A review on synthesis, advantages and disadvantages of Nanofibers

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Abstract

This review paper aims to study the synthesis of nanofibers using Chitosan, Gelatin (which consists of a mixture of peptides and proteins produced by partial hydrolysis of collagen extracted from the skin, bones, and connective tissues of animals).. The nanofibres were fabricated through the electrospinning technique.The research paper discusses the detailed analysis of nanofibres with respect to our synthesized materials. It has proper description of the purpose of synthesizing, Advantages, and disadvantages of various methods in preparing Nanofibers, and it also covers brief description and application in various important fields of sciences by using nanofibers.

keywords:. Nanofibers Chitosan, Gelatin, electrospining

I.Introduction

Nano-fibre, can be defined in the terms by splitting into two parts namely “nano” and “fibre”. The textile industry defines fibres as a filament natural or synthetic as cotton or nylon capable of being spun into yarn. A “fibre” is defined from a geometrical standpoint as a slender, elongated, threadlike object or structure [1]. The term “nano” is technically referred to the scale of billionth of the unit. Generally, nano-fibre is a term used for fibres with a diameter between 50 and 300 nano-meters [2].

Nanotechnology is the science concerned with the study of the phenomena and functions of matter within the dimensional range of 0.1 – 100 nm. A nano-meter abbreviated as nm, is a unit for length the measures on billionth of a meter [3-4] unusual and unique properties of nano-scale materials arise from their exhibited profile compared to macro materials. Novel properties exhibited by these materials investigated from their minute dimension which converted into unusual mechanical, thermal, biological, optical, magnetic and electrical properties [5].

Nano materials is currently under investigation in different fields such as self assembly and thin films, quantum dots, nano-fibres, nanorods, nanotubes, nanowires, nanocrystals and nanofoams[6]

Nano-fibre technology incorporated in different application area such as batteries and fuel cells, capacitors, transistors and diodes, system for energy transfer, composites for aerospace structures, drug delivery and tissue engineering.

Nano-fibre technology is a branch of nanotechnology whose primary objective is to create materials in the form of nano-scale fibres in order to achieve superior function. The unique combination of high specific surface area, flexibility and superior directional strength makes such fibres a preferred material for many application ranging from clothing to reinforcements for aerospace structure. The effect of fibre diameter on the performance and process ability of fibrous structures has long been recognized. Several scientists such as Professor Parallel Reneker almost a decade ago had popularized the electro-spinning technology [7].

Several methods have been developed to fabricate nano-fibres, such as templates [8-9] self-assembly[10-12], phase separation[13], melt-down[14] and electro-spinning[15-18]. Electro-spinning is currently the most promising technique to produce continues nano-fibres on a large scale and the fibre diameter can be adjusted from nano-meters to microns. Also, electro-spinning is a relatively easy and fast process to produce nano-fibres.

Although, the first patent on electro-spinning technique was published as early as in 1934. [19], this technique has not been well established until recent times [20-23]. Technically, electro-spinning is a process that uses a strong electric field to draw a polymer fluid into the filaments[24-27].

Although there are several alternative methods for generating fibres in a nanometre scale, nano matches the popularity of the electro-spinning technology due largely to the simplicity of the electro-spinning process. Electro-spinning can be carried out from polymer melt or solution. The structures and properties of the fibres produces by the electro-spinning process are then examined. Recognizing the enormous increase in specific fibre surface, bioactivity, electro-activity and enhancement of mechanical properties, numerous applications have been identified including filtration, biomedical energy storage, electronics and multifunctional structure composites.

Chitosan is a polysaccharide derived from chitin; Chitin is the second most abundant polysaccharide in the world, after cellulose. The presence of amino group in the Chitosan structure might be protonated. Providing solubility in diluted acidic aqueous solution, several remarkable properties of chitosan offered unique opportunities to the development of biomedical applications. Elucidation of Chitosan for medical and pharmaceutical interest has been done. The haemostatic activity of chitosan can also be related to the presence of positive charges on chitosan backbone. Due to its positive

Advantages and Disadvantages Of Various Methods In preparing Nanofibers Table No.1 [43]

charges, chitosan can also interact with the negative part of cell membrane, which can lead to reorganisation and an

S.	*Technique*	*Advantages*	*Disadvantages*
1.	*Drawing*	*It produces single long nano-fibres.*	*It limits to viscoelastic material, depending on the orifice size of the extrusion mould which leads to difficulties in obtaining fibres of diameters less than 100nm.*
2.	*Template synthesis*	*It uses Nano- porous membrane as a template.*	*It cannot craft the long continuous nano fibers.*
3.	*Freeze drying*	*It is simple and cost effective.*	*Its uniform porosity cannot be maintained.*
4.	*Phase Separation*	*It controls the pore size and structures and the range of shapes and sizes.*	*Long continuous fibres cannot be produced due to its limitations which is limited to a very few polymers. The high cost of synthesis of biomaterials have limited their applications; engineered peptide nanofibers can be fragmented which are suspect-able to endocytosis.*
5.	*Self-*		*The long continuous fibres cannot be produced because of its limitation a very few polymers.*
6.	*Electrospi*	*Fibres are of diameter size, ranging from nanometre to the few microns ,which are relatively inexpensive technique and have high aspect ratio and have enhanced mechanical properties.*	*They undergo several difficulties in making a large volumeofscaffold.*

opening of the tight junction proteins, explaining the permeation enhancing property of this polysaccharide.

The polycationic nature of Chitosan also allows explaining Chitosan analgesic effects. Now, to explain Chitosan biodegradability, it is important to remember that Chitosan is not only a polymer bearing amino groups, but also a polysaccharide, which consequently contains breakable glycosidic bonds. Chitosan is actually degraded in vivo by several proteases and mainly lysozyme, Chitosan is biocompatible, biodegradable and non-toxic, so that it can be used as medical application as antimicrobial and wound healing biomaterials. It is used as chelating agent due to its ability to bind with cholesterol, fats, proteins and metal ions [28].

Chitin and Chitosan nanofibers with (50-500nm diameter) are biocompatible and biodegradable, so they can used as haemostatic and wound healing material [29].

Synthesis:

Several techniques are used for the synthesis of nano-fibre that electrospining is the promising one. The advantages and disadvantages are discussed in the table no.1

Electrospinning :-

Nonwoven fibrous materials can be effortlessly and constructively made by using electrospinning technique. But for synthesising nanofibres, detailed study of electro-spinning parameters is very essential [30]. Highly precise manufacture of nanofibres can be done using process like self-assembly[31-34] whereas large volume manufacture is done using process like island-in-sea[35]. Due to its comparatively large manufacture rate and affordability, Electro-spinning technique has an edge over the other methods.

The apparatus usually consists of collector, spinneret and high power supply. The required potential is applied and maintained between the spinneret and collector [36-37]. And both of them are placed at a fixed distance.

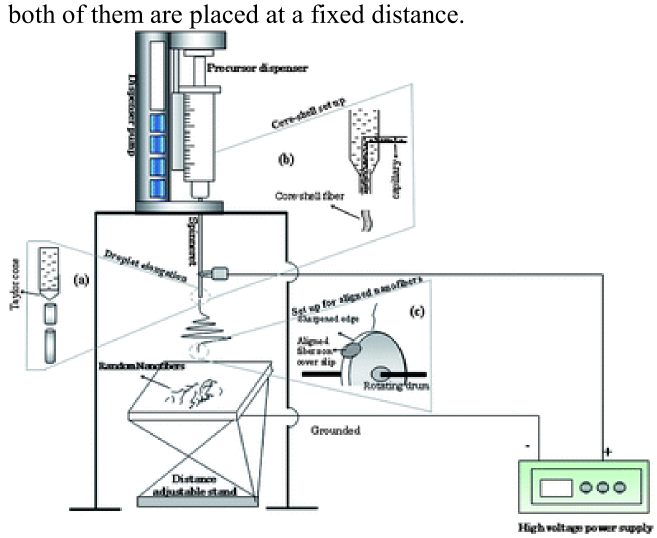

fig. 1 Schematic of electrospinning set up to obtain random nanofibers. (a) Enlarged view of formation of fiber starting from the Taylor cone. (b) Set up to obtain aligned nanofibers using rotating drum with sharp edge. (c) Set up to obtain core-shell nanostructures [38].

Electrospinning inherits attributes of both conventional solution dry spinning and electro spraying of fibers[39]. Nano fibers can be of two types : aligned and non-aligned. Usually non-aligned nano fibers can be formed using this set up but in order to form aligned nanofibers external set up like a circular rotating disc is used or electric field is optimised. Circumferentially oriented nano fibers are a consequence of spinning of cylindrical collector at high speed [40-42].

Applications

1. Filtration

Filters have been widely used in both households and industry for removing substances from air or liquid. Filters for environment protection are used to remove pollutants from air

or water. In military, they are used in uniform garments and isolating bags to decontaminate
aerosol dusts, bacteria and even virus, while maintaining permeability to moisture vapour for comfort. Respirator is another example that requires an efficient filtration function. Similar function is also needed for some fabrics used in the medical area. For a fiber-based filter, removal of particles is determined by different mechanisms. Large particles are blocked on the filter surface due to the sieve effect. Particles that are smaller than the surface-pores will penetrate into the filter, which could still be collected by the fibers, via either interception or impaction, or static electrical attraction. Also, very fine particles could be captured due to the Brownian motion effect. The filtration efficiency is normally influenced by the filter physical structure (fiber fineness, matrix structure, thickness, pore size, etc), fiber surface electronic properties, and its surface chemical characteristic (e.g.surface free energy). The particle collecting capability is also related to the size range of particles being collected. Besides the filtration efficiency, other properties such as pressure drop and flux resistance are also important factors to be evaluated for a filter media.

2. Recovery of metal ions and affinity membranes

Surface chemistry, incorporation of functional materials, and coating techniques are some of the methods which provide electrospun nanofibers a very good potential to be operational. These nanofibers would possibly be able to accumulate metal-ions or fine molecules from a solution. For instance, dye cibacron blue F3GA (CB) was surface functionalized with electrospun cellulose nanofibers, and further the electrospun membrane depicted a powerful affinity towards bovine serum albumin (BSA) [44]. A membrane was synthesized from electrospun polysulphone (PSU) fibers of the same affinity as BSA which was suface functionalized with toluidine blue O [45], another dye. In comparison to conventional microfibers, the two nanofiber-based affinity membrane exhibited higher flux and lower pressure drop. In extension to this, silk/keratin wool electrospun fibroin blend nanofibers have demonstrated to have an attribute to chelate absorb Cu(II) ions from H2O [46]. During an experiment, it was observed that if nanofiber membrane is surface coated with conducting polymer then , it gained the ability to accumulate teh gold ions from aqueous solution. The gold ions were eventually converted to elemental gold particles [47].

3. Wound healing

Wound healing is a native process of regenerating dermal and epidermal tissues. When an individual is wounded, a set of complex biochemical actions take place in a closely orchestrated cascade to repair the damage. Normally, body cannot heal a deep dermal injury. In full thickness burns or deep ulcers, there is no source of cells remaining for regeneration, except from the wound edges. As a result, complete re-epithelialization takes a long time and is complicated with scarring of the base[48]. Dressings for wound healing function to protect the wound, exude extra body fluids from the wound area, decontaminate the exogenous microorganism, improve the appearance and sometimes accelerate the healing process. For these functions, a wound dressing material should provide a physical barrier to a wound, but be permeable to moisture and oxygen. For a full thickness dermal injury, the adhesion and integration of an “artificial dermal layer” consisting of a 3D tissue scaffold with well cultured dermal fibroblasts will considerably assist the re-epithelialization. A study on using electrospun polyurethane membrane as wound dressing material revealed that the membrane effectively exuded fluid from the wound, without fluid accumulation under the membrane cover, and no wound desiccation occurred either[49]. Details about skin tissue engineering have been summarized already. In vivo wound healing of diabetic ulcers was investigated using electrospun block copolymer (PCL-PEG) and PCL. When the nanofibers were chemically modified with a recombinant human epidermal growth factor (rhEGF), the expression of keratinocyte-specific genes and EGF-receptor were enhanced[50]. Post-surgery tissue adhesion is a widely recognized problem for abdominal surgeries. It not only renders future operations more difficult but also causes other problems such as small bowel obstruction, female infertility, and chronic debilitating pain[51,52].

4. Reinforcement

Early studies on electrospun nanofibers also included reinforcement of polymers. As electrospun nanofiber mats have a large specific surface area and an irregular pore structure, mechanical interlocking among the nanofibers should occur. When a thin electrospun nylon-4,6 nanofiber mat was added to epoxy, the composite showed transparency to visible light, and both the stiffness and strength were increased considerably compared with the pure epoxy film[53]. Electrospun polybenzimidazole (PBI) nanofibers have been used as fillers to reinforce epoxy and rubber[54]. An epoxy containing 15 wt% electrospun PBI nanofibers was found to have higher fracture toughness and modulus than the one containing 17 wt% PBI whiskers. Also the Young’s modulus and tear strength of styrene-butadiene rubber (SBR) containing the PBI nanofibers were higher than those of pure SBR. In addition, electrospun nylon PA 6 nanofibers were used to improve the mechanical properties of a BISGMA/TEGDMA dental restorative composite resins[55].

5. Release control

Controlled release is an efficient process of delivering drugs in medical therapy. It can balance the delivery kinetics, minimize the toxicity and side effects, and improve patient convenience[56]. In a controlled release system, the active substance is loaded into a carrier or materials science device first, and then releases at a predictable rate in vivo when administered by an injected or non-injected route. As a potential drug delivery carrier, electrospun nanofibers have exhibited many advantages. The drug loading is very easy to implement via electrospinning process, and the high applied voltage used in the electrospinning process had little influence on the drug activity. The high specific surface area and short diffusion passage length give the nanofiber drug system higher overall release rate than the bulk material (e.g. film). The release profile can be finely controlled by modulation of nanofiber morphology, porosity and composition. Nanofibers for drug release systems mainly come from biodegradable polymers, such as PLA[57], PCL[58,59,60], poly(D-lactide)(PDLA)[61], PLLA[62—64], PLGA[65,66], and hydrophilic polymers, such as PVA[67-69], PEG[66,70] and PEO[71]. Non-biodegradable polymers, such as PEU[72], were also investigated.

Conclusion:

This review has covered the diverse applications of electrospun nanofibers. The review is by no means exhaustive, and new nanofibers and applications are emerging continuingly. . It has proper description of the purpose of synthesise, advantages and disadvantages of various methods in preparing Nanofibers and its also covers brief description and application in various important fields of sciences by using nanofibers**.** While the potential for nanofibers is enormous, there are also considerable challenges ahead. Most of the studies in this area have been conducted on fibers produced on a very small scale, using a needle based system to electrospin nanofibers from a polymer solution. The fibers produced on the large scale equipment to ensure consistent fiber quality and address the environmental issues associated with solvent/solution based electro-spinning technology. Producing uniform fibers with an average diameter below 100 nm remains a challenge

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