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Manufacturing of Wet-Spun Synthetic Fibers and Types of Fibers Used

Ahmed G. Hassabo [1]*, Elham A. Dabour [2], Eman S. Youssif [2], Mahmoud A. Almouregi [3], Eman A. Awad [3], Sherouk A. Zaher [4], Lamia T. Mohamed [2], Hanan A. Othman [3]

[1] *National Research Centre (Scopus affiliation ID 60014618), Textile Research and Technology Institute, Pre-treatment, and Finishing of Cellulose-based Textiles Department, 33 El-Behouth St. (former El-Tahrir str.), Dokki, P.O 12622, Giza, Egypt*

[2] *Benha University, Faculty of Applied Arts, Spinning, Weaving and Knitting Department, Benha, Egypt*

[3] *Benha University, Faculty of Applied Arts, Textile Printing, Dyeing and Finishing Department, Benha, Egypt*

Abstract

The manufacturing of wet-spun synthetic fibers is a very important process. The main commercially available wet-spun fibers are covered in this context. The extrusion, coagulation, and drawing stages—as well as the fundamentals of wet spinning—are explained. A brief explanation of the factors influencing the spinning process and polymer solution, which ultimately impact the behavior and performance of the resulting fiber, is provided. The manufacture of acrylic and cuprammonium fiber and the resulting fiber properties receive particular attention. Wet-spun fibers' end-use characteristics are also assessed. Lastly, a summary of recent advancements in the production of wet-spun fiber and potential futures is provided. Keywords: welry, enamel materials , metal, jewellery making process , metal products

Keywords: Manufacturing Wet-Spun Synthetic Fibers

Introduction

In order to use solution spinning processes, the polymer must dissolve in a solvent without becoming degraded. The process of wet spinning entails the extrusion of fiber into a nonsolvent. Lower temperature applications make it a gentle technique that has been the go-to approach for producing fibers that cannot be melt spun. One benefit of the wet spinning method is that a large range of fiber cross-sectional shapes and sizes may be produced. In the past few years, wet spinning has shown success in achieving higher production speeds. The concepts of wet spinning are covered in this chapter, with a particular focus on cuprammonium. [1-8]

Principles of wet spinning

Pumping the polymer solution through a spinneret's fins and into a coagulating bath is necessary for wet spinning fibers. Take-up rollers are then used to draw the fibers off continuously. In order to solidify the as-spun fabrics, the bath eliminates the sol vent. They are gathered in one piece to create a continuous rope or tow.

In order to create rayon (Chardonnet Silk), the alcoholic solution of cellulose nitrate was first extruded through a mouthpiece dipped in cold water using the wet spinning method. The flowers are stretched and solidified as the cellulose nitrate solution, known as collodion, flows through the water. From the outside in, the fragment solidifies towards the center. Initially, compressed air is used to force the shredded viscous fluid onto the rotating frame.

The viscose is typically produced by a gear-type pump, which allows the viscose to pass through a funnel and then a spinneret. Typically, the fins are immersed in an acidic solution and positioned in such a way that they almost perfectly angle out from the bath's surface. Because of the cellulose's regeneration, the viscous solution solidifies into a film as it moves past the jets and into the acid bath.

Wet spinning involves the use of significantly lower speeds than melt and dry spinning procedures because the greater viscosity fluids used in the spinning process create tremendous tension on the filaments. Low speeds can be used to get around this issue. A range of precipitating baths can be used for acrylic fiber wet spinning. In the baths,

* Corresponding author: Ahmed G. Hassabo, E-mail: aga.hassabo@hotmail.com, Tel. 00201102255513
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either water or glycerol is used. As of yet, a specific yarn production method has not been made public. The qualities of the acrylic fibers produced differ significantly depending on the composition of the bath. Below is a summary of some of the baths used for acrylic fibers:

- After heating a 20% polymer solution in ethylene carbonate to 120°C, the mixture is extruded into a 130 °C bath containing 80% dipropylene glycol and 20% ethylene carbonate. Water is added to the yarn at 80°C, it is stretched ten times at 150°C, and then it is finally relaxed at 140°C (Fig.1).
- At 140°C, a 20% polymer solution in dimethyl acetamide is spun into glycerol and wound onto a bobbin, which is then rinsed with water to remove any remaining glycerol and dried. Tension is applied to the yarn as it passes through the glycerol bath. Occasionally, two glycerol baths-one at 120°C and the other at 170°C-may be employed.
- At 90 °C, a 40% solution of calcium chloride in water is spun from a 20% solution of polymer in dimethyl acetamide.
- A mixture consisting of two parts dimethyl acetamide and one part polymer is spun from an 18% solution in dimethyl acetamide. water. Water is added to the yarn as it comes out of the bath and flows into the spinning bath counter-currently at a pace that maintains the bath's composition. During the extrusion process, the polymer is continuously infused with dimethyl acetamide.
- The polymer used in Courtelle®, a commercial kind of acrylic fiber produced by Acordis Acrylic Fiber, formerly known as Courtaulds, was first dissolved in a strong calcium thiocyanate aqueous solution before being spun in an aqueous bath.

(Fig.1) Production of wet-spun acrylic fiber. (*Source*: Courtesy of Aksa, amember of AKKOK Group of Companies, Turkey.)

(Fig. 2) Extrusion of acrylic fi bers from the spinneret. (*Source*: Courtesy of Aksa, a member of AKKOK Group of Companies, Turkey.)

In addition to dimethyl acetamide, 60% zinc chloride, 70% nitric acid, and dimethyl formamide are solvents that are suitable for making acrylic fillers (Fig. 2).

The wet spinning procedure is also used to create alginate fibers. Sodium alginate is produced by reacting solid sodium alginic acid with sodium carbonate; this product is utilized in spinning. Lower grades (lower viscosities) result in poorer fibers; the grade utilized for fiber spinning has a viscosity of roughly 60–80 centistokes in 1% solution at 25 ° C. Although much higher grades are more difficult to dissolve and filter, they might provide fiber that is of higher quality. compared to those made of seaweed. A bactericide is added to a prepared 8–9% sodium alginate solution to sterilize it. It is filtered and spun into a coagulating bath that contains a small amount of a cationic surface active agent, 0.02 N hydrochloric acid solution, and regular calcium chloride solution. Calcium alginate precipitates are formed when the sodium alginate is expelled from the jet. After being drawn together, the filaments are cleaned, lubricated, dried, and wound. The cationic agent's job is to prevent filament attachment, while the hydrochloric acid's is to stop the jets from closing due to the formation of calcium alginate on their surfaces.

Wet spinning is the method used to create aramid fibers. P-phenyleneterephthalamides (PPTA), the most basic type of AABB para-polyaramide, are what Twaron and Kevlar are. P-phenylenediamine (PPD) and terephthaloyl dichloride (TDC or TCl) combine to form PPTA. N-methyl pyrrolidone (NMP), an organic component, dissolves the aromatic polymer in a co-solvent containing an ionic component (calcium chloride, $CaCl_2$) to occupy the hydrogen bonds of the amide groups and facilitate the production of PPTA. The aramid fiber is created by spinning the dissolved polymer from a liquid chemical blend to form a solid fiber after the polymer has been formed. 100% anhydrous sulfuric acid

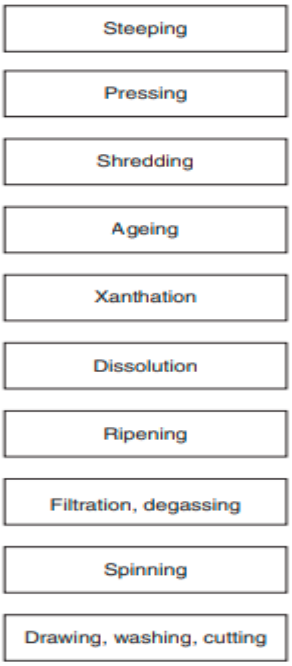
(H_2 SO_4) is typically used as the polymer solvent while spinning PPTA.

A modacrylic fiber called Dynelis a fiber that is wet-spun. A 2:3 co-polymerization of acrylonitrile and vinyl chloride results in a copolymer that dissolves to a 21% solution in acetone. After being de-aerated, filtered, and extruded using the standard wet spinning technique, the acetone solution is placed in a water bath and coagulates to create continuous filaments of fur.

Types of fibers used

Since viscose and cuprammonium rayon are two of the earliest wet-spun man-made fibers, their production will be discussed.

1. Production of viscose rayon: Because it requires spinning fiber from a liquid of regenerated cellulose in a spinning bath, the manufacture of viscose rayon fiber benefits from the wet spinning process. The following steps make up the viscose process (Fig. 3)[9]. Steeping: at a temperature of 18 to 25 degrees Celsius, cellulose pulps in big white sheets are submerged in vats containing 17 to 20 percent aqueous sodium hydroxide (NaOH). Alkali cellulose is created from cellulose, and the cellulose sheets swell.
2. Pressing: A press weight ratio of 2.7–3.0 is achieved by pressing the inflated alkali cellulose sheets. This is the weight ratio of air-dried pulp to pressed alkali cellulose sheet. [9]
3. 3. Shredding: The alkali cellulose sheets are mechanically broken into finely split particles known as "crumbs." This procedure increases the surface area of alkali cellulose, which improves its capacity for reaction.
4. 4. Ageing: Ageing attempts to bring alkalicel cellulose's degree of polymerization down to the appropriate level. Through this method, the alkali cellulose can achieve the necessary viscosity for spinning at regulated temperatures and humidity levels.
5. 5. Xanthation: this process produces a mass of cellulose xanthate by reacting old alkali cellulose with carbon disulfide. At the conclusion of this operation, the cellulose fragments take on an orange hue.
6. 6. Making the viscose solution: In a stirring tank, cellulose xanthate is combined with an aqueous caustic solution to create the viscous solution. Because of its high viscosity, this solution is referred to as "viscose." After carefully filtering the viscose solution to eliminate any undissolved material, all air bubbles are eliminated by de-aerating it.
7. 7. Ripening: The produced solution is left to ripen for a while in order to reduce its viscosity. The xanthate groups convert back to cellulosic hydroxyls and release CS 2 throughout this process.
8. 8. Filtering and degassing: To prevent the interruption of the spinning process, the solution is filtered again. Since air bubbles could cause fractures or weak points during spinning, they are eliminated.
9. 9. Spinning: A wet spinning procedure is used to spin viscous rayon filaments. The spinneret receives the viscous fluid and is submerged in a spin bath that contains zinc sulfate, sodium sulfate, and sulfuric acid. The cellulose xan thate breaks down into regenerated cellulose while the rayon fibers quickly coagulate and stretch.
10. 10. Drawing, cleaning, and cutting: the viscous rayon fabrics are dragged to show how the molecular chains are oriented along the fiber axis. The goal of this phase is to get the necessary tenacity for usage as textile fibers. Salts and contaminants are removed by washing. If cutting is required to transform the fabrics into staples, this comes next.
11. The viscose process mostly uses continuous procedures rather than batchwise ones. An increased degree of automation has ensured process continuity. [9]. The usage of scarce resources, energy consumption, disposability of the goods, and the environmental impact of viscose procedures have all been significant. [9]

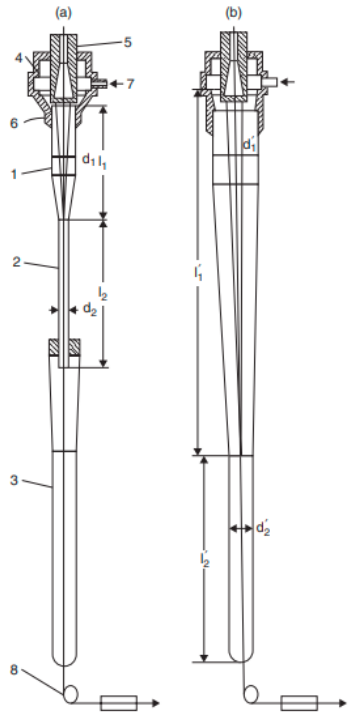


(Fig. 3) Viscose fi ber production steps.

problems in the most recent years. Since the production of viscose fibers is essentially a wet process involving large volumes of process water, these facilities also generate wastewater. The use of carbon dioxide poses a significant environmental impact. It is not possible to keep sulfur recovery at 100% since it produces sulfur compounds including CS_2, H_2S, COS, and SO_2. Waste, spin baths, and exhaust gases all contain these substances. [10] Important goals of the viscose industry's environmental concerns have been the efficient recovery of CS_2 and H_2S, as well as initiatives to minimize the usage of chemicals like NaOH and H_2SO_4. Since CS_2 is a costly material, it is best to reuse it. To facilitate recovery, the high concentrations of CS_2 and H_2S are eliminated through degassing. Spinning liquors evaporate, and the majority of CS_2 is recovered from highly and lowly concentrated process exhaust gases by adsorption or condensation, respectively. The majority of precipitated crystals of Na_2SO_4 (Glauber's salt) in viscose plants are heated until sodium sulfate (anhydrous) is ready for usage. Because of environmental concerns, zinc sulfate found in the viscose spinning bath must also be recovered. Chemical or biological treatment is used to make effluent treatment. [11]

Production of cuprammonium rayon

The American Bemberg Corporation initially employed the cuprammonium rayon method in 1926 at a plant in Elizabethton, Tennessee. This rayon yarn was sold under the trade name Bemberg. Actually, J.P. Bemberg, a German, devised the technique needed to produce Bemberg, and the first commercial manufacture of the product started in Germany in 1897. VereinigteGlanzstoffFabriken's German affiliate was the parent company, J. P. Bemberg. Bemberg is currently produced by Asahi Chemical Industries Corporation in Japan and Bemberg SpA in Italy. The short fibers on the cotton's surface are called cotton linters. For this procedure, seeds that have been ginned are used, and a solution of copper hydroxide and aqueous ammonia is employed as the solvent. After filtering and degassing the mixture of cellulose, aqueous ammonia, and copper hydroxide (or basic copper sulfate), a tiny quantity of aqueous sodium hydroxide is added. Bemberg was produced using a method known as "stretch spinning," which was developed by Edmund Thiele in 1901 in Germany and initially employed by J. P. Bemberg AG. When the sol vent exits the spinnerets and passes through a cone-shaped tunnel filled with degassed and deionized water, the fumes are created. During the passage of the feathers, ammonia and a portion of copper are eliminated. This tunnel is used for coagulation, which means that the coagulated dope is stretched hundreds of times before fibers are formed. After giving the yarn a good wash in water, it is dried. Between 1950 and 1990, Asahi Chemicals Industries Corporation invented the bath and the double or triple funnel system. The "two-step funnel" idea was improved with the filing of several patents. Aizawa et al. developed a better stretch-spinning technique in 1962 by releasing the spinning solution into a coagulating liquid flow stream. The traditional understanding of the innovation and its sectoral view the funnel type is shown in (Fig. 4). A coagulation zone, a long straight tube, and a conical tube made up the equipment. Extruded into a stretch coagulation zone, the cuprammonium spinning solution with a coagulating liquid was stretched. Then, before the first coagulation process was finished, they were moved into a second coagulation zone where the coagulating liquid's flow rate was reduced. The coagulation process was finished in a comfortable manner. Thus, cuprammonium rayons with exceptional durability, a uniform structural structure, and a resin finishing characteristic that is simple to handle were obtained. [12, 13]



(Fig. 4) (a) Sectional view of the apparatus invented by Aizawa *et al*., (b) Typical conventional funnel type apparatus.

Production of lyocell

In the 1980s, Courtaulds Fibers, UK, developed and produced the first lyocell fibers under the brand name Tencel TM fiber. Under the brand name "Lyocell by Lenzing," lyocell is produced in Austria by Lenzing AG.[10] Although the fibers are produced under several brand names, including Tencel (Acordis, formerly Courtaulds), Lenzing Lyocell (Lenzing), Newcell (Akzo Nobel), and specific brands like Seacell (Zimmer AG), the generic name for the fibers is "lyocell." 2. Viscose and lyocell are made from wood pulp, however the processes are different procedures. Unlike viscose rayon, lyocell is made via a direct dissolving technique that doesn't use any derivatives. Wood pulp is dissolved using a hot solution of N-Methylmorpholine-N-oxide (NMMO), a cyclic amine oxide that has shown to be a superb cellulose solvent. After filtering, the viscous solution is whipped into an amine oxide aqueous solution bath. (Kothari, Gupta). The fabrics are washed and dried after the spinning process. The technology offers the benefits of fewer processing steps, nearly 99% solvent recovery, and fiber qualities not possible with the traditional methods of production. (8–10) After additional biological treatment, the waste water contains very little NMMO. The qualities of lyocell fibers and their environmentally friendly production methods make them advantageous. One of the most important characteristics of lyocell fiber is its ability to fibrillate, which can be used to create the desirable "peach-skin effect" on fabric.[10]

Fiber properties

The wet spinning method, which is gentle on the fibers, has process parameters that have a significant impact on the qualities of the fiber. Another benefit of the method is that it provides a large variety of cross-sections.

Cross-section

Numerous cross-sectional shapes, such as round and bean-shaped, are possible with wet spinning. Additionally, wet-spun fibers have been roughly rounded by rapidly stretching them. This holds true for materials like alginate, lyocell, acrylics, cuprammonium, and so forth. It is important to remember that the primary cause of this is that wet spinning uses an aqueous bath. Lyocell fibers are smooth on the surface and have a circular cross section.

Density

At 25 °C, acrylics have a density of 1.17 g/c.c. It is 1.52 g/c.c. for viscose fibers, which is greater than cellulose acetate but equal to cupram monium. The density of casein fibers is 1.29 g/c.c., which is fairly close to that of wool. Conversely, alginate fibers have a high metal concentration; calcium alginate, for example, has a specific density of 1.75 g/c.c. due to its 10% calcium content. At 1.5 g/c.c., lyocell also has a rather high density.

Mechanical properties

About 0.8–1.0 g/den and 15% elongation are present at breakage in casein fibers. The primary flaw with casein fibers is their extremely poor tenacity when wet, although they also have a larger elongation at break. The tensile strength of ordinary viscose fiber is approximately 2.6 g/den. This is in extremely good comparison to 1.3–1.7 g/den of dry tenacity for cellulose acetate. Initially, viscose fiber had a wet strength of roughly 1.4 g/den. Many efforts have been made to improve viscose fibers' wet strengths, and as a result, many of its varieties now have comparatively good wet strengths. While calcium alginate fibers' extensibility is sufficiently high to satisfy most textile requirements, their wet strength is modest compared to that of viscose fibers. When dry, lyocell is the strongest cellulosic fiber—stronger than linen or cot ton—and when wet, it outperforms cotton in terms of strength. When wet, lyocell is far stronger than viscose fiber. The degree to which textiles can be properly machine washed is typically determined by this high wet strength feature. Fibers made of lyocell have ahigh degree of crystallinity and orientation. Regarding acrylics, the equivalent figures for wet fiber are 2.0 g/den and 44%, while the dry tensile

strength is 2.5 g/den and the extension at break is 35%. The tenacities of dry-spun and wet-spun acrylic fibers have been examined in a study by Aghanouri et al. following photooxidative degradation, since photooxidation of acrylic fibers can result in discolouration and a decrease in mechanical capabilities. Degradation was discovered to be dependent on the spinning technique. The toughness of wet-spun fibers decreased more than that of dry-spun fibers. [14]

Moisture regain

Under normal conditions (20 °C, 65% relative humidity), lyocell has an 11.5% moisture recapture, compared to 11–13% for viscose rayon. The moisture regain value of acrylic is between 1 and 2%. Nonpolar fibers have minimal to no regain, however polar groups are present in cellulosic fibers, which exhibit substantial regain. [15]

Factors affecting wet spinning

Because the process requires filling formation by coagulating in a spin bath, the spinning rates in wet spinning are lower than in dry spinning, which has even lower speeds than in melt spinning. Low spinning rates are compensated for by the application of low temperatures and the flexibility to have all spinning and post-spinning activities in a continuous process, which makes this technology advantageous.

The steps involved in wet spinning are preparing the polymer solution, extruding it into a liquid bath, coagulating it there, and then applying further processes to the spun fibers. Polymer solubility and spinning pressure limitations are the primary factors that determine the polymer concentration in the dope. [15, 16] The complex process of fiber creation in the coagulation bath involves temperature, extrusion, take-up velocity, and composition of the bath.

One of the most crucial elements in the coagulation of the dope's outer layer is the mass transfer rate differential, which also determines the final characteristics and microstructure of the as-spun fibers. In the literature, mass transfer in wet spinning has been thoroughly researched. To comprehend the connection between the coagulation bath factors and the coagulation of polyacrylonitrile, Rende constructed a physiochemical model. According to the model, the distance at which the polymer precipitates from the fiber axis changes over time. [17]

Ji defined the mass transfer rate differential between the coagulant and solvent and examined the impact of coagulation factors. Dopes made of polyacrylonitrile and dimethylsulfoxide (DMSO) were submerged in coagulation baths containing various coagulants, and during the coagulation process, the dope showed weight loss. [18] The impact of factors on the coagulation of cellulose from different solutions has been studied by Liu et al. It was shown that the coagulation rate depended on the coagulant's molecular volumes, bath compositions, bath temperatures, and cellulose concentrations. [19]

Applications and future trends

Novel techniques for wet spinning are being created and applied to diverse fiber configurations. By using the wet spinning approach, which includes repeatedly washing with water to halt the coagulation process, hollow tubular chitosan fibers have been created. While the coagulation bath is an aqueous solution of sodium hydroxide, the chitosan dope is made by dissolving chi tosan in acetic acid. Because water cleaning baths disrupted the reaction in the coagulation bath, interrupted wet spinning made it possible to generate hollow chitosan fibers. The creation of a chitosan outer membrane gel is made possible by this procedure. as well as a core chitosan solution, which was then removed to allow the hollow fiber structure to develop. A smaller internal fiber diameter of less than 200 μ m was obtained by using diluted chitosan dope that was less than 2.5% (w/w). [20]

Fiber experts are also investigating wet spinning techniques to create conducting polymer fibers. A similar plifi ed wet spinning procedure was used to create continuous poly(3,4-ethylenedioxythiophene): poly(styrenesulfonate) (PEDOT:PSS) fibers. It was proved that the ideal wet spinning conditions generate fibers with favorable electrical and mechanical characteristics. The spinning solution was extruded from the top of the fiber spinning setup and passed into a vertical glass column that held the coagulation bath. During spinning, the coagulation rate was lowered by using isopropanol as a coagulation bath. [21]

The wet spinning technique was used to create continuous graphene fibers, which were then chemically reduced. One of the most intriguing and alluring carbon-based compounds is graphene. Graphene oxide (GO) dopes were introduced into a hexadecyltrimethyl ammonium bromide (CTAB) coagulation bath. Because of its positive charge, the CTAB solution was chosen to serve as the coagulation bath. One could pull a 1.6 m long fiber out of the bath. Most effectively, chemical reduction came next. [22]

To sum up, wet spinning is a somewhat economical production technique. Lately, the disadvantages associated with low spinning speeds have been eliminated. Furthermore, wet-spun fibers offer a wide range of applications in the field of high-tech textiles, as demonstrated by recent advancements.

Artificial fibers can be processed during the preparation process by wet spinning by adding some different materials to the polymers during

preparation, which leads to giving these fibers new functional properties that enable the user to use them for different technical purposes.

Fibers can be equipped with some substances such as (ketosan, tea extract, some different oils and algin) in order to give the fibers antibacterial properties, so they can be used in different medical fields.

- Ya Wen et al have studied the Antibacterial and Antioxidant Composite Fiber Prepared from Polyurethane and Polyacrylonitrile Containing Tea Polyphenols and this study confirmed that The addition of TP improves structural compatibility between PU and PAN. The biomedical features of TP-loaded fibers include release ability, cytocompatibility, antioxidant capacity, and antibacterial activity. These fibers can be fabricated into 2D fabric and 3D conduit, offering potential applications in wound dressing and tissue conduit (Antibacterial and Antioxidant Composite Fiber Prepared from Polyurethane and Polyacrylonitrile Containing Tea Polyphenols. [23]
- Li-Jun Qu et al have studied the Antimicrobial Fibers Based on Chitosan and Polyvinylalcohol and this study confirmed that A blend of chitosan and PVA fibers was created using a coagulation bath and aqueous NaOH. FTIR spectra showed strong hydrogen bonds between PVA and chitosan, with chitosan's key antimicrobial molecules not crosslinking with PVA molecules. The fibers showed improved tensile strength and antibacterial effects against Escherichia coli and Staphylococcus aureus, making it a potential material for wound dressing and food packing.(Antimicrobial Fibers Based on Chitosan and Polyvinylalcohol. [24]
- H P Felgueiras et al have studied the Biodegradable wet-spun fibers modified with antimicrobial agents for potential applications in biomedical engineering and this study confirmed that The resourcefulness of the wet-spinning technique, in polymer selection, loading methodology and biomolecule, and fiber morphology (porosity, shape and size), has led to an increase amount of reports on the abilities of biodegradable microfibrous constructs, originated from natural and synthetic resources, for biomedical applications. 3D wet-spun architectures with a pre-established external shape and macropores internal structure can now be tailored to fit a desirable need. Further, biofunctionalization via biomolecule loading has increased their effectiveness in various areas of biomedical research, turning these systems very promising, and opening new opportunities to integrate such microfibers and scaffolds to currently unexplored areas of tissue engineering.(the Biodegradable wet-spun fibers modified with antimicrobial agents for potential applications in biomedical engineering. [25]
- Helena P. Felgueiras et al have studied the Physical, Thermal, and Antibacterial Effects of Active Essential Oils with Potential for Biomedical Applications Loaded onto Cellulose Acetate/Polycaprolactone Wet-Spun Microfibers and This study analyzed the antibacterial spectrum of 20 essential oils (EOs) and found that CLO, CO, and CJO oils were most effective against Gram-positive and Gram-negative bacteria. These EOs were immobilized onto CA/PCL microfibers, demonstrating uniform and homogeneous morphology. FTIR and TGA data confirmed the successful fiber modification, and even at small amounts, the EO-modified microfibers promoted cell death. These findings suggest the potential of CA/PCL wet-spun microfibers loaded with EOs for biomedicine applications, particularly in treating infections. Future studies should explore new strategies for loading amounts and mechanisms of action. (the Physical, Thermal, and Antibacterial Effects of Active Essential Oils with Potential for Biomedical Applications Loaded onto Cellulose Acetate/Polycaprolactone Wet-Spun Microfibers. [٢٦]
- Ying Zhang et al have studied the Multifunctional sodium Alginate@ urushiol fiber with targeted Antibacterial, acid corrosion resistance and flame retardant properties for personal protection based on wet spinning and this study confirmed that A new multifunctional fiber with anti-acid corrosion, flame-retardant, and targeted antibacterial properties was created by a combination of urushiol and sodium alginate fiber. The fiber has high acid resistance, excellent targeted bacterial properties against S. aureus and E. coli, and is the first to apply marine engineering anti-corrosion coating and furniture coating urushiol in personal protective clothing. The fiber has low cytotoxicity and good biocompatibility, offering a new idea for environmentally friendly "green" personal protective clothing. (Multifunctional sodium Alginate@ urushiol fiber with targeted Antibacterial, acid corrosion resistance and flame retardant properties for personal protection based on wet spinning. [27]
- Helena P. Felgueiras et al have studied the Activity of Wet-Spun Fibers Chemically Modified with Active Biomolecules against Gram-Positive and Gram-Negative Bacteria †and this study confirmed that The versatility of the wet-spinning technique is one of its most important features. Its ability to offer new opportunities

for the incorporation of various antimicrobial agents remains of great importance to biomedical applications. This research is an example of that. Indeed, the results demonstrated the potential of CA/PCL wet-spun microfibers loaded with EOs for applications in biomedicine, in which treatment of infections caused by the Gram-positive bacteria S. aureus and the Gram-negative bacteria E. coli are a main target. (Activity of Wet-Spun Fibers Chemically Modified with Active Biomolecules against Gram-Positive and Gram-Negative Bacteria.[٢٨]

Anti-UV preparation

- Yujiao Wang et al have studied the Enhanced Thermal, UV Blocking and Dye Absorptive Properties of Chitosan/poly (vinyl alcohol)/Graphene Oxide Fibers and this study confirmed that the multifunctional chitosan/poly(vinyl alcohol)/graphene oxide composite fibers, obtained through wet-spinning with ethanol, exhibit exceptional anti-ultraviolet capabilities, adsorptivity, and thermal properties. GO, with its highest thermal stability and absorptive capacity, shows excellent properties at a 1 wt.% content, making them promising for textile and wastewater treatment applications.(Enhanced Thermal, UV Blocking and Dye Absorptive Properties of Chitosan/poly(vinyl alcohol)/Graphene Oxide Fibers). [29]
- Qing Wei Wang et al have studied the Chemical and Physical Modification of Poly(p-phenylene benzobisoxazole) Polymers for Improving Properties of the PBO Fibers. I. Ultraviolet-ageing Resistance of PBO Fibers with Naphthalene Moiety in Polymer Chain and this study confirmed that the PBO copolymers with a 2,6-naphthalene group (3-9 mol% NDCA) have been prepared through in-situ polymerization. These fibers can be obtained by dry-jet wet spinning. The naphthalene moiety improves UV ageing resistance of PBO fibers by retarding tensile strength reduction. The diameter of PBO fibers decreases with UV exposure time.(Chemical and Physical Modification of Poly(p-phenylene benzobisoxazole) Polymers for Improving Properties of the PBO Fibers. I. Ultraviolet-ageing Resistance of PBO Fibers with Naphthalene Moiety in Polymer Chain). [30]
- J. Li et al have studied the synthesis of PBO-α-(amino phthalocyanine copper) composite fiber with excellent UV-resistance and tensile strength and this study confirmed that The successfully prepared PBO composite fibers containing α-TDMACuPc through in-situ synthesis and dry jet-wet spinning. The copolymerization of α-TDMACuPc with PBO molecules was demonstrated through FTIR and surface elemental analysis. The addition of α-TDMACuPc significantly improved UV aging resistance and tensile strength, thereby broadening the application of PBO fiber and its composites. (synthesis of PBO-α-(amino phthalocyanine copper) composite fiber with excellent UV-resistance and tensile strength). [31]

Conflict of Interest

There is no conflict of interest in the publication of this article.

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