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Review Article

Nanofibers in Drug Delivery Systems: A Comprehensive Scientific Review of Recent Approaches

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ABSTRACT

Pharmaceutical formulations, polymer-based nanofibers, which have higher surface area per unit mass of solid, enable and contribute to functions linked to surface shape. Nanofibers can be made using a number of different methods, but only electrospinning technology has been specifically focused on producing a wide variety of these common polymer-based nanofibers. The manufacturing potential of just this method is enormous. Electrospinning is also the most versatile, as it can produce a wide range of nanowire assemblies that, with the right tweaks, might improve the performance of goods made from Nanofibers. For these reasons, it is crucial and necessary to study the many factors and procedures that go into making the best possible nanofibers. Standard processes and tools may be used to examine nanofibers' structure, morphology, and geometry, as well as their tensile and elongation characteristics. In this article, we take a look at the various ways in which polymer composite nanofibers can be used in tissue engineering, such as in tissue scaffolds and cutting-edge wound dressings for chronic wound therapy, in addition to their potential roles in drug delivery systems, in clothing protectors, and sensors. There are just a select few of these products that have been released so far, but more nano- and bio-sciences products are expected to hit the market shortly. Polymer-based nanofibers have emerged as a result of efforts to commercialize these applications. A variety of fields, including biology, nutrition, bioengineering, pharmaceuticals, and healthcare, find this structured fiber useful.

Keywords: Nanofibers, Electro spun, Natural fiber, Polymer composites, Filtrations, Tissue engineering, Drug delivery systems.

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INTRODUCTION

Materials for nanofibers are those with a diameter smaller than 100 nanometers. A wide range of polymers, including gelatin, chitosan, collagen, CMC-carboxymethylcellulose, and PVA-polyvinyl alcohol from electrospinning, be acceptable materials for the development and production of nanofibers. Due to their higher surface area, reduced porosity, and identical unique properties, nanofibers can offer considerable advantages in wound care management.[1]

To aid in the recovery and healing of wounds, polymeric matrix structures, including nanofibers embedded with drugs or growth factors, demonstrate the advantages of nanofibers. These nanowires, particularly in biomedical applications, conduct unique mechanisms such as the absorption of exudates or the ability to provide anti-adhesive action (addition of drugs containing polymer-based nanofibers). Many targeted drug delivery systems also use nanofibers to control the release profile of the medication packaged in a polymer at a specific spot.[2]

Fabrication of nanofibers by electrospinning

Electrospinning is the most adaptable and cost-effective method for producing fine strands or filaments of the congaing drug-polymer solution when exposed to a high-voltage electric field. Compared to the typical diameter of human hair, these tiniest fibers are a thousand times smaller in diameter. The high voltage on the metal syringe provides a usual electric charge on the solution's surface, which causes nanofibers to develop. Using a needle that shoots out a tiny stream of polymer solution, this charge is attracted to an electrically grounded collector enclosed by a piece of aluminium foil. As a syringe is charged with high voltage, nanofibers are formed on the solution's surface, and this charge attracts an electrically grounded collector enclosed by aluminium foil. Because of voltage differences, the solvent tries to escape as it comes from the needle of a syringe.

The electrospinning technique has more advantages than disadvantages, including the ability to produce nanofibers at a fast rate, ease of setup, and the most cost-effectiveness. It also

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helps to maintain the desired diameter of nanofibers while using the electrospinning method.[3]

Influence of Parameters on Surface Morphology of electro spun Nanofibers

The following variables may influence the morphology of electro spun fibers: (i) processing variables (e.g., flow rate,[4] electric potentials,[5,6] capillary tip-to-collector distance,[7] and collector set-up).[8] (ii) system characterizations (e.g., the molecular weight of polymer,[9] conductivity,[10] surface tension of polymer solution,[11] and viscosity).[12,13] (iii) The applied electric field strength influenced the form and diameter of electro spun fibers.[14] Increasing the applied voltage always increases fibre diameter, while increasing the field strength causes bead flaws in electro-spun fibers. Fibers that collapse into beads or cannot be extruded due to considerable polymer entanglement are not extremely dilute or highly concentrated.[15]

Reneker D. H. *et al.* proposed a critical role in achieving desired nanofiber sizes is played by jet size, which is a crucial step in evaporating the solution to produce nanofibers that the jet might be split into several jets, which leads to the creation of varied diameters of nanofibers (Figure 1).[16]

When there is no splitting from the jet, and when a polymer solution is viscous, fiber diameter is also influenced. If a key is denser, it produces fibers with greater diameters.[17-20]

A linear relationship between viscosity and polymer concentration will exist in any solvent in which a solid polymer dissolve. As a result, a solution with higher viscosity is always larger in diameter with increasing polymer concentration.[21] Deitzel *et al.* found that nanofiber diameters grow with increasing polymer concentration based on a power law relationship. Fiber diameter is also greatly influenced by the voltage applied to it. Higher voltage results in a larger fiber diameter because more fluid is ejected in a jet (Table 1).[22,23]

Nanofibers In a different context

Polymer-based electrospun nanofibers have been intensively explored recently, notably for nanofiber composites. A US patent in this respect describes the filtering system and medical science's dominance in detail (Figures 3 and 4). Nanofibers have several applications, including electromagnetic shielding and de-lamination of complex resistance. Many applications have not fulfilled industrial standards, although the research was done at the laboratory level. Academics, government agencies, and businesses worldwide are taking notice of and investing in these promising new technologies (Figure 5).

Biomedical Applications of electro spun nanofibers

The majority of the human body comprises nanofibers, including bones, dentin, collagen, and skin, according to biomedical applications. Nanometer-scale manipulation of fibrous components is well known for these components. This current study might focus on manufacturing nanofibers employing a unique electrospinning technology for bioengineering purposes. One of these new tools will thus assist in discovering their promising potential in a broad range of biological disciplines, some of which are described below (Table 4).

Nanofibers in Energy storage materials

In addition to fossil fuels, nanofibers may store various forms of energy, such as natural gas and hydrogen. These carbon-based nanofibers' numerous huge specific areas and high pore volume have been noted. Physical adsorption can be used to deposit these natural gases and hydrogen, making the utilization of gases simple. It was therefore compared to other materials, such as graphite, activated charcoal, and carbon nanotubes in Figure 5, to see how well these nanofibers could store energy.[63]

Engineered fibers such as Kevlar, glass, and carbon should be used as a backbone in developing complex-based nanofibers rather than traditional (μ) fibers such as cotton. The structural qualities of complex materials, such as more remarkable ability and superior mechanical strength to mass ratios, which any other mono-type materials could not promote causes alone, are good.[1]

This is why they have a more significant potential for use in constructing nano-complex structures. Because of this, nanofibers have been reported to have superior mechanical qualities over

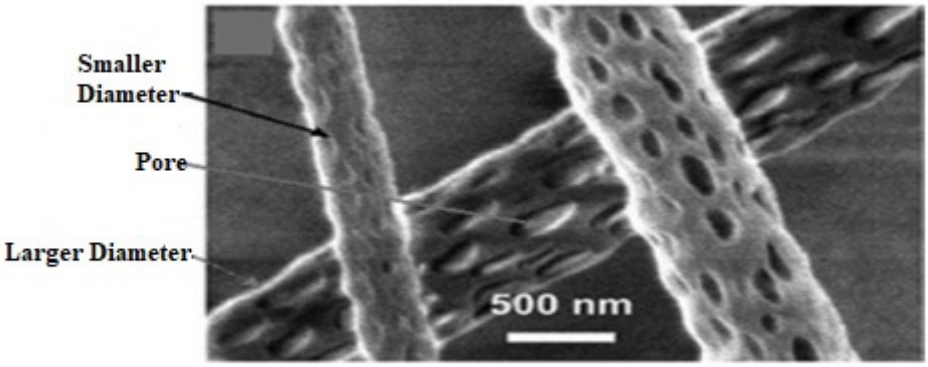

Figure 1: Poly-lactic acid nanofibers with different diameters and pores.[16]

Table 1: Composition, solvent, concentration, and functionality and applications of polymer fibers.

Authors	Composition	Solvent	Concentrations	Functionality and Applications
Chang H.Y. *et al.*-2019.[24]	Polymethylmethacrylate	THF, acetone, Chloroform.	10 wt%	Super-hydrophobic units for active packaging.
Gaaz-2015 Park *et al.*-2018.[25,26]	Polyvinyl alcohol	DI water	8-16 wt% 1-10 wt%	Biofilters and biomembranes.
Fornaguera *et al.*-2015.[27]	Poly lactic-co-glycolic acid.	Polysorbate 80, ethanol/ ethyl acetate	4 wt%	Produced through low-energy nano-emulsification.
Suwantong O. *et al.*-2016 Potr c *et al.* -2015.[28,29]	Polycaprolactone	Chloroform acetone	10% (W/W)	Oro-mucosal drug delivery techniques show great potential.
Valente *et al.*-2016.[30]	Poly (L-lactic acid)	N, N- DMF and Dichloromethane.	10 wt%	Sterilize PLLA membranes for regenerative medicine applications.
Ghosh S.K. *et al.*-2017.[31]	Gelatin	DI water	30-50% (W/V)	This biomaterial's adaptability to tissue regeneration.
Muzzarelli *et al.*-2015 Haider *et al.*-2011.[40,41]	Chitosan	TFA	1-6 wt%	Wound healing and tissue engineering.
Wang W *et al.*-2016.[32]	Starch	DMSO, glutaraldehyde	25 wt%	Tissue engineering, drug therapy, and medical
Huang G.P. *et al.*-2015.[33]	Collagen	TFA	42.85% (W/W)	Structural fibers for tissue engineering
Mohanty C. *et al.*-2017 Esmaili Z *et al.*-2018.[34,35]	PLGA-curcumin	Chloroform/ methanol	40 wt%/ 60 wt%	Slowly releasing curcumin
Sadeghi A.R. *et al.*-2016.[36]	PLGA-collagen	Hexafluoroiso-propanol	20% (W/V)	Synthetic bioengineered skin
Fukunishi T. *et al.*-2016.[37]	PCL-chitosan	HFIP acetic acid	20:1 (W/W)	It promotes cellular influx, neovascularization, and neo-tissue development without degenerative changes or catastrophe.
BaradaranRafii A *et al.*-2015 Choi M.O. *et al.*-2018.[38,39]	PHBV-gelatin	Tetrafluoro-ethylene	50 wt%	The amniotic membrane may be used as an alternative.
Shao W *et al.*-2016.[40]	Hydroxy apatite-tussah silk fibroin	Ammonia, citric acid	31 wt%	Tissue and bone regeneration scaffolds
Sessini V *et al.*-2018.[41]	Polylactic acid/PCL-cellulose nanocrystals	Acetone, DCM, toluene with phosphorus pentoxide	1wt%	Biodegradable packaging for biomedical or food

Authors	Composition	Solvent	Concentrations	Functionality and Applications
Saberi A *et al.*-2015 IspirliDogac Y. *et al.*-2017.[42,43]	PVA/alginate-bioglass	DI water	10 wt%	Hard and soft tissue biological and mechanical properties
Dhand C. *et al.*-2016.[44]	CaCO3-collagen/Poly catecholamine	HFIP, $CaCl_2$ solution	8% (W/V), 10% (W/W)	A multipurpose scaffold is required for bone tissue engineering.
Pranav Kumar Shadamarshan, R *et al.*-2018.[45]	PCL/ PVP-trans anethole	Chloroform: methanol	10% (W/V), 30% (W/V)	We can help mend and regenerate bone by growing osteoblasts *in vitro*.
Unnithan, A.R.*et al.*-2015.[46]	Polyurethane-estradiol-dextran	DMSO THF	10 wt%	Post menopause wound care
Shao W. *et al.*-2016.[40]	PLGA-tussah silk-graphene oxide	HFIP	13 wt%	Biomaterials for cancer therapy and bone regrowth
Hong B. *et al.*-2013 Liu C *et al.*-2018.[47,48]	Polyvinylidene fluoride-silver-graphene oxide	Acetone DMF	2 wt%	Magnetoelectric devices, energy harvesters
Liao N *et al.*-2015.[49]	Poly("-caprolactone)-cellulose acetate- tetracycline HCl-dextran	DMF, THF	10 wt%	Strong cell adhesion and proliferation, antimicrobial activities, wound dressing and skin engineering

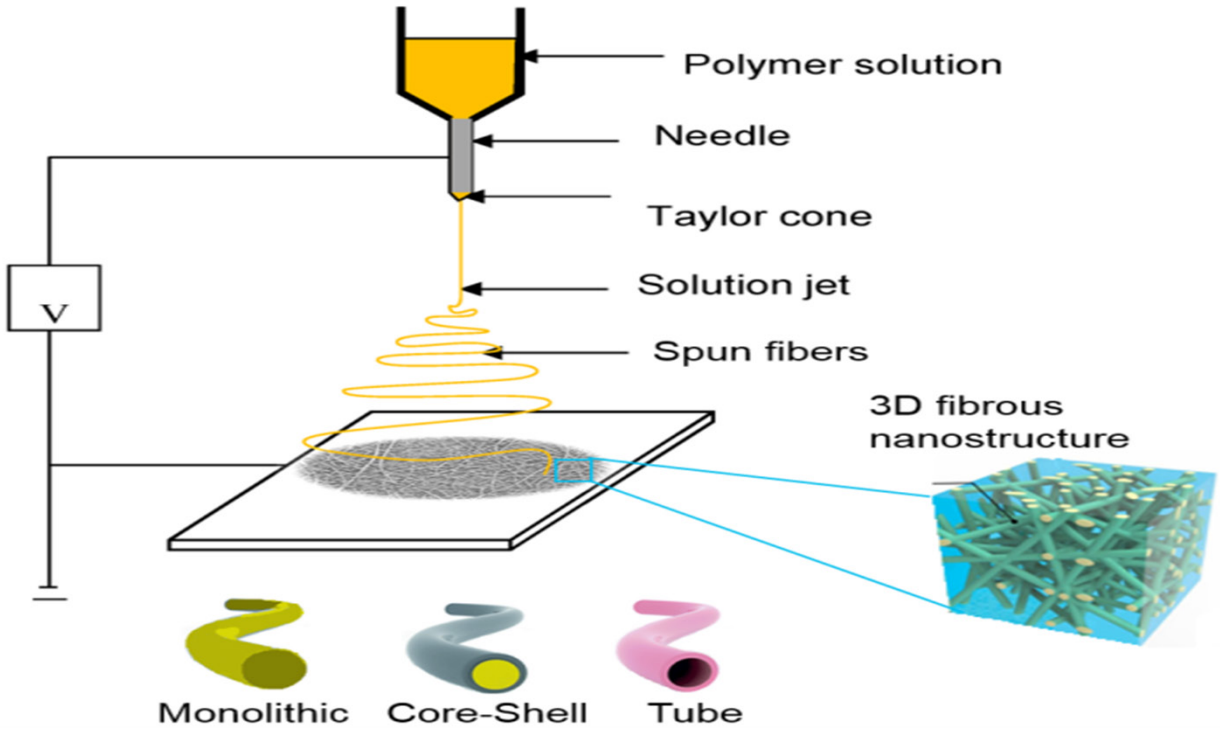

Figure 2: Diagram of the electro spinning apparatus.[126]

microfibers made with the same materials; hence nanocomposites have been anticipated to have excellent structural capabilities. It also has a few additional advantages that regular (microfiber) complexes can't take advantage. It is possible to generate an opaque or non-transparent complex by mixing fibers and matrix with differing refractive indexes (one of the physical properties of the solid-state). It is possible to bypass this restriction if the diameter of the fiber is so short that it exceeds the wavelength of visible light.[64]

Nanofibers infiltration

On the other hand, nanofibers are used in a wide range of technical applications that need filtering. For the year 2020, it was estimated that the global filtration industry would be worth up to the US $700 billion.[65]

Filter media with fibrous material are widely used in these applications because they increase filtering effectiveness while simulating air resistance. It is essential to remember that fiber porosity is one of the vital factors in filter performance. A typical coalescing filter is employed to extract clean compressed air in large-scale businesses. Because of the tiny oil droplets, these filter media are essential (0.3 microns).[66,67] It has been discovered that the electrospinning approach can deal with micron-sized particles. On the other hand, nanometer-sized fibers in the filter structure must fulfill the requirements of the particles or droplets

Table 2: Comparison of various processing methods for producing polymer Nanofiber.

Author	Processing methods	Descriptions	Fiber dimensions		Features
			Dimensions	Length	
Sadeghi A.R. et al. -1996, Z. M. HUANG *et al.*-2003.[50,51]	Electrospinning	A Nanofiber-producing polymer solution or melt to get started, you need a polymer solution, two electrodes, and a direct current supply.	3 nm to several µm.	continuous	-Easy and affordable from top to bottom -Multipurpose -continuous and randomly distributed industrial fibers.
G. F. Ward *et al.*-2001 B. Gu *et al.*-2003.[52]	Melt-blown	Microfabrication processes create the orifices, and molten polymers are extruded using high-velocity hot air gas.	150 to 1000 nm.	continuous	-orifice size affects fiber size -challenging to obtain fibres thinner than 100 nm; still under development.
P. X. Ma *et al.*-1999 F. Y. *et al.*-2004.[53,54]	Phase separation	Composed of five steps: dissolving, gelation, phase separation, freezing, solvent extraction, and freeze-drying.	50 to 500 nm.	few µm	-Making Nano fibrous foam right after freeze-drying; -Making foam takes a lengthy time; -Using specific (gelling) polymers like PLLA and its mix.
J.D. Hartgerink *et al.*-2001 X. Yan *et al.*-2001.[55,56]	Self-assembly	Atoms, molecules, and molecular aggregates at the micro and nanoscale form stable and geometrically well-defined functions via this process.	Well below 100 nm.	up to a few µm	-self-assembled materials -Inorganic synthesis is not capable of producing unique properties and functioning. -In some instances, more preparation time.
C. R. Martin *et al.*-1996 L. Feng *et al.*-2002.[57,58]	Template synthesis	Making nanoscale fibers using commercially available nanostructured films as templates for making them.	A few to hundreds nm.	µm	-nanotubes and fibrils made of polymers, carbons metals -mono-dispersed fiber diameters.

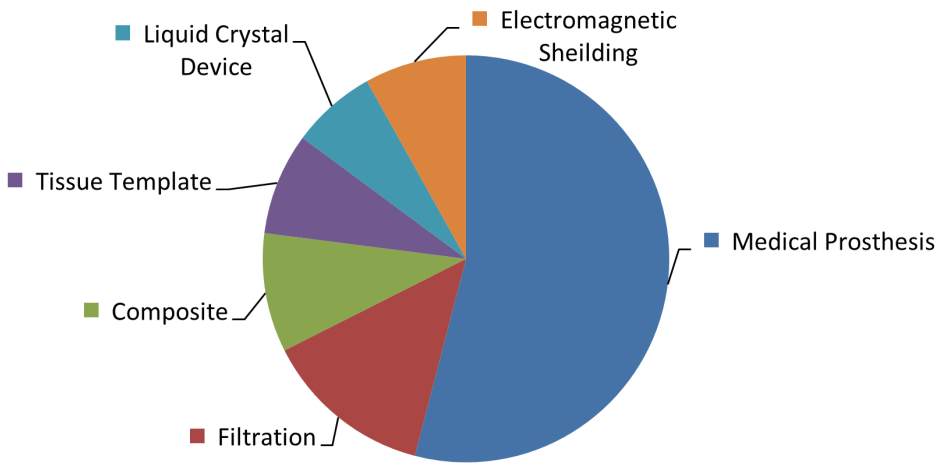

Figure 3: Application fields targeted by US patents on electrospun nanofibers.[59,60]

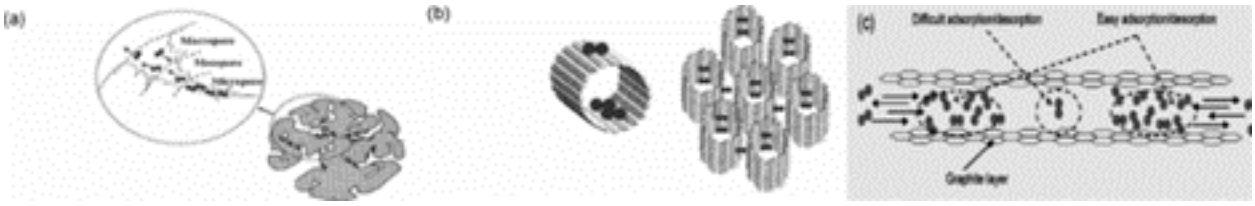

Figure 4: The mechanism of hydrogen adsorption using various carbon materials. (a): activated carbon, (b): single-walled carbon nanotube, (c): graphite.[61,62]

Table 3: Fiber surface area per mass of fiber material for different fiber sizes.

Fiber Type	Fiber size (μm)	Fiber surface area per mass of fiber material (m^2/g)
Nanofibers	0.05	80
Spun bond fiber	20	0.2
Melt blown fiber	2.0	2

that may be tracked in a filter to achieve more efficient and effective filtering (Table 3).[26,27]

Nanofibers in tissue regeneration

Organ and tissue failure may be treated using nanofibers, which are used to create new and optimal scaffolds that can imitate the human extracellular matrix' functions. These malfunctioning human cells can bind the tiniest diameter of nanofibers and restore the tissue well throughout this procedure. Additionally, these nanofibre scaffold materials will generate a threshold amount of template for cells to seed, migrate, and increase. Regenerative tissue and organs may be successfully regenerated using a variety of nanofiber structures, including those that promote cell deposition and tissue growth (Table 5).[88-90]

Nanofibers in wound care

They also serve an essential role in treating skin burns or wounds and hemostatic devices because of the identical unique qualities of polymer-based nanofibers. Electro-spun fibers have many unique properties, including the ability to form fibrous nest-like structures and resemble fibrous mat dressings when sprayed onto the injured area of skin, which aids in the healing of wounds by mimicking the formation of average skin growth and removing scar tissue, which would be done traditionally.[92,93] As a result of their tiny diameters, these non-woven fibrous mats protect the wound against bacteria penetration by administering aerosol dosages. Additionally, these nanoparticles' 5-100 m^2 surface area makes them ideal for dermal delivery system dressings and effective sorption of fluids at damaged sites (Figure 6).[103,104]

In addition, these characteristic electros spun polymer nanofibers are used as skin care protectants for the treatment of skin healing

Table 4: Electro spun drug-loaded Nanofibers in drug-delivery applications.

Author	Route of Application	Drug incorporated	Polymer
Vashisth P, *et al.* 2017.[68]	Oral route	Ofloxacin/gellan	PVA
Vuddanda PR *et al.* 2016.[69]		Ondansetron HCl	PVA
Potr C T *et al.* 2015.[70]		Ibuprofen/carvedilol	PCL
Yu D-G *et al.* 2009.[71]		Ibuprofen	Polyvinyl pyrrolidone
Li X *et al* 2013.[72]		Caffeine/riboflavin	PVA
Nagy ZK *et al.* 2010.[73]		Donepezil HCl	PVA
Colley HE *et al.* 2018.[74]		Clobetasol-17-propionate	Eudragit RS100/PVP/PEO
Li C *et al.* -2018.[75]		Salmon calcitonin	Sodium alginate/PVA
Nageh H *et al.* 2014.[76]	Dermal	Ciprofloxacin HCl	PVA/chitosan/PCL
Yun J *et al.* 2011.[77]		Ketoprofen	PVA/poly(acrylic acid)/multi-walled carbon nanotubes
Suwantong O-2008.[78]		Asiaticoside	Cellulose acetate
Taepaiboon P-2007.[79]		Vitamin A acid/ Vitamin E	Cellulose acetate
Ngawhirunpat T *et al.* 2009.[80]		Meloxicam	PVA
Mendes AC-2016.[81]		Curcumin/ diclofenac/ vitamin B12	Chitosan/ phospholipids
Souriyan-Reyhani pour H, *et al.* 2018.[82]		Tetracycline HCl/ phenytoin Na	Cellulose acetate/PVA
Zhang X-2016.[83]	Other implants	Collagen/salicylic acid	PVA
Zhang L *et al.* 2018.[84]		Amoxicillin	Polyethylene glycol/PLGA
Hu J *et al.* 2013.[85]		Cefradine/5-fluorouracil	PLGA/gelatin
Doustgani A-2017.[86]		Doxorubicin	PLA
75- Aguilar LE *et al.* 2015.[87]		Paclitaxel	Polyurethane/ Eudragit L100-55

and cleansing, either with or without the presence of various excipients. Usually, these skin care nanofibrous materials can provide a larger surface area, allowing for more straightforward application and increasing the effectiveness of medication potentiality in the skin. Since electro spun nanofibrous may be applied quickly, without discomfort, and immediately to 3-D skin photography, this unique characteristic can help minimize skin condition mechanisms (Table 6).[105]

Nanofibers in drug delivery system

Medical applications rely heavily on these nanofibers, which are used for anything from medication delivery to gene therapy. Hollow carbon nanofibers, similar to nanotubes, are smaller than human blood cells and have a higher potential for transporting medications into blood cells than other nanofibers (Table 7 and Figure 7).[105]

The list of electrospun-applied commercial products in biomedical applications are shown in Table 8.

Overcoming challenges and prospects for electrospun polymer nanofibers

Electrospinning has advanced dramatically in the last two decades. It has shown to be a powerful method for creating a range of functional nanostructures for various purposes. Electrospinning produces nanofibers with high specific surface area, homogeneous pore size, and high porosity, which increases their performance.

Furthermore, Electro spinning has started to reach the industrial industry. DuPont, Ahlstrom, Donaldson, and others have produced electrospinning-related filtering products. The electrospinning method may also be used to build nanofiber architectures by controlling polymer content, solvent, molecular

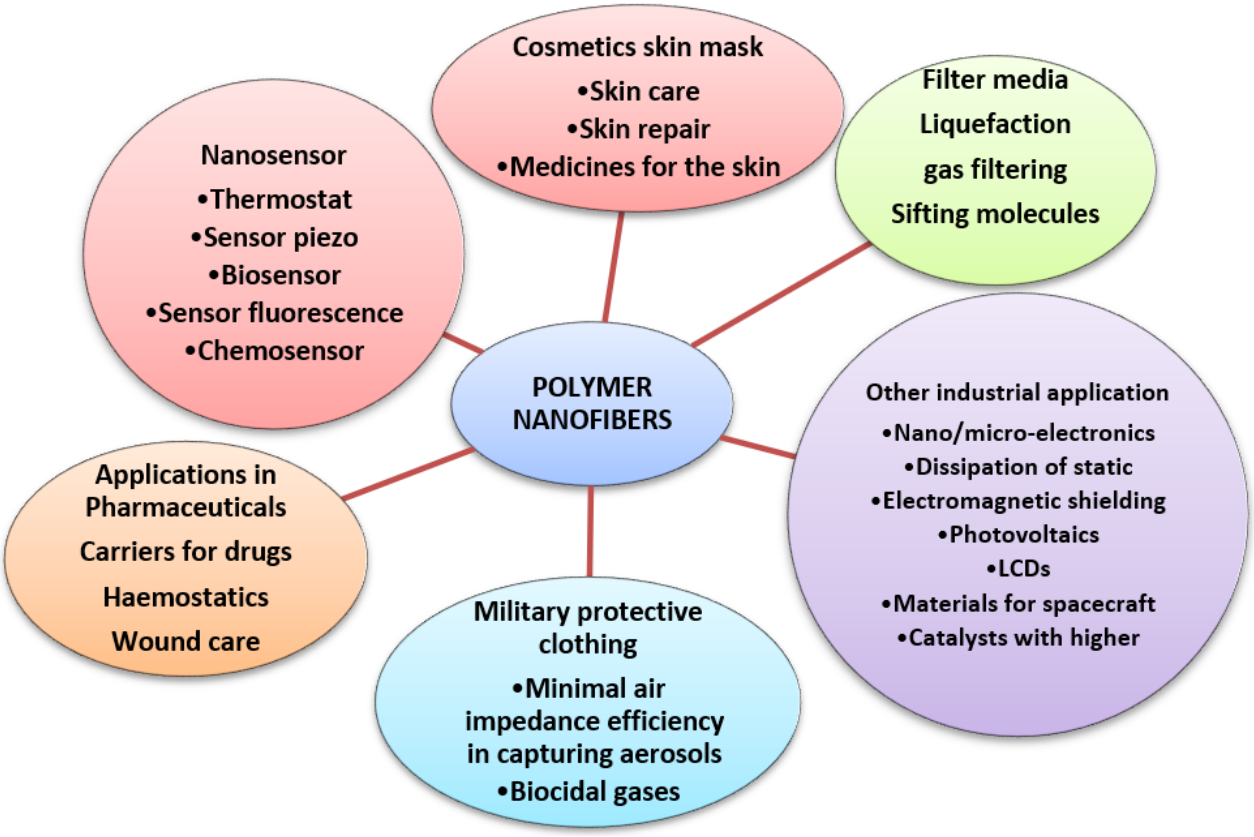

Figure 5: Potential applications of electro spun polymer nanofibers.

Table 5: Applications of the electrospun nanofibers in tissue engineering.

Author	Application	Electro spun material/ Electro spun scaffolds
Hu J *et al.* 2013.[91]	Tissue engineering	Cefradine/5-fluorouracil/PLGA/gelatin
Tian L *et al.* 2013.[100]		Hydroxyapatite/laminin/PLCL
Xu W *et al.* 2017.[101]		Alginate/PLA
Roy T *et al.* 2018.[102]		Silk fibroin/PCL
Tan GZ-2018.[103]	Vascular grafts	PCL/collagen (type I)
Fu W *et al.* 2014.[104]		Gelatin/PCL and collagen/PLCL
Du F *et al.* 2012.[105]		Chitosan/PCL
Vatankhah E *et al.* 2014.[94]		Tecophilic/gelatin
Sankaran KK *et al.* 2014.[95]		PLA/PCL
Kim MJ *et al.* 2008.[96]		PLGA/smooth muscle cells and endothelial cells
Ao C *et al.* 2017.[97]		Cellulose/nano-hydroxyapatite
Heydari Z-2017.[98]		PCL/octacalcium phosphate
Li C *et. al.* 2006.[99]		Silk fibroin/bone morphogenetic protein -2/hydroxyapatite
Haider A-2014.[100]	Bone grafts	PLGA/nHA/insulin
Sharifi F *et. al.* 2108.[101]		PCL/carboxymethylchitosan
Enayati MS *et al.* 2018.[102]		Nanohydroxyapatite/cellulose nanofibers/PVA

Table 6: Applications of the emulsion electrospinning technique in wound dressing.

Author	Application	Electrospun material
Wang Z *et al.* 2015.[5]	Wound dressing	PCL/hyaluronan/epidermal growth factor.
Basar AO *et al.* 2017.[6]		Ketoprofen/PCL/gelatin.
Garcia-Orue I *et al.* 2017.[106]		Human epidermal growth factor and aloevera/PLGA.
Chitrattha S-2016.[4]		Gentamicin sulfate/metronidazole/PLA.
Ajalloueian F *et al.* 2014.[8]		PLGA/chitosan/PVA.
Fu R *et al.* 2016.[107]		Sodium alginate/PVA/moxifloxacin hydrochloride.
Yao C-H *et al.* 2017.[108]		Gelatin/keratin/PVA.
Saeed SM *et al.* 2017.[109]		PCL/PVA/curcumin.
Wang M-2017.[110]		Chitosan/PVA/ampicillin.
Ghalei S-2018.[123]		PVA/zeinnano particles/Diclofenac.
Abdelgawad AM-2014.[124]		Chitosan/silver-NPs/PVA.
Alavarse AC *et al.* 2017.[125]		PVA/chitosan/tetracycline hydrochloride.
Aruan NM *et al.* 2017.[114]		PVA/soursop leaves extract.
Shan Y-H *et al.* 2015.[115]		Silk fibroin/gelatin.
Shin YC *et al.* 2016.[116]		Hyaluronic acid/PLGA.
Alippilakkotte S 2017.[117]		PLA/Ag NPs/*Momordicacharantia* fruit extract.
		PLA-hyper branched polyglycerol/curcumin.
Choi JI *et al.* 2017.[118]		Spirulinaextract-alginate PCL.
Rath G *et al.* 2016.[119]		Collagen/silver nanoparticles.
Lee C-H *et al.* 2014.[120]		PLGA/metformin

Table 7: Applications of electro nano spun fibers in drug delivery system.

Author	Application	Electro spun material
Hu J *et al.* 2015.[13]	Drug delivery	Metformin-hydrochloride/metoprololtartrate/ PCL/poly-3-hydroxybutyric acid-co-3-hydroxyvaleric acid.
Shin J-2018.[10]		Phytoncide/PVA.
Xu X *et al.* 2005.[11]		Doxorubicin hydrochloride/PEG-PLLA.

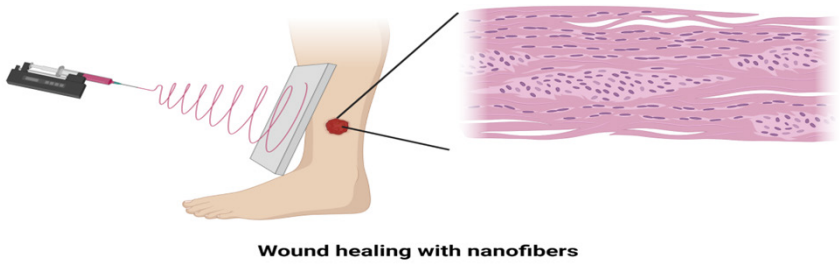

Figure 6: Nanofibers for wound dressings.[103,104]

Table 8: List of Electro spun-applied commercial products in biomedical applications. [121-125]

Sl. No.	Product	Company	Country	Applications
1	RIVELIN patch	Bioinicia	Spain	Drug delivery
2	PKpapyrus	Biotronik	Germany	Coveredstent
3	ReDuradurapatch	Medprin	Germany	Duraplasty
4	Nano fiber scaffolds	Stellenbosch (SNC)	SA	Biomedical
5	Scaffolds for tissue regeneration	The Electrospinning Company	UK	Biomedical
6	Antimicrobial dressings	PolyRemedy	USA	Wound care
7	AVflo™ vasculargraft	Nicast	Israel	Biomedical
8	ReBOSSIS	OrthoRebirth	Japan	Biomedical, Synthetic bone

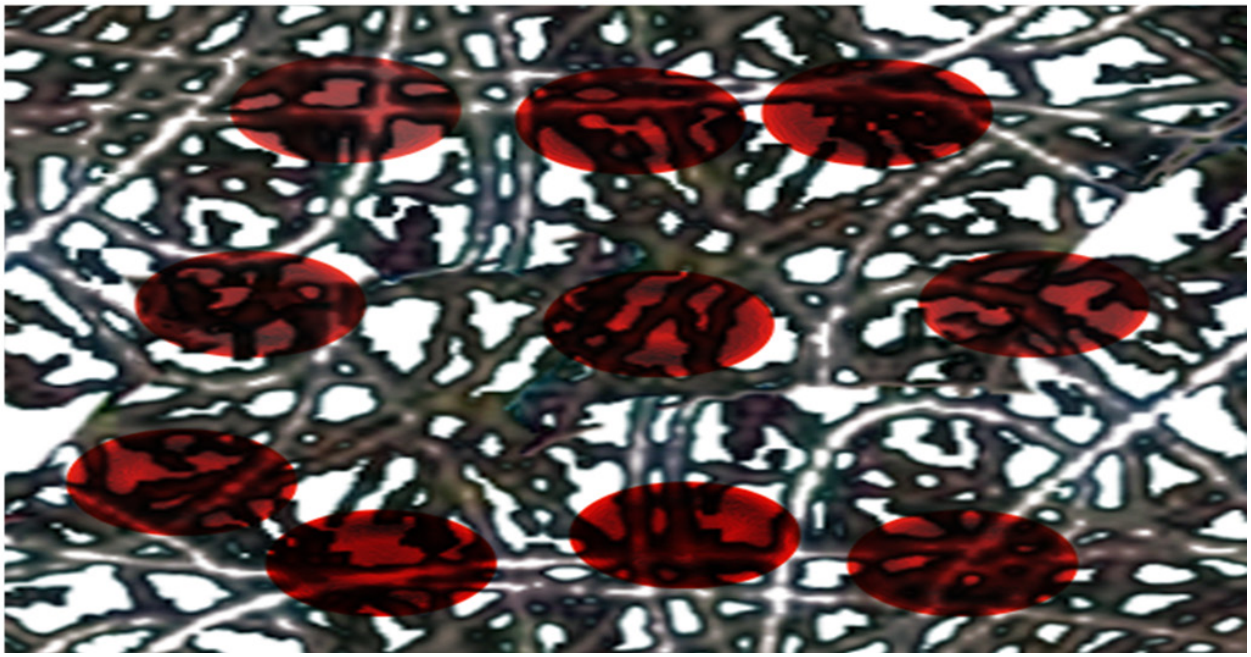

Figure 7: Comparison of red blood cell with nanofibers.[105]

weight, and conductivity. Meanwhile, chitosan, cellulose, lignin, PLA, PCL, PEO, and PVA have been used singly or in combination[111] to construct nanostructures.

Nanofibers may be used for packaging, medicine delivery, filtration, fuel cells, and other purposes. Compared to standard pharmaceutical technology, electrospun side-by-side fiber architectures may achieve innovative two-phase drug release. This sustained-release behavior may boost medication plasma concentration and quickly cure symptoms by giving a "loading dose."[112]

Despite these benefits, achieving therapeutic uses of electrospun mats will need precise and repeatable control of fiber shape, structure, and homogeneity.

Also, producing electrospun scaffolds with therapeutically relevant dimensions is complex. Despite its great flexibility and cheap cost, electrospinning's collection pace is modest, raising questions about the process's scalability. For biomedical applications, the absence of cell infiltration has lately hindered emerging technologies such as multilayer electrospinning, cell electrospray, and dynamic cell culture. Despite these obstacles, electrospun nanofibers and novel nanostructures have wide applications in various scientific fields.[113]

CONCLUSION

These nanofibers and webs have a greater possibility of delivering the drug directly to the target site. Anti-adhesive materials are increasingly being created using nanofibers comprised of cellulose. Current researchers have developed conventional spin. Blood contains nanofibers, which may be used in various medical applications, including the production of surgical bandages and sutures that dissolve fast in the body. As with infection rates and blood loss, these nanofibers are rapidly absorbed by the human body. Increased efficiency and reduced time necessary for

filtering may be achieved by using nanofibers. The experts at the Natick Soldier's Center in the United States proved the effect of nanofibers on filter aids for effective aerosol dosage form filtering. As opposed to the majority of filters that use a nanofiber substrate like sintered bronze or melt-blown fabric, they are superior. These nanofiber web components are included to offer mechanical stretto optimize filtration length, stabilization, and folding. Filter media deformation with an elastic MB coating led researchers to find that covering the substrate with nanofibers improves filtering performance.

From the above discussion, the present review concluded that these electros-spun nanofibers play a vital role in biomedical applications. These systems deliver good high-release profiles that could be attained successfully by preferring the electrospinning method side-by-side, which is very difficult to fabricate by traditional conventional techniques. Finally, these polymer-based nanofibers may convey a broad range of new drugs to supplement the natural biological rhythm for maximum therapeutic results.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

ABBREVIATIONS

CMC: Carboxy methyl cellulose; **PVA:** Polyvinyl Alcohol; **Nm:** Nanometer; **µm:** Micrometre; **PS:** Polystyrene; **PAN:** Polyacrylonitrile polymer; **THF:** Tetrahydrofuran; **DI water:** Deionized water; **DMF:** Dimethylformamide; **PLLA:** Poly Lactic Acid; **TFA:** Trifluoroacetic acid; **DMSO:** Dimethyl sulfoxide; **PCL:** Poly Capro Lactone; **DCM:** Di-chloro methane; **PVP base:** Polyvinyl Pyrrolidine; **PLA:** Poly Lactic Acid; **PEO:** Poly ethylene oxide; **PLCL:** Poly(L-Lactide-co-ε-caprolactone**; nHA:** Hydroxyapatite nanorods; **NPS:** Nano particles; **PEG:** Polyethene glycol; **PLGA:** PolyLactic- co- Glycolic acid; **PCL:** Polycaprolactone; **HFIP:** Hexafluoro-2-propanol.

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