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# Nonwoven Fabrics: Manufacturing, Finishing, Applications, and Possibilities

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## Abstract

The nonwovens industry in Europe has been around since the mid-sixties, with the first production of nonwoven fabric dating back to the 1930s. Since then, the manufacturing of nonwovens has expanded rapidly, with applications in hygiene, healthcare, civil engineering, household and automotive, cleaning, filtration, clothing, food wrap, and packaging. However, confusion and ignorance about nonwovens remain. This review provides a comprehensive view of nonwovens, their manufacturing process, applications, and possibilities. It aims to help those within and outside the industry, as well as attract young talents to the growing industry, which still needs to develop machinery, raw materials, and properties for optimal use.

**Keywords**: Nonwoven Fabrics, Manufacturing, Finishing, Applications, and Possibilities

## Introduction

### Definition of Nonwoven

The term "manufactured sheet, web, or batt of directionally or randomly oriented fibers, bonded by friction, and/or cohesion and/or adhesion, excluding paper and products which are woven, knitted, tufted, stitch-bonded incorporating binding yarns or filaments, or felted by wet-milling, whether or not additionally needled" is used in ISO 9092 to describe nonwoven materials. The fibers might be from man-made or natural sources. They might develop in situ or be staples or continuous threads [1-3]

A textile structure created by bonding or interlocking of fibers, or both, achieved by mechanical, chemical, thermal, or solvent processes, and combinations thereof, is referred to as nonwoven in ASTM specifications [4].

The European Disposables and Nonwovens Association (EDANA) and the North American Association of the Nonwoven Fabrics Industry (INDA) are the two major nonwoven associations in the world today. Nonwoven textiles are often described as sheet or web structures that are joined together mechanically, thermally, or chemically by entangling fibers or filaments (and by perforating films)," according to INDA. These are directly formed from discrete fibers, molten plastic, or plastic film. They are flat, porous sheets. They don't involve turning the fibers into yarn and aren't created by knitting or weaving [5].

### Classification of Nonwoven

Numerous factors may be used to categorize nonwoven textiles, including:

- In accordance with the production process spun, dry, and wet bond.
- In accordance with raw material technology: filament, nonwovens, and staple fibers.
- Based on the final purpose of the materials: semi-durable, disposable, and durable.

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- Based on their characteristics: water-replanting, flame-retardant, and water-absorbing [5]

Raw materials for the production of nonwovens

The usage of natural or biodegradable fibers is becoming more popular due to the environmental effect of disposable items including adult incontinence, infant diapers, and feminine hygiene products. Cotton, jute, kenaf, flax, and in smaller amounts, hemp, coir, sisal, milkweed, wood, and some animal fibers are examples of natural fibers used in nonwoven fabrics. The following synthetic biodegradable fibers have also been used to nonwoven applications

- regenerated cellulosic fibers like rayon, lyocell, and cellulose acetate.
- synthetic fibers like polylactic acid (PLA), poly(caprolactone) (PCL), poly(hydroxybutyrate) (PHB), poly (hydroxybutyrate-co-valerate) (PHBV), polytetramethylene adipate-co-terephthalate (PTAT), and poly (vinyl acetate) (PVA) [6].

## Nonwoven manufacturing processes [6]

The name "nonwoven" originates from at least 50 years ago, when these materials—which were often produced using carded, "dry" fibers on modified textile processing machinery—were frequently considered low-cost alternatives to conventional textiles. But the nonwovens sector has, with a piratical contempt for the widest variety of end-use goods, borrowed methods and expertise from many other areas of the materials production business. Being connected to the traditional textile business and its commodity connotations would be difficult these days. The textile business gave rise to nonwoven technologies that work with fibers when they're dry. Paper-based nonwoven textiles, on the other hand, are called "wet-laid" and are produced using equipment meant to work with short fibers floating in liquid. "Spun-laid" nonwovens, which include apertured films, melt blown, spun bond, and the numerous layered combinations of these products, are produced using equipment designed for polymer extrusion. The fiber structures are created from molten filaments and are handled similarly to plastics.

## Three primary paths lead to web forming

### Formation of dry-laid nonwovens

The textile business gave rise to nonwoven technologies that work with fibers when they're dry. The fibers are joined using a variety of techniques, including needle punching, thermos-bonding, chemical bonding, hydroentanglement, and aerodynamically produced fibers. Much of the basic wool felting technique that has been around since the Middle Ages was borrowed into the earliest dry-laid systems.

#### *Carding*

Carding is mostly used to provide individual fibers in the shape of a web and to extract tangled tufts of fibers from bales. The mechanical motion of carding involves holding the fibers in place with one surface while another combs them out. Known as the "card clothing," the card's central feature is a large revolving metallic cylinder coated with wire, needles, or tiny metallic teeth. An infinite belt of slender, cast-iron flats arranged around the top of the cylinder partially encircles the cylinder.

#### *Air-laid*

The three main processes in air-laying are web generation, web bonding, and fiber defibration. Fluff pulp is provided on a highly compacted roll that feels like cardboard throughout the defibration process. The pulp is divided into individual loose fibers by feeding the rolls into hammermills, which are equipped with a number of tiny hammers that revolve quickly. After that, the fibers are sent to the web-forming apparatus, and in the meantime, staple fibers are fed into opening systems from bales, which separate and loosen the individual fibers.

### Wet-laid nonwovens

The wet-laid technique of manufacturing nonwovens involves three distinct stages:

- the fiber's swelling and dispersion in water, as well as the suspension's movement on a continuously moving screen.
- constant filtration-induced web development on the screen.
- the web's bonding and drying.

Due to its high capital requirements and large water consumption, the wet-laid technique is only used by a relatively small number of businesses. End-use applications for "textile-like" nonwovens include surgical items, hospital supplies, bed linens, napkins, and towels. Glass-based products include circuit print mats, floors, roofing, batteries, filters, and ornamental materials. Specialty papers are used for filtering dust, liquid, and air; they are also used as overlay papers for wood and laminate floors, as well as for tea bags, plug wrap, sausage skin papers, and other purposes.

### Formation of spun-laid nonwovens

Machines are used in the production of spun-laid nonwovens, which include spun bond, melt blown, apertured films, and the numerous multi-layer combinations of these goods. originated from polymer extrusion, and the fiber architectures were created at the same time. from melted wires and worked with. The closest approach to a continuous polymer-to-fabric process is achieved in a simple spun bonding system where sheets of synthetic filaments are extruded from polymer onto a conveyor as a randomly ordered web.

#### *Melt blowing of nonwoven fabrics*

The US Naval Research Laboratories was interested in creating such fibers to gather radioactive particles in the upper atmosphere to monitor the global testing of nuclear weapons, so they first demonstrated the idea of melting thermoplastics to create microfibers smaller than ten microns back in the early 1950s. The process that was developed at the time was able to produce very fine fibers of about 0.3 microns by operating at very high temperatures of over 450 ºC. It involved using an adjustable extruder to force a molten polymer through a row of fine orifices directly into two high velocity streams of heated air and forming fibers within the gas stream when cooler, ambient air solidified with the fibers.

**Nonwoven application sectors [7]**

Nonwovens are the only technical textiles that provide affordable solutions for a broad variety of applications due to their many unique and varied properties.

Nonwovens are used in many items that we use daily, but we frequently are unaware of this because the nonwoven is mixed with other materials or has functions that are hidden from our view.

Nonwovens are made with certain features in mind, making them appropriate for a particular use. By combining their different qualities, nonwovens may achieve the necessary functionality while also achieving the ideal balance between predicted product life and cost. Additionally, the aspect, structure, and resistance of conventional textiles may be replicated with the help of contemporary nonwoven technology, bearing in mind that in addition to flat fabrics, the market also provides multi-layer composites, laminates, and tri-dimensional nonwovens.

**Personal care and hygiene**

- Baby diapers
- Sanitary napkins
- Products for adult incontinence
- Dry and wet napkins
- Cosmetic wipes
- Breath-aiding nose strips
- Adhesives for dental prosthesis
- Disposable underwear
- Medical use
- Caps, gowns, masks, and overshoes for operating rooms
- Curtains and blankets
- Sponges, bandages, and tampons Bed linen
- Pollution-controlled gowns
- Gowns for medical examinations
- Controlled release plasters
- Fastening tapes
- Mattress fillings

**Clothing**

- Components for bags, shoes, and belts
- Insulating materials for protective wear
- Outfits for fire protection
- High visibility clothing
- Safety helmets and industrial shoes
- One-way work clothing
- Clothing and shoe bag
- Outfits for chemical and biological protection
- Interlinings

**Leisure and travel**

- Sleeping bags
- Suitcases, handbags, and shopping bags
- Containers for food transport
- Vehicle headrests
- CD slipcases
- Pillowcases
- Surfboards
- Loudspeaker membranes

**Household**

- Handkerchiefs, wipers, towels
- Washing machine bags
- Vacuum cleaner bags.
- Filters for kitchen hoods and air conditioners
- Coffee and tea bags
- Coffee filters
- Table linen
- Shoe and clothing bags
- Dust removing cloths and dusters.
- Stain removers
- Descaling filters for boilers and kiers.
- Food envelopes

**School and office**

- Book covers
- Postal envelopes
- Maps, signals, and pennants
- Blotting paper

**Upholstery**

- Furniture
- Protections for shock absorbers
- Dustproof coverings
- Furniture reinforcements
- Armrest and backrest paddings
- Beds
- Quilts and eiderdowns
- Dustproof coverings
- Spring protection
- Mattress components and linings
- Curtains
- Wallpapers
- Carpet backing
- Lampshades

**Filtering of liquids, air, and gas**

- HEVAC/HEPA/ULPA filters
- Filters for liquids: oil, beer, milk, refrigerant liquids, fruit juices, etc.
- Activated carbons.
- Oduor control

**Transports**

- Boot linings
- Shelves
- Heat shields
- Inner coatings of engine casing

- Rugs, mats, and sunshades
- Oil filters
- Waddings
- Air filters in car cabin
- Decoration fabrics
- Airbags
- Silencer materials
- Insulating materials
- Car roofs
- Moquette backing.
- Seat covers.
- Car door borders

**Industry**

- Fabric coating
- Electronics: floppy disks cases
- Air filters, liquid, and gas filters
- Surface of clothing fabrics – veils
- Insulating materials for cables
- Insulating tapes
- Abrasives
- Conveyor belts
- Reinforced plastics
- PVC substrates
- Fire barriers
- Imitation leather
- Sound absorbent panels
- Air-conditioning
- Battery separators for ion exchange and catalytic separation
- Anti-slip mats

**Agriculture**

- Covers for greenhouses and cultivation.
- Protections for seeds and roots
- Fabrics for pests' dominance
- Pots for biodegradable plants
- Materials for capillary irrigation

**Geo-textiles**

- Covers for road asphalting.
- Soil stabilization
- Drainage
- Sedimentation and erosion control
- Water-hole sheathings
- Sewer's sheathings

## COMPARISION:[8]

Nonwoven composite materials may be contrasted with woven fabrics in three unique approaches viz.

**Considering Manufacturing Process**

- The whole manufacturing process of nonwoven textiles may be set up as a single line under one roof.
- The initial investment is relatively minimal.
- The nonwoven process is about five times faster and up to thirty percent cheaper than the conventional woven fabric production.
- There is a relatively minimal requirement for labor and land.

**Considering Properties**

Here, the characteristics of woven and nonwoven textiles and nonwoven composites are contrasted.

- Breaking Strength

  While nonwoven materials yield 500N in the transverse direction and 1200N in the longitudinal direction, woven fabrics have a breaking strength of around 450N in the transversal direction and 1100N in the longitudinal direction. Therefore, compared to woven textiles, nonwovens offer 10-12% higher breaking strength.

- Tear Strength

  The ripping strength of nonwoven textiles that are currently being developed is roughly double that of woven fabrics.

- Fabric Stretch

  The extensibility of currently invented nonwoven fabrics is at least approximately 50%, and more preferably at least approximately 60%, with an initial recovery of at least approximately 85%, with an initial recovery of at least approximately 90% being particularly preferred. This is approximately 20% more than that of woven fabrics.

- Abrasion Resistance

  Because of their loose structure, nonwovens are less resistant to abrasion than woven textiles, which have a compact structure.

- Fabric Weight

  When clothes made of the same area of fabric are compared, clothing made of newly created nonwoven materials are 25% lighter than those made of woven fabrics and 50% lighter than those made of knitted fabrics.

- Fabric Thickness

  When comparing textiles of identical weight per unit length, newly developed nonwoven fabrics are 10–20% thicker than woven and knitted materials.

- Air Permeability

  Nonwoven textiles offer more air permeability than woven fabrics because of their more open structure. This characteristic of nonwoven materials gives the human body exceptional comfort.

- Thermal Properties

  Because unconventional nonwoven fabric reduces thermal retention, it makes sense that when exposed to hotter temperatures outside, the user will stay cooler and feel more comfortable.

- Moisture Absorbance

  The fibers used to make the cloth have a major impact on its moisture absorbing qualities. Compared to textiles made from hydrophilic fibers, nonwoven fabrics made from hydrophobic fibers have a lower moisture absorption capacity.

Thus, we get the following advantages over woven fabrics considering properties.

- Compared to woven textiles, newly developed nonwoven fabrics are stronger and thinner.
- Compared to woven materials; nonwoven fabrics are lighter.
- Compared to woven materials; nonwoven fabrics are softer.
- Compared to woven textiles; nonwoven fabrics have greater air permeability.

**Nonwoven fabric finishing [9]**

Traditionally, finishing is classified as

- wet finishing, for example, washing, chemical impregnation, dyeing and coating.
- dry finishing, for example, calendaring, embossing, emerising and micro creping.
- Application of chemical finishes

One of the main ways to functionalize materials is to apply topical finishes and treatments to nonwovens; however, not all these finishes can withstand wet treatment or other types of wear. It is noteworthy that masterbatch additives have become accessible, allowing for the integration of various functions into the fiber or filament before web conversion, bonding, and finishing. UV absorbers, UV stabilizers, and UV filters, as well as migratory, conductive, and permanent anti-stats, antimicrobials, and various perfumes, are examples of masterbatch additives.

Numerous scholarly inquiries have delved into the treatment of nonwoven fabrics, exploring their potential applications across diverse sectors such as medicine, filtration, protective and agriculture applications…… etc

**Nonwoven fabric finishing for medical applications.**

Nonwovens are extensively used in medicine due to their protective properties against infections and diseases. Newer, improved nonwovens have self-cleansing, electrostatic, and antimicrobial features, making them crucial in wound care. Innovations include biological tissue regeneration structures, implantable tissues, and filters with nanofibers for particle capture [7]

Ramamurthy et al have investigated the antimicrobial activity of polypropylene (PP) hydroentangled nonwoven fabrics coated with transition metal oxides. The fabrics were prepared using a Rieter Perfo-jet hydroentangle nonwoven plant and needle punched nonwoven webs. The pulsed laser deposition technique was used to coat the fabrics with nano-scale coatings of Zno and Cuo. The results showed higher antibacterial activity against S.aureus than E.coli for all coatings. The coated PP nonwoven fabrics could be used as wound dressings with appropriate antibiotics [10]

Bulman et al have investigated the antibacterial activity of manuka honey (MH) and microcrystalline cellulose (MGO) when applied as a physical coating to a nonwoven fabric wound dressing. Results showed that an MGO concentration of 0.0054 mg cm-2 was sufficient to achieve a 100% reduction in bacteria against gram-positive S. aureus and gram-negative K. pneumonia. However, higher concentrations of MGO were required for a good antibacterial effect against E. coli and S. aureus. The MH-coated nonwovens produced zones of inhibition at low MGO concentrations [11].

Al fawakri et al have been studied the Improving of the Efficiency of the anazd Quality of nonwoven Medical Fabrics to Enhance their Competitiveness via fabricated fabric with different compositions, and treated with copper oxide, zinc oxide, or a blend of both. Statistical analysis revealed that copper oxide (Cuo) demonstrated superior bacterial resistance, followed by a blend of copper and zinc oxide. Zinc oxide (Zno) showed the highest performance, with concentrations of 0.15 grams per liter surpassing those of 0.10 and 0.05 grams per liter [12].

Liu et al have developed three functional wound dressings (Zn@ Cotton, Ag@Cotton, and Ag/Zn@Cotton) using template-assisted magnetron sputtering of cotton nonwovens. The Ag/Zn@Cotton dressing showed a lower defect area on animal models' full thickness skin wounds. It promoted fibroblast cell migration and prevented potential infection through electrical stimulation and continuous release of Ag+/Zn2+. Histopathological analysis showed re-epithelialization, granulation tissue formation, and enhanced collagen deposition, accelerating wound healing. The dressing also showed moderate air and moisture transport, excellent swelling ability, and acceptable tensile strength, indicating its suitability for wound healing applications [13].

Kubíčková et al have studied the Nonwoven textiles from hyaluronan for wound healing applications and the study explores the potential of unmodified sodium hyaluronate (HA) nonwoven textiles for wound healing applications. The textiles were found to be soft, flexible, and paper-like, with mechanical properties influenced by the microscale fiber structure. The flow regime in the coagulation bath also influenced the properties, with laminar and transitional flows producing softer textiles and turbulent flows resulting in higher strength. The noncytotoxicity and nonpyrogenicity of the textiles were confirmed in vitro, making them promise for use in medicine, particularly in wound healing [14].

Sikorski et al have studied the Antibacterial and Antifungal Properties of Modified Chitosan Nonwovens. And this article explores the use of acids and chitosan nonwovens to achieve antibacterial and antifungal effects. The study found that all acids were well incorporated into the nonwoven structure, with better activity against bacteria observed in samples treated with an ethanolic solution of organic acid without rinsing. The best results were obtained for materials treated with hydrochloric acid and acetic acid, and for chitosan nonwovens modified using an acetic acid solution in ethanol without rinsing [15].

Baysal have studied the Sustainable polylactic acid spun-lace nonwoven fabrics with lignin/zinc oxide/water-based polyurethane composite coatings. And the study explores the use of lignin/zinc oxide/water-based polyurethane composite coatings on polylactic acid spun-lace nonwoven fabrics. The results show improved antibacterial activity, tensile strength, and ultraviolet light protection. However, the composite coatings decrease air and vapor permeability and hydrophobicity, making them promise for protective medical textile applications [16].

## Nonwoven fabric finishing for filtration applications.

Nonwovens are used in various applications for gas and liquid filtration, including pharmaceuticals, food, and beverages. They offer permeability, resistance to pressure, and protection from viruses and bacteria. Recent innovations include nanofiber filters and electrostatically charged filters, providing antibacterial protection while remaining breathable. They also serve in critical installations like operating rooms and water filtering systems [7].

Peer et al have studied the Preparation and characterization of fibrous non-woven textile decorated by silver nanoparticles for water filtration. And this study proposes an environmentally friendly method for producing antibacterial non-woven textiles for water filtration. Silver nanoparticles, made from silver nitrate, fructose, ascorbic acid, and sodium borohydride, were prepared using bacterial cultures from S. Aureus and E. Coli. The size and density of the nanoparticles were influenced by reduction time and reducing agent, with ascorbic acid showing the most positive results [17].

Fan et al have studied the Preparation of superhydrophobic and superoleophilic polylactic acid nonwoven filter for oil/Water separation. And this study confirmed that a green superhydrophobic/superoleophilic polylactic acid (PLA) nonwoven filter was developed for oil and wastewater separation. The filter, made from PLA, showed high separation efficiency exceeding 95%, even after 20 cycles. The filter is suitable for ocean pollution cleanup and can effectively separate oil and solvents from water/oil mixtures, making it a promising solution [18].

Jalvo et al have studied Water filtration membranes based on non-woven cellulose fabrics: Effect of nanopolysaccharide coatings on selective particle rejection, antifouling, and antibacterial properties. And this study comparing the surface characteristics and water purification performance of commercially available cellulose nonwoven fabrics modified with nano-dimensioned bio-based carbohydrate polymers, cellulose nanocrystals (CNC), TEMPO-oxidized cellulose nanofibers (T-CNF), and chitin nanocrystals (ChNC), was conducted. The results showed that the nanopolysaccharide coatings significantly improved the fabric's hydrophilicity/wettability and altered the surface charge. CNC and ChNC modifications improved membrane permeance, and the nanocrystals or nanofibers impregnated on the original fabrics increased mechanical properties. T-CNF modified fabrics successfully separated 2 μm particles, showing potential for microplastics filtration. All systems showed excellent separation properties within a 500 nm size range, making them suitable for separating bacteria and viruses. The modified fabrics showed potential for use as water treatment membranes due to their easy processing, enhanced performance, reduced energy cost, and longer service life [19].

Wu et al have studied the Preparation of Non-woven Fabric Reinforced Poly (vinylidene fluoride) Composite Membranes for Water Treatment. This study demonstrates the fabrication of a non-woven fabric reinforced poly (vinylidene fluoride) (PVDF) composite membrane using poly (vinyl pyrrolidone) (PVP) to control the viscosity of casting dopes. The membrane's structure and properties were explored during the phase inversion process. The non-woven fabric accelerated the diffusion of non-solvent and gelatification, resulting in more dense pores and finger-like pores. The PVDF-PVP composite membrane increased pure water flux and BSA rejection by 1315% and 213%, respectively, and improved surface hydrophilicity [20].

Ahmed et al have studied an eco-friendly hydroentangled cotton non-woven membrane with alginate hydrogel for water filtration. And This study demonstrates the creation of a hydroentangled non-woven from cotton waste fibers, which is then immersed in a solution of sodium alginate and calcium chloride, resulting in a gel. The composite membrane's properties were analyzed using various tests. The hydrogel-based nonwoven membrane showed increased contact angle, decreased water flux, and reduced air permeability. The hydrogel-based composites have separation efficiencies of 97.5-99.5% for oil-water mixtures. The hydrophilic and hydrophilic nature of the composites can speed up wound healing. The non-woven fabric and sodium alginate hydrogel are biodegradable, environmentally friendly, and sustainable materials [21].

### Nonwoven fabric finishing for thermal protection.

Nonwoven is a kind of fibrous fabric material formed by fibers with orientation or random arrangement that compose into schistous matters or fiber web, which is one of the most important components for good thermal insulation of a body from the surrounding [22].

Chakraborty et al have studied the Radiant heat protective performance of clothing assemblies with flexible aerogel-Nomex nonwoven composite as thermal insulation. Where Aerogel-Nomex nonwoven composite felts have been used as the middle layer in 3-layered fabric for superior radiant heat protection. The study analyzed the effect of precursor concentration on radiant heat protection using methyltrimethoxysilane (MTMS) precursor to methanol molar ratios. The results showed better protection with increasing MTMS concentration [23].

Bhuiyan et al have studied Silica aerogel-integrated nonwoven protective fabrics for chemical and thermal protection and thermophysiological wear comfort. And this study confirmed that Silica aerogel-integrated breathable nonwoven fabrics offer chemical and thermal protection. The aerogel layer provides effective protection, while the addition of aerogel particles increases fabric thickness. The fabrics show improved chemical resistance and thermal resistance, providing adequate breathability and thermal comfort. They also have high air permeability, improved evaporative transmittance, and high-water uptake, allowing for better clothing comfort in hot and humid conditions. This material is promising for developing protective clothing with reliable chemical and thermal protection, making it suitable for emergency operations in hot and humid environments [24].

Shaid et al have studied Aerogel incorporated flexible nonwoven fabric for thermal protective clothing. Where this study developed a nonwoven fabric using viscose staple fiber and Enova aerogel particles. The nonwoven fabric offers higher flexibility than commercial aerogel fabrics and is securely entrapped within two layers of needle punched nonwoven fabrics. This makes it a better option for heat protective clothing, offering better particle shedding, fabric flexibility, and thermal comfort [25].

Liu et al have studied the Evaluation on Thermal Protection Performance of TiO2@ ATO Coated Aramid Nonwoven. Where this study aimed to enhance the protective performance of analytic-grade TiO2 particles coated with Sn (Sb)O2 (ATO) by utilizing its high refraction in visible light and near-infrared range. Core-shell TiO2@ATO particles with high solar reflectance and low thermal conductivity were synthesized, improving the mechanical, heating insulation, and thermal protection properties of an analytic-grade reagent [26].

Zhai et al have studied Hybrid aerogel composites reinforced with aramid fiber fabric for thermal protection. Where This study presents a novel method for improving thermal protection performance of protective materials in high temperature flame environments. The composites, made with aramid fiber needle felt (AF), water glass, MTMS, hydrochloric acid, ammonia, and deionized water, showed high thermal protection, second degree burn time, and tensile strength. The AF-PMSQ composites also showed intrinsic hydrophobicity, making them suitable for high temperature and humid environments [27].

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## Conflict of Interest

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

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