every moisturizers are oil in water emulsions with additives to improve stability or provide other benefits such as sun screening properties. Nano-encapsulated topical steroids get absorbed in the epidermis without penetrating the dermis. This help avoiding steroid side effects such as dry skin condition and atrophy, therefore using in treatment of spongiotic skin disorder. Conditions of atopic dermatitis and pruritus are prevented when the skin is well hydrated and supple. Additionally, nano-emulsions are applied to moisturizing products, exhibiting a feelingof smoothness and high penetration. They increase the content of nourishing oil and helps in preserving the transparency and the lightness of the formula. Sometimes active ingredients that are fragile in air such as vitamins, these vitamins are protected and kept fresh inside nanometric capsules. The active ingredients are released upon contact with the skin at the time of application where nano-emulsions are open. Elsom Research company involve nano-emulsions and liposomes into skin care products. Nanostructured lipid carriers and solid lipid nanoparticles are newer nano-sized particles with better delivery and stability than the liposomes. When used in moisturizers they reflect high bioavailability and controlled occlusion, thereby providing enhanced skin hydration. Nano gold is also being used in one moisturizer available in the UK, allegedly bringing healing and anti-oxidant properties. In the market Lancôme, a cosmetic manufacturer has Hydra Flash Bronzer Daily Face moisturizer made of nano-capsules vitamin E with claims of ensuring a natural, healthy glowing skin [83].

Facial powders: Face powders such as talc, kaolin, iron oxide, zinc oxide and titanium dioxide are used to provide sunscreen protection with the inclusion of strong light scattering components and help to give the face a glossy and smooth feel. Face powders are made up of nano-powder which are solid particles that measure on the nanoscale, usually comprised of three to five molecules together [83].

Skin cleansers, Disinfectants and Antiseptics: Soaps, toothpastes, wet wipes as well as face and body foams or creams used in recent times for body cleansing contain nano silver. Silver ions have long been used for their inherent antimicrobial effects. Silver ions are thought to inhibit bacterial enzymes and bind to DNA, whereas silver nanoparticles are reported to induce bacterial cell wall and cytoplasmic membrane damage. "Natural Korea cleanser (Cosil Nano Beauty Soap) and Evolut® hand sanitizer contain silver nanoparticles and it is claimed to be highly effective as disinfectant and for skin protection. Evolut ®is even said to be hypoallergenic yet builds immunity against airborne germs" [82,83]. Nitric oxide is applied on skin as it promotes skin healing and also is highly effective affective against cutaneous methicillin resistant Staphylococcus aureus infection in a mouse model. Another example is Chlorhexidin-loaded nanoparticles, uncoated titanium dioxide possesses anti-bacterial properties due to their photocatalytic action.

Functional nano-coatings: Nano-coatings refers to nanoscale thin films that are applied to surfaces in order to create or improve a product's functions like protection, water protection, heat and radiation resistance and antibacterial properties. There are catalytic activity present on the surface of particles such as acid, base, oxidation, reduction because some cases were reported when they deteriorate the perfumes or oils that are present together, and it is very important to inactivate the catalytic activity on the surface when nanoparticles with a large specific surface area are applied in cosmetics. Functional nanocoating using chemical vapor deposition, which is used in the formation of thin films of semico-nductors, is suitable for surface treatment of nanoparticles. The functional nanocoating is that of making cyclic silicone called tetramethyl-cyclotetra-siloxane come into contact with the surface of the particles in the vapor phase thereby forming on the surface a mesh-shaped silicone film with a thickness of 1 nm or less. Because of nano-coatings, the catal-ytic activity of the nanoparticles is inactivated thereby preventing the deterioration of the fragrance, oils, and agents present together with the nanoparticles in cosmetics.

Functional nano-coatings is utilized to combat antibiotic-resistant bacteria and researchers have shown that a novel coating they made with antibiotic-releasing nanofibers has the potential to better prevent serious bacterial infections. Nano-coatings aid in giving the desired surface property to the core particles. For example, it is possible to control the dispersion by introducing hydrophilic or hydrophobic groups or to introduce alkyl groups thereby improving the dispersion in oil of the pigment and preparing lipsticks with strong hues. Furthermore, by introducing glycerin residue, dual-purpose foundations having moisture retentivity that can be used both with and without water have been developed [86].

USES AS COMPOUND PARTICLES

Color correction: Human skin is largely translucent and color correction is an aspect of skin beauty. Structural colors that give out color due to interference of light such as the colors in the wings of a butterfly are being used actively. It has been known that blue moles or red moles such as nevus of Ota or vascular neoplasm disappear giving a natural appearance by the use of titanium dioxide-coated mica having interference color. However, because titanium dioxide coated mica has gloss, it gives an unnatural finish when used in a foundation. To improve its shine, a compound particle was developed with the surface of titanium dioxide-coated mica covered with spherical particle of polymethyl methacrylate (PMMA). While correcting the reflectivity of red color using itsred interference color because the gloss of titanium dioxide-coated mica is controlled by the diffused reflection of spherical PMMA particles, it was possible to formulate a fine makeup skin texture having transparency as well. An example of skin color correction using fluorescence is a reduced form of zinc oxide. The reflectivity of about 500 nm is increased due to the ultraviolet light present in sunlight or fluorescent light thereby attempting to correct the reflectivity of light in the blue to green region. There are items in which the reflectivity on the long wavelength side is increased using the fluorescence of carthamin [86]. Moreover, color comes from a combination of skin type and ambient light striking on skin. Only about 5 % of surface light is reflected, it penetrates the skin, where it is scattered and absorbed. Melanin absorbs UV radiation; hemoglobin absorbs mid-wavelength yellow and green light and the exiting light is red. The pattern of this light gives the skin its appearance and beauty. Nanometer-thick titanium coating mica powders can alter this pattern. Titanium-coated mica powders in foundation excel at color correction but give the skin too much gloss. Further, nanoparticles may be able to enhance the internal reflection of light at the skin-air interface or alter the wavelength of outgoing light to create a glow. This could be used for color correction or for surface correction of fine lines, wrinkles, blemishes or shadows [83]. Carbon black, an intense cosmetic colorant, can be used in nano-form and is a good example of reducing the pigment particle size that can alter the opacity of the color.

Adapting to the Environmental Light: While a skin with makeup applied to it looks whitish and has a floating appearance in sunlight outdoors butappears as a blurred yellow surface indoors in fluorescent light. To solve this problem, a photochromic powder was developed using 25 nm titanium dioxide doped with iron [87]. These skin-colored nanoparticles change to golden brown color when exposed to ultravioletlight and have not only the effect of preventing whitishness outdoors but also the effect of protecting against ultraviolet light [86]. After developing the photochromic nature type, color rendering type pearl material has been developed [87]. It has changed color phase due to the effect of interference within titanium dioxide-coated mica. For instance, bycoating iron-doped titanium dioxide having photochromic action on the surface of titanium dioxide coated mica having red interference color, the material will appear white when no ultraviolet light is incidenton it, and when ultraviolet light is incident on it,the outer layer changes to black and the interference color becomes clear [88]. Therefore, the particle changes from white to red due to ultraviolet light. This color rendering type red pearl material prevents the blurred yellowish appearance under fluorescent light withslight yellowishness by generating a red interference color. On the other hand, under a strong light source such as sunlight, the overall reflectivity decreases and exhibits superior color rendering that prevents whitishness. Thus, it is possible to realize beautiful makeup skin in any light environment [86].

Diagnosis and Treatment of Skin Infections: Carbon nanotubes have some similarities and properties like nucleic acid and antibodies therefore can bind their receptors. The electrical conductivity is different for isolated, coupled and receptor-bound coupled carbon nanotubes. It diagnosed skin infections through a highly sensitive biomarker sensor that can be developed [75,76]. Photodynamic therapy is used for treatment of skin cancer and other related skin conditions and is done by using gold nanoparticles however its use has been limited due to high cost and patient compliance. Nanoparticulate chitosan has been used to encapsulate various volatile antimicrobial gases such as nitric oxide which is released when polymer dissolves. It is more commonly used in the treatment of skin infections and abscesses.

Hair care products: Nanoparticles can be used in hair care products to maintain shine, silkiness, porosity, density and good scalp. Hair care products include shampoos, hair conditioners, hair dyes, hair serums, hair sprays and other hair styling products. Nanotechnology has been used to study the mechanical characteristics of hair. Nanotechnology plays a significant role in understanding the differences between hair types, allowing companies and chemists to formulate products according to the type and conditions of the hair. Nanoparticles has been employed in order to treat hair related diseases, increasing hair growth and density and improve the hair quality. Nanoparticles like poly lactic-co-glycolic acid, poly e-caprolactone, blockpolyethylene glycol, neutral liposomes, solid lipid nanoparticles and roxithromycin (ROX) loaded pluronic lecithin organogel (PLO) are used in the treatment of hair disorders such as alopecia. This is done by increasing drug penetration into the hair follicle openings and can act as a depot for sustained drug release within the hair follicle [89,90]. In a study, sericin nanoparticles which have been prepared using sericin protein extracted from cocoons of silkworm bombynx mori have been used in hair products using quaternary ammonium salts hence producing sericin cationic nanoparticles. These nanoparticles will be used in the repair of damaged colored hair and after application of sericin cationic nanoparticles, the hair became smooth, shine thus improving the hair quality [91]. Different metal nanoparticles, metal oxide nanoparticles, carbon have extensively been used in hair coloring products. Sinere company use liposomes and ethosomes in hair growth products. Nanotechnology researchers have developed a surface engineering technique for hair dyes that does not use chemical reactions and therefore does not damage the hair. For instance, halloysite clay nanotubes, a biocompatible clay which self-assemble in a set pattern on the hair surface during hair drying via physical adsorption. This is a new technique allowing the use of water-insoluble dyes, which were not suitable for hair care products. Therefore, this new method facilitates medical treatment such as hair loss, dandruff and anti-lice [92]. Metallic nanoparticles such as silver, gold, copper, selenium, and cadmium along with their alloys are used in hair dyes. Carbon nanotubes are used to impart black color to human hair, forming a thin layer upon human hair and then imparting a soft feel and texture. Selenium sulfide and nanoparticles of zinc are used in anti-dandruff shampoos.

Nail care products: Nail care products is a set of manicure preparations consisting of a number of different cosmetic products which decorate and clean the nails. The use of nanoparticles softens the ease of application of nail care products because of elasticity and also resists shock, scratch and crack [93]. Nano-emulsions of other compounds that can penetrate the nail and the pilosebaceous unit are being used to treat onychomycosis and acne, respectively. Silver and gold nanoparticles have both aesthetics and anti-bacterial and anti-fungal effects hence are able to treat nails related conditions especially onycholysis, onychodystrophy or onychomycosis [93,94].

Lip care products: Lip care products consist of lipstick, lip balm, lip gloss, lip pencil and lip volumizer. The incorporation of nanoparticles in lip care products are as they soften and soothed the lips by preventing trans-epidermal water loss from the lip surface so as to prevent the loss of moisture and natural lips nutrients. Many nano-pigments are used to impart silk, glossy and pearlescent attributes. Nanoparticles create silky and satin effects while larger particle sizes create high luster effects such as sparkle. Besides, silica nanoparticles in lipsticks hydrate the lips and evenly spread the color pigments thus preventing pigment bleeding into fine lines of lips [95].

Oral care products: Oral care products comprised of toothpaste, toothbrushes, tooth powders, mouthwashes and dental floss. Oral care products forms part of our daily life. Several metal oxides or metal nanoparticles such as gold, silver, zinc oxide, copper oxide and titanium dioxide have anti-bacterial properties as well as anti-inflammatory properties. Nanoparticles act against bacteria mainly by producing reactive oxygen species such as hydroxy radical, the superoxide radical and hydrogen peroxide, these play an important role in cell signaling and cellular homeostasis. The incorporation of zinc oxide nanoparticles in toothpaste and mouthwash enables the fighting of gingivitis due to bacterial effects and helps in remineralization of dentin. Chitosan nanoparticles, nano-Hydroxyapatite and chlorhexidine nanoparticles are antimicrobial agents which increase biological efficacy through rapid penetration and bioavailability and decrease cytotoxicity [96].

Nanoparticles as delivery vehicles: Vitamin A (retinol) and its derivatives (retinoids) are among the most commonly used active ingredients in skincare. They encourage growth, differentiation and maintenance of epidermal cells, regulate sebum and help to reduce fine lines, wrinkles and acne, to increase epidermal turnover rate. They help to treat uneven hyperpigmentation as they inhibit melanogenesis and block the transport of melanin to epidermal cells [97-99]. Another nanoparticle as delivery vehicles is antioxidants which protect against DNA damage caused by the presence of reactive oxygen species generated after several internal or external stimuli. When skin is exposed to ultraviolet rays, it causes an excessive production of reactive oxygen species (ROS) which is responsible for aging and skin cancer. These can be tackled by the application of antioxidants such as catalase, superoxide, glutathione, coenzyme Q10, vitamin C, vitamin E and polyphenols. The antioxidants also help in increasing the photoprotective power of sunscreens [100]. Peptides are added into anti-aging products to enhance permeability and protect them from degradation. Ceramides are moisturizing agents used to increase skin hydration thus help to retain moisture.

TOXICITY ISSUES AND HEALTH HAZARDS

Research has found some alarming problems with nanoparticles when it comes to destroying useful microorganisms in the environment and human health. The toxicity is affected by their properties, which are attributable to their smaller size, chemical composition, surface structure, solubility, shape and aggregation.

Smaller size of nanoparticles creates opportunity to increase interaction with biological tissues. Production of reactive oxygen species result in oxidation stress, inflammation and related damage to proteins, membranes and DNA. Because of their relatively small size, they can easily get access to the blood stream via skin or inhalation or injection therefore it can penetrate to all organs, tissues of the body resulting in dysfunction [101,102]. Carbon nanotubes have been demonstrated to cause the death of kidney cells and inhibit further cell growth. Moreover, fullerenes are carbon tubes used in anti-aging and eye creams. [105-107]. Fullerenes may penetrate into the epidermis and dermis of the skin [107]. They also make the skin unusually sensitive to light, leaving cells vulnerable to the effects of UV light exposure. Titanium dioxide particles (500 nm) have only a small capacity to cause DNA strand breakage, 20 nm particles of titanium dioxide are capable of causing complete destruction of super coiled DNA, even at low doses and in the absence of exposure to UV [103,104].

Nanoparticles are produced in a variety of shapes like spheres, tubes and sheets and this may be a major role for health risks caused by them. A study has shown that exposing the abdominal cavity of mice to long carbon nanotubes are linked with inflammation of abdominal wall [108].

As the size of particles decreases, their surface area increase causing an increase in their reactivity. Nanoparticles are highly reactive due to high surface area to mass ratio, providing more area by weight for chemical reactions to occur, as some nanoparticles may be potentially explosive and photoactive. For instance, anoscale titanium dioxide and silicon dioxide may explode if finely dispersed in the air and they come into contact with a sufficiently strong ignition source [109].

Nanoparticles can penetrate into skin especially when the skin is tightened. Penetration of nanoparticles are up to 1000 nm in size [110]. Moreover, sunscreens contain insoluble nanoparticles like titanium dioxide which reflect and scatter UV light most efficiently at a size range of 60 nm to 120 nm. Sunscreen-grade nanosized titanium dioxide particles range from an ultrafine particle to form with a primary diameter of 15 nm, which will form stable larger aggregates. In addition, zinc oxide is used in the form of particles at a size range from 30 nm to 200 nm. The results of various published studies regarding penetration of titanium dioxide in human skin were summed up in a report issued by the Scientific Committee on Cosmetic Products and Non-Food Products (SCCNFP). These studies have shown that micro- and nanosized titanium dioxide particles remain on the skin surface or on layers of the epidermis. It was further compared to zinc oxide and the result has shown that zinc oxide does not penetrate skin. Both titanium dioxide and zinc oxide are incorporated in sun care products as they provide protection of skin from UV rays. Titanium dioxide nanoparticles are thus more toxic than the standard size particles. Exposure to titanium dioxide nanoparticles can result into major lung inflammation and significant DNA damage. Nevertheless, a review of the risks of nano-structured titanium dioxide and zinc oxide found nanoparticles of titanium dioxide and zinc oxide are unlikely to pass through the skin due to how they are bound. The researchers concluded both materials are safe to use as UV filters; however, these two types of nanoparticles are still undergoing major studies. [114]. The presence of acne, eczema and wounds may enhance the absorption of nanoparticles into the blood stream and may further lead to skin complications. A research study has found that nanoparticle penetration was deeper in affected part of skin especially by psoriasis compared to the unaffected skin [111]. Recently, the base carriers are being adjusted in order to increase skin penetration by adding certain penetration enhancers, both physically and chemicals. They are prepared by using newer vesicular systems and increased skin penetrability such as ethosomes and transferosomes [111]. "In a study published by Minghong Wu and co-workers at Shanghai University, they have discovered that zinc oxide nanoparticles used in sunscreens can damage or kill the stem cells in the brains of mice [112]. To investigate the potential neurotoxicity of zinc oxide nanoparticles, Wu et al. prepared cultures of mouse neural stem cells (NSCs), and treated them with zinc oxide nanoparticles ranging from 10 to 200 nano-meters in size. After 24 hours, the cell viability assay indicated that zinc oxide nanoparticles manifested dose-dependent, but not size-dependent toxic effects on NSCs. Through analysis using confocalmicroscopy, transmission electron microscopy examination, and flow cytometry, many of the NSCsshowed clear signs of apoptosis. This zinc oxide nanoparticle toxicity was found to be the effect of thedissolved zinc ions in the culture medium or inside cells [113]. In another work by Arnaud Magrez at theNN Research Group, it was found that titanium dioxide based nanofilaments were found to be cytotoxic, which was affected by their geometry and also enhanced by the presence of defects on the nanofilamentsurface, resulting from chemical treatment. Nanofilament internalization and alterations in cell two morphology were observed" [115,116]. Cellular toxicity can also occur with silver nanoparticles may lead to oxidative stress and resulting cell damage [117]. "Silver nanoparticles have shown toxic effects on the male reproductive system, as research suggests that nanoparticles cross the blood-testes barrier where they can be deposited into the testes with the potential for adverse effects on sperm cells [118]. Research shows that silver nanoparticles can bind to different tissues and can cause a number of toxic effects that gradually lead to cell death"[119,120].

Workers may be exposed to nanomaterials during the production of nanomaterials or during the formulation of products containing nanoparticles. Exposure may also occur in cleaning and maintaining research, production and handling facilities [121]. Till date, there is insufficient information on the number of workers exposed to nanoparticles in the work place or the effects on human health of such exposure, according to the European Agency for Safety and Health at Work. In addition, the use of nanoparticles in cosmetic products are increasing at a steady pace thus increase the chance of exposure to nanoparticles. The occupational risks associated with nanoparticles are cellular cytotoxicity, lung inflammation and can further lead to cancer. Furthermore, after multiple exposure to nanoparticles is concerning and Chinese Hamster Ovary cells (CHO) have a concentration dependent increase in reactive oxygen species (ROS) in both acute and chronic titanium dioxide exposed cells. Overall, the effect of titanium dioxide diminishes in chronically exposed cells. Overall, however, CHO cells appear to adapt to chronic exposure of nano titanium dioxide. The effect of titanium dioxide on cells seems to be low without light [122].

Health risks that nanoparticles pose to humans depend on route and extent of exposure.

Inhalation: According to the National Institute of Occupational Health and Safety, the most common route for exposure of airborne nanoparticles is inhalation. For instance, workers and consumers may inhale nanoparticles while producing nanoparticles and using products made from nanoparticles like perfumes, powders, aerosol, and spray versions of sunscreens respectively. Results received from studies conducted on animals suggest that the vast majority of nanoparticles inhaled enter the pulmonary tract and some may travel via nasal nerves to the brain and gain accessto other organs via blood stream [123,124]. Moreover, silica nanoparticles may lead to pregnancy complications when injected intravenously into pregnant mice as it seems that nanosized silica can cross the placenta, leading to deposits in the fetal liver and fetal brain. Nanoparticle sized crystalline silica (silicon dioxide) nanoparticles may cause cell damage which could cause cell mutations and creation of cancer cells with two nuclei in human in vitro cells. [120,125,126]. Additionally, inhalation of silicon dioxide toxicity study reveals that the particle size of 1- 5 nm produces more toxicological response than 10 nm equivalent dose [129,130]. Experiments were performed on carbon nanotubes have revealed that on chronic exposure interstitial inflammation and epithelioid granulomatous lesions are caused in lungs. Fullerenes might oxidize cells or may be hazardous when inhaled. [127-129]. Furthermore, nanoparticle-sized carbon black particles may alter the genetics of lung cells, lead to inflammation and inhibit the growth of cells that line the circulatory system. Research now suggests that nanoparticle-sized carbon black may lead to mutations in the lung cell of rats after a 15-month exposure time [120,131,132].

Through skin: The dermal exposure of lesser size particles (less than 10 nm) can penetrate more readily and can result to more harmful and toxic effects than greater particles (greater than 30 nm). Studies have demonstrated that certain nanoparticles have penetrated layers of pig skin within 24 hours of exposure [133,134]. Prolonged erythema, eschar formation, and oedema were reported with nanoparticles less than 10 nm. Fullerenes are carbon tubes often used in anti-aging, moisturizing creams and eye creams that may penetrate into the top two layers of the skin (the epidermis and dermis). These nanoparticles also make the skin unusually sensitive to light, leaving cells vulnerable to the effects of UV light exposure [120,137,138]. Titanium dioxide and zinc oxide generate ROS and free radical when exposed to ultraviolet (UV) radiations, which have potential in inflammation and oxidative stress and can significantly damage membranes, proteins, RNA, DNA, and fats within cells [139,140]. "A research on titanium dioxide nanoparticles toxicity shown that when these nanoparticles subcutaneously given to the pregnant mice, they were transferred to the offspring and there was a reduced sperm production in male offspring and brain damage as well. Nanoparticles of cobalt-chromium have potential that they can cross the skin barrier and damage fibroblast in humans [141].

Perspectives of nanoparticles in cosmetic science: Nanoparticles are found throughout nature, during combustion reactions, in volcanic eruptions, erosion and people are naturally exposed to nanoparticles without our own knowledge. In fact, cosmetic industry is one of the leading industries involving nanoparticles and have potential to enhance sunscreens, shampoos and conditioners, lipsticks, eye shadows, moisturizers, deodorants, after shave products and perfumes. The advantages of using nanoparticles in cosmetic science include they act on the top of the skin, they are used in tiny measures, they improve the texture of cosmetic products, they enhance the rate of absorption and the solubility of products. Other benefits are that they increase surface area of the products and they increase shelf life in cosmetics. Cosmetics giant L'Oreal invested USD 927 million in cosmetic and dermatological research in 2011 and is an industry leader in nanotechnology- related cosmetics. As recently as July 6, 2010, the Office of Science and Technology.

CONCLUSION

Nanotechnology has hailed by many as being twentieth miracle of science. Nanoparticles in cosmetic science has definitely improved the formulation of the cosmetic products. Despite the remarkable properties attributed to nanoparticles involved in cosmetics, nanotechnology has yet to win greater universal acceptance in scientific fields. Research has shown nanosized particles can be potentially harmful when inhaled hence consumers should avoid loose cosmetic powders and aerosol sunscreen products that contain nanosized titanium dioxide or Zinc oxide. We as consumer need to pay particular attention by checking the ingredient labels of the personal care products in order to reduce cellular toxicity and health hazards.

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