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APPLICATION OF NANOFIBER IN COSMECEUTICAL ARENA

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ABSTRACT

Nanofiber is the broadest class of nanomaterial with various unique application in multidimensional fields. The unique properties of nanofiber are high surface area to volume ratio, small pore size, low diameter, high strength value and high porosity makes it an excellent nanomaterial and has a great use in cosmeceutical area. It is used in facial masks, deodorants, treatment for alopecia, as a wound dressings material and for drug delivery purposes. Nanofiber has a high surface area due to which a good amount of drug can be entrapped and used for extended releases purpose. Nanofiber used in wound healing dressings mainly contains antibacterial drugs are much more effective than the commercially available marketed products. In this article, a brief description is given about the nanofiber properties, production method and the novel application of nanofiber in cosmeceutical arena.

KEYWORD: Nanofiber, facial mask, wound healing, alopecia, wound dressings

INTRODUCTION

Cosmeceutical is a new category of multifunctional product that rely on science and technology to deliver the active ingredients into the skin. It has numerous cell protective effects for rebuilding healthy skin at a cellular level. Implementation of nanotechnology in the cosmeceutical sector has given a new point of view by improving its efficacy and acceptability of the cosmeceutical product.[1]

Nanomaterial is defined as a material that has size of around 100 nm or less. Since the discovery of nanomaterial, it has been rapidly increasing interests in academic and industry sector due to several advantages of nanomaterials like small particle size, site specific action, high drug loading capacity and reduced the side effects.[2,3] Nowadays in cosmetics nanomaterial is also used in anti-aging cream, sunscreen, hair products, facial masks, tooth paste, deodorants, shampoo.[3,4,5] Among these applications skin wound healing, drug delivery to the skin for anti-wrinkle and anti-aging purposes and for treatment of alopecia are some of challenging areas for nanomaterials in cosmeceuticals.[6,7]

Nanofiber

In recent years, a class of nanoparticles has been discovered with interesting biomedical application. It is a type of nano structured carrier known as nanofiber in which fiber is described as a unit of matter characterized by length, fineness, and high ratio of length. Nanofibers are characterized as a nanomaterial with a diameter less than 100nm. Fibers with diameters in sub-micrometer range (less than 1000 nm) produced by certain ultra-fine fiber manufacturing technique such as electrospinning are also referred to as nanofibers.[8,9] Electrospin microfibers or nanofibers have a different potential application in tissue engineering, implants, cosmetics, neural cells and also as a drug delivery vehicle.[9] In this review we highlighted the importance of nanofibers for the various types of cosmetics products.

Characteristics of Nanofibers

The unique characteristics of nanofibers make them indispensable in numerous application[10-13]

- Low unit length (diameter).
- Large specific surface area.
- High porosity.
- High- strength value.
- Low weight.
- Small pore size.

Method of Preparation

Nanofibers are prepared by using a suitable polymer, compatible additives or a proper production method to fulfill the requirements of its potential application. Nanofibers are manufactured by various methods such as self-assembly, drawing, melt blowing, template synthesis, phase separation, melt spinning, centrifugal spinning, and electrospinning.[14]

Although, nanofiber is manufactured by all the above-mentioned methods, but electrospinning considered as a best method for the production of nanofibers in cosmetics. All the methods are briefly described below,

I) Self- assembly

Self-assembly is a traditional method for production of nanofiber production. The term "self" represents formation of molecules and molecular chain by atom, then forming of fibers by molecular chain with least external factors.[15] The two major drawbacks of this method are, firstly this is a complicated method and the secondly the diameter of each fiber is not uniform it changes uncontrollably.[16]

II) Drawing

The method mainly consists of drawing of individual nanofibers produced by micromanipulator probe. From the viscoelastic polymer solution, a small amount of polymer solutions is being taken and placed it in a flat surface. The contact of probe onto the flat surface is placed at a distance sufficient for fiber length so that individual fibers are produced. Solvent evaporation method and drawing rate are the most important process parameters in this method of production.[16,17]Polycaprolactone, polyethylene oxide, hyaluronic acid, fish gelatin blend, and polymethylmethacrylate are the biopolymer nanofiber produced by the drawing method. The nanofiber produced in this process is used in skin tissue scaffolds or skin wound healing. [18]

III) Melt blowing

This method is based on the principal of melt blowing fiber spinning technology. In this method the polymer extruding out of a capillary tube is in contact with hot air at a high flow rate.[19] The nanofiber produced is of diameter 250nm formed within a short duration of time and is mostly used in cosmetic purposes like facial mask manufacturing.[20, 21]

IV) Template synthesis

The name of this method is understood by this name, template synthesis used for the production of the nanofibers with the help of biodegradable polymer. Chemical vapor deposition, chemical, sol-gel, electrochemical are some types of template synthesis methods. [22] The pore size of the template is determined by the diameter of the fiber. The nanofiber produced by this method is mostly used for tissue engineering application. But the major drawback of this method is it is very time-consuming.[23]

V) Electrospinning

Electrospinning is the most suitable method for production of nanofibers. The nanofiber produced by this method are in the range of micrometer to nanometer. It is a very simple and cost-effective method for produce large volume of nanofibers with diverse molecules.[24] There are mainly three components in electrospinning apparatus for producing nanofibers, these are: high voltage power supply, a polymer solution reservoir (a syringe, with a small diameter needle), with or without flow control pump, and a metal collector screen. The step followed in this process is described in six points below.[25, 26]

i) The polymer solution was placed in a reservoir and connected to a power supply for establishment a charged polymer jet.[27]

ii) Generation of jet by increasing the power supply, cause deformation in jet.[28]

iii) The straight jet segment is elongated from the taylor cone.

iv) Deformation takes place in the straight jet segment, creation of instability.

v) Solidification of nanofibers is done by evaporation of the solvent or cooling it.[29, 30]

vi) Finally, fibers are collected on the collector plate.[31]

The nanofiber produced by this method has diverse application, i.e. in biomedical application, wound dressing, tissue engineering, drug delivery, cosmetics and etc.[32]

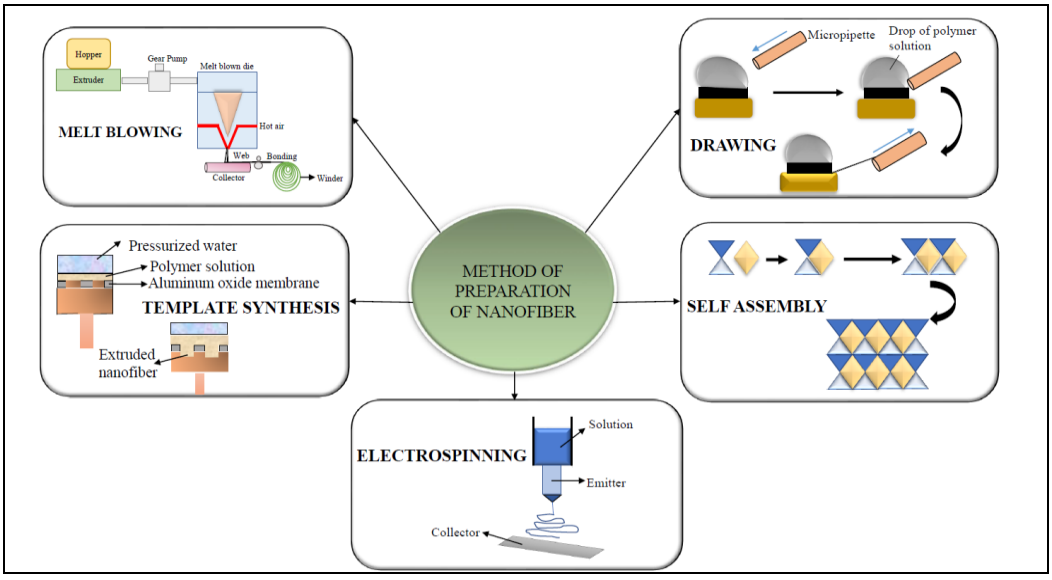

Fig 1: Various methods of preparation of Nanofibers.

Application of nanofibers in cosmetics

Along with a wide range of application in drug delivery, tissue engineering and also a considerable range of therapeutics drugs, nanofibers are also currently investigated in cosmetics preparation. Nanofiber provide a controlled release of cosmetics ingredients over a long period of time.[33] The main advantage in comparison with the conventional form of cosmetics products is that nanofibers provide a prolonged released of the ingredients in a controllable manner and increases the skin contact time and increases the surface area with the three-dimensional structure. Various types of vitamins are delivered though nanofiber for skin care. The most common potential use of nanofibers in cosmetics are in healing, skin therapy, cleansing, facial mask and skin care products.[32,34]

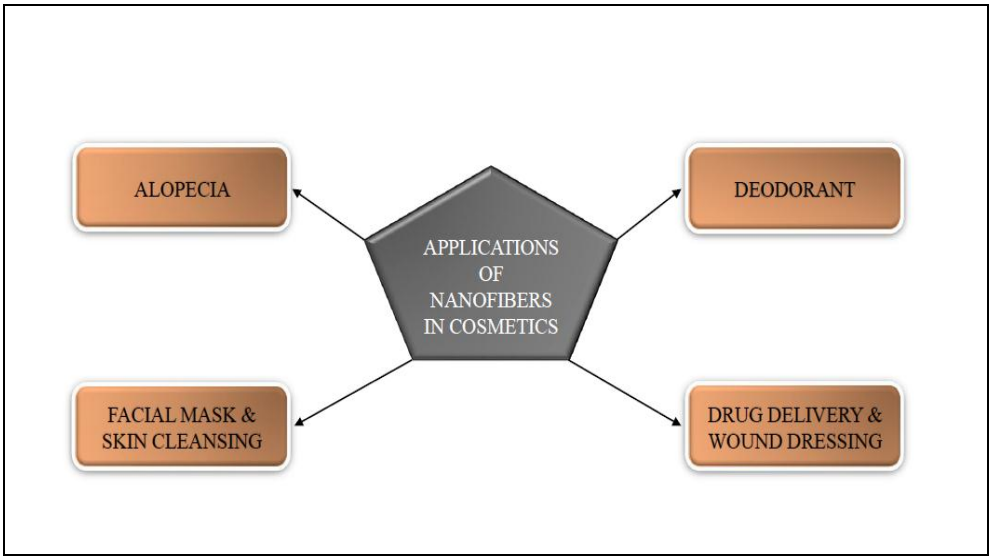

Fig. 2 Different applications of Nanofibers in cosmetics.

Deodorant

Hoik Lee et al have presented on the deodorant activity of a complex nanofiber containing phthalocyanine. For the fabrication of nanofiber, they prepared two different polymer solutions of poly vinyl alcohol (PVA), silk and a total 4% phthalocyanine was incorporated into them, respectively. Phthalocyanine is an aromatic compound widely used as good gas sensing agent in gas sensors, solar cells. The deodorant activity test showed a significant reduction of methyl mercaptan gas in both phthalocyanine incorporated PVA and silk nanofibers.[35]

Facial mask and skin cleansing

L-ascorbic acid, retinoic acid, collagen, gold nanoparticle is widely used in cosmetic and dermatological product for the ability to scavenge free radicals and destroying oxidizing agent. Collagen is used for regeneration of the skin function and strength, since the level of collagen in the skin declines with the age, so it is used in the facial mask for these purposes. Vitamin-c is also incorporated in anti-wrinkle face mask and for its photoprotective effects, also Vitamin-c scavenges the free radical and destroys the oxidizing agent.[36, 37] Vitamin-a (Retinoic acid) used for anti-wrinkle cosmetic formulations in order to repair damaged skin and acne.[38] Sonavane G et al. showed in a study that gold nanoparticles can perform in-vitro permeation of rat skin and rat intestine used for cosmetic purposes. [39] These above-mentioned active ingredients like L-ascorbic acid, retinoic acid, collagen, gold nanoparticle are used in the facial masks for their respective function. But the main problem lying with the current cotton facial masks available in the market i.e. it is pre-moistened, which means the masks contains some fluid and due this some active ingredients may be oxidized become unstable such as ascorbic acid, as a result it leads to reduced therapeutic efficacy of active ingredients.

Anahita Fathi-Azarbayjani et al. presented on his paper the nanofiber facial mask is much more effective than the cotton face mask. The dry nature of the nanofiber facial mask increases the stability of the antioxidant and also the shelf life as compared to the pre-moistened cotton facial mask. The nanofiber facial mask will be available in dry form in the market and will only be moistened with water prior to the application. Once moistened, the content of the facial mask is gradually dissolved and release the ingredients in a slow manner with deep skin penetration. The high surface area of nanofiber will ensure the maximum contact time with skin and also helps in the restoration of the skin appearance. Electrospun nanofiber gives attractive results compared to the cotton face mask.[40]

Nanofiber facial mask also used for the cleansing purposes for removal of dirt and oil from the skin, this is very effective compared to commercially available facial mask for cleaning. The high surface area of nanofibers causes the long contact time with the skin and also increases dissolution of nanofibers by water and for this reason the skin adhesion of nanofiber is good for effective cleaning.[40]

Drug delivery product and wound dressings

The delivery of drug to the skin can be considered as a cosmetic application, especially in dermo-cosmetics and drug delivery at the specific site without causing side-effects is the most important issue to be dealt with in the pharmaceutical field.[41] The basic concept of drug delivery is to achieve the drug delivery at the targeted site, reduced the side effects and the various other parameters are also being investigated by different researchers in order to maintain the optimal pharmacological effects. So, the main aim of the researchers is to administer the drug at lower doses and have a site-specific action.

Exposed wounds are very susceptible to toxin, water loss, protease caused by bacterial infection, which may generate the excessive inflammatory response that delays the regeneration process in skin. Recently nanofiber technology has been revolutionized by impregnating various antibacterial agents for wound dressing application.

Nanofiber is one of the most recent purposes of drug delivery. It releases the active ingredient in a controlled manner. The main advantage of nanofiber is to provide a high surface area, to achieve an initial burst effect of the drug and followed by the sustained released of the active ingredients. This high surface area also provides a high drug loading efficiency, simple operational technique and is also quite cost effective. Various types of antibiotics, antibacterial molecules have been investigated by different researchers for wound healing process. The polymer used in the preparation of nanofiber should be of hydrophilic/hydrophobic characteristics for providing better efficacy and better drug loading capacity.[42, 43]

Various materials such as natural, synthetic polymers is used to obtain the electrospun nanofibers for wound dressing application. Synthetic polymers are easy for synthesis and it has a good flexibility but there is a low hydrophilicity nature due which it causes a lack of cell affinity and surface recognition sites. As compared to synthetic polymer, natural polymer has good biocompatibility, low immunogenicity, exhibits intrinsic antibacterial property for many clinical applications. Natural polymer include polysaccharide (cellulose, chitin, chitosan, dextrose), protein (collagen, gelatine, silk) etc.[44, 45] Lee at al described in his paper the characteristic of various natural polysaccharide such as cellulose, chitin, alginate, chitosan, dextrose that can be used for electrospinning and their biomedical application for wound dressings and drug delivery.[46]

Antibiotics drugs are the most suitable candidate and most investigated group of drugs on nanofiber formulation. According to the nature of the nanofiber formulation, they are commonly used for wound dressing application and therefore antibacterial agents take a role for the wound healing process. The main objective behind these kind of wound dressing formulations is to provide broad-spectrum antimicrobial activity against gram-positive, gram-negative and antibiotic resistant bacteria. Antibiotics and antibacterial agents are the biocides loaded into the nanofibers, various antibiotics such as tetracycline hydrochloride, ciprofloxacin, levofloxacin, moxifloxacin, neomycin and antibacterial agents (8-hydroxyquinoline derivatives, fusidic acid, benzalkonium chloride, sliver nanoparticles) are also encapsulated in nanofibers for wound dressings.[47] Mainly in most cases PLGA, PLA and PCL are used as a carrier and along with other synthetic and natural polymer are added to control the biodegradability and hydrophilic nature, to show a controlled release profile of the drug. [48]

In this case, antibiotics like ciprofloxacin, doxycycline, neomycin, ampicillin and tetracycline hydrochloride have been loaded in the different polymeric back cones. Ciprofloxacin hydrochloride is a board spectrum antibiotic that is very effective against both gram negative and gram-positive bacteria that cures wound infection. But Ciprofloxacin hydrochloride is insoluble in both polar and nonpolar solvent in room temperature. For preparation of wound dressings mat incorporated with Ciprofloxacin hydrochloride Unnithan et al. used DMF: THF (1:1) mixed solvent to prepare dextran and polyurethane composite polymer solutions. Polyurethane is a good biodegradable hydrophobic polymer and also has a good mechanical strength but it lacks of cell affinity, so in order to overcome this problem polyurethane is mixed with the dextran. Polyurethane 10% solution and 20% concentrate of dextran and 10% drug were added to prepare composite nanofiber mats by electrospinning. The growth inhibition against gram negative and gram positive were measured. The results showed Ciprofloxacin hydrochloride loaded polyurethane-dextran nanofiber caused inhibition against gram positive bacteria S. aureus and B. subtilis and inhibition zone were around 15 to 20 nm, respectively. In case of gram-negative bacteria E. coli, S. typhimorium and V. vulnificus the inhibition zone was 20nm. Finally, it was concluded that the Ciprofloxacin hydrochloride loaded polyurethane-dextran nanofiber mat have excellent antibacterial activity against wide range of bacteria.[49]

For example, Kenawy et al. described on his paper the application of electrospun nanofiber for the drug delivery, here tetracycline hydrochloride is used as a model drug and poly (lactic acid), poly (ethylene- co-vinyl acetate) combination blend is used as a polymeric career. The results showed that the release of the drug is influenced by the polymeric nanofiber carrier. Smooth and sustained released of drug is observed over 5 days by electrospun nanofiber and the therapeutics efficacy has also found to increase.[49] Verrek et al. used non-biodegradable polyurethane-based nanofiber of itraconazole, a hydrophobic antifungal agent. The system provided an ultrafast delivery of drugs (<24) and the

therapeutics efficacy was also found to increase [50] Kim et al. demonstrate the prolonged released of cefoxitin sodium, a hydrophilic antibiotic. He produced a PLGA based electrospun nanofiber and loaded the drugs into the nanocarrier and an *in-vitro* inhibition assay performed on S. aureus. The results showed that the drugs released from the nanocarrier for up to seven days in a controlled manner.[51] Said et al. demonstrate the released of fusidic acid improved over 9-15 days by incorporation it in a PLGA nanofibers, which was very efficacious against P. aureus, P. aureginosa and methicillin resistance S. aureus.[52] Ignatova et al. demonstrated that photo-crosslinked between poly (vinyl acetate) and poly (ethylene oxide) nanofiber mats containing iodine, have a biological activity against S. aureus and candida albicans.[53]

Another antibacterial drug neomycin loaded into electrospun poly (styrene sulfonic acid-co-maleic acid) (PSSA-MA) blended with PVA nanofibers was studied by Nitanan et al. PSSA-MA is an ionic polymer contains strong sulfonic acid and weak maleic acid group ion-exchangeable groups. So, the nanofiber mats were called as PSSA-MAA/PVA. The cationic drug neomycin was loaded and released based on ion exchanging. PVA is a non-toxic, biodegradable and biocompatible polymer and also enhances the fiber forming ability with the other polymers. The neomycin loaded PSSA-MA loaded nanofiber mats also showed a burst release in early exposure time and was found to be effective. According to the results provided by Ballal et al. it was slightly toxic. Neomycin loaded nanofiber showed a good antibacterial activity against S. aureus and E. coli, and also it has an excellent activity against Gram-negative bacteria and partially active against Gram-positive bacteria. Comparing neomycin loaded nanofiber mats with the commercially available antibacterial gauze dressing for wound healing, the result showed the healing effect of neomycin loaded nanofiber mats is significantly better than the commercially available gauze.[54]

In a distinct approach, Yang et al. studied an extended release of ampicillin (AMC) from polyacrylonitrile (PAN) / agar composite nanofiber. It is a beta-lactam antibiotic that is very effective against both Gram-negative and Gram-positive bacteria. Agar was found to increase the surface area to volume ratio and the drug loading capacity. The prepared nanofibers were found to be in 30-230 nm size range based on the agar concentration. 4% weight of agar is used for obtaining good quality of fibers and fewest beads were formed. The good solubility and compatibility between the drug and agar hydrophilic drug easily loaded into the PAN / agar system. It showed a 13% release for 24 hrs after that and the release of drug was slightly slowed for next 7 days. The inhibition ring of this drug delivery system was slightly small, actually provided the extended slower release of AMC from AMC/PAN/Agar nanofiber.[55] So, AMC/PAN/Agar nanofiber based wound dressings facilitated the wound healing process as compared with the commercially available gauze wound dressings materials with the extended release profile. From the above-mentioned research studies, it can be considered that majority of antimicrobial drugs can be easily incorporated in the nanofiber and exhibited a better drug release profile.

Treatment for alopecia

Alopecia is a the most common problem now a days and many people are facing this problem from their middle age. Current therapies for alopecia are hair transplantation and medication with minoxidil and finasteride and various types of cosmetics products. Minoxidil sulphate, applied topically, is widely used for the treatment for the androgenic alopecia. It is also reported that 40% of people noticed hair regrowth after 3 to 6 months. It also has very less side effect. But the most minoxidil formulation have various disadvantages like instability, messy application and also the formulation is quite expensive. [56] In a recent studies an excellent activity of electrospun nanofiber is found for the treatment of alopecia, Fadilah Sfouq Aleanizy et al. studied polyvinylpyrrolidone (PVA) minoxidil sulphate loaded nanofiber solid nano formulation used for the restoring hair and also as a shading colour for beauty coverage upon application. The high surface area also increased the drug loading capacity and the nanofiber showed a 47.4% encapsulation efficiency and 73% yield. The PVA-minoxidil loaded nanofiber had an average diameter within 273 nm and 511 nm. *in vitro* release study of PVA-minoxidil loaded nanofiber exhibited an initial burst release followed by a controlled release pattern. Overall, the prepared solid/coloured nano formulation will be an ideal application as compared to the commercially available market preparation.

Conclusion and Future perspectives

Nanofibers will be of great potential use in cosmetics. Nanofibers produced by electrospun method have a versatile application in cosmetics industries. Due to the high surface area the drug loading capacity also increases, and provide have a site-specific action and releases the drug over a longer period of time for skin care, wound dressings material, deodorant, treatment of alopecia and also for delivering of antibacterial drugs for wound healing process. Nanofiber are found to be more effective in cosmetic application as compared to the commercially available marketed product. The investigation is still going on for improving the drug delivery and also to scale up the technology from laboratory to industrial scale up process.

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