3

Natural and Manufactured Fibers

OBJECTIVES

Use fabrics in the Fiber section of the Fabric Science Swatch Kit for this chapter.

To know the classifications of textile fibers.

To correlate fibers with their properties for end-use requirements.

To recognize various trademarks, logos, and names used to market textile fibers.

To recognize the importance of fibers to the industrial products industries.

KEY TERMS RELATED TO TEXTILES

acetate
acrylic
alpaca
anidex
antistatic
aramid
azlon
bast fibers
bicomponent
camel hair
carbon
cashmere
cotton
elasterell-p
felting
flax
fluorocarbon
glass
HWM rayon
hemp
heterogeneous fibers
jute
lastrile
lastrol
llama
lyocell
matrix
matrix-fibril
metallic
microfiber
micron
modacrylics
mohair
multicomponent
nano technology
novoloid
nylon
nytril
olefin
PBI
PLA
polyester
ramie
rayon
rubber
saran
silk
spandex
sulfar
trademark
triacetate
vicuna
vinal
vinyon
wool

A fiber is usable and viable only when it possesses certain desirable physical and chemical properties and characteristics. In addition, it must be able to be supplied in commercial quantities at economical or value prices. Otherwise, the fiber will not be of practical value or commercial importance.

This chapter discusses the various major natural and manufactured fibers. The focus is on their properties and characteristics because fibers are the major building blocks of any material (see Figure 3.1 for end uses). Using the proper fibers helps produce the appropriate fabric for a specific end use.

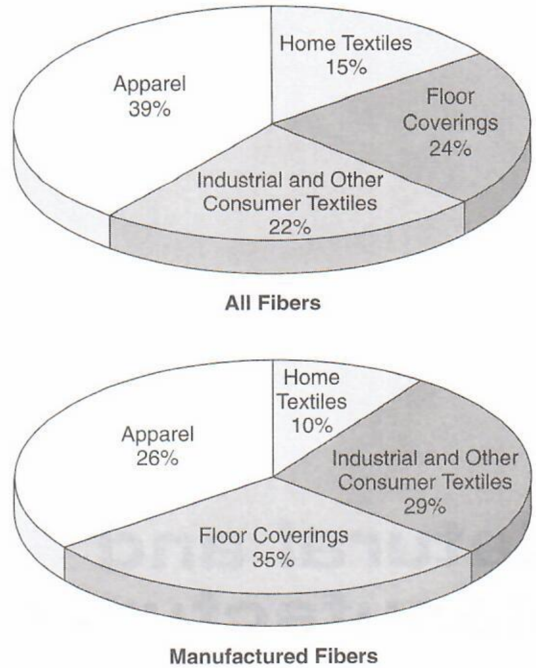


Figure 3.1
A comparison of end uses for all fibers and manufactured fibers.

Natural Fibers

Natural fibers have been used throughout the world for thousands of years. Early civilization relied on crude coverings and simple clothing made from natural fibers collected in the wild. Cotton, wool, silk, and flax are the most commonly used natural fibers found in the apparel and home textiles markets (Table 3.1). They are discussed in more detail than the other natural fibers included in this chapter.

COTTON

Cotton is a seed fiber—that is, it is attached to the seed of the cotton plant—and has been used for over 5,000 years (see Figure 3.2). It is the most widely used fiber in the world. The leading producers of cotton include the United States, China, India, Egypt, and Pakistan (Figure 3.3a and b). The most used cotton species in the United States is American Upland cotton. The other major species raised in the United States is American Pima cotton, which is a high-quality cotton because it has an extra-long staple length, over 1³/₈ inches (approx. 3.49 cm). Sea Island cotton, perhaps the best quality cotton in the world, was once grown in the United States, but now grows only in a small quantity in the West Indies. Egyptian cotton is another species of high-quality, long-staple cotton.

Cotton is classified not only by its species, but also by its fiber length, color, and cleanliness (leaf and stem content), all of which contribute to the cost of the fiber. The fiber length is the most important because the longer the staple length, the better the fiber properties. Additionally, color and cleanliness can be addressed in processing. The more expensive extra-long staple Pima cotton has greater strength, more luster, and a silkier hand than Upland cotton. Cotton is grown predominately in Texas, Mississippi, and California. Farmers often plant genetically modified crops which offer a greater yield per acre with less dependence on pesticides.

Interestingly, cotton became a major fiber in the United States only after the Industrial Revolution began in this country (in the late 1700s). Cotton, with its

Table 3.1
Comparison Chart of the Most Commonly Used Natural Fibers

Fiber	Durability		Comfort	Appearance	
	Abrasion Resistance	***Strength***	***Absorbency***	***Resiliency***	***Pilling Resistance***
Cotton	Good	Good	Good	Poor	Good
Flax	Fair	Excellent	Excellent	Poor	Good
Silk	Fair	Good	Excellent	Fair	Good
Wool	Fair–good*	Poor	Excellent	Good	Fair

*Fair for finer apparel wool; good for coarser carpet wool.

Figure 3.2
A cotton boll.

short fiber length, was not suited to the hand carding and spinning being performed before that time. Wool, flax, and hemp, whose fibers are longer, were the main fibers the colonists used to make their clothing and other textile products.

Because it is a plant fiber, cotton is composed mainly of cellulose. It is a medium-weight fiber of natural cream or tan color with a length between 1/2 and 2 1/2 inches (1.27 and 6.35 cm). Most cotton used is about 1 to 1 1/2 inches (2.54 to 3.18 cm) long. Under a microscope, cotton looks like a flat twisted tube.

Properties

Favorable The fiber has good strength and abrasion resistance. It is hydrophilic (8 1/2 percent moisture regain), absorbs moisture quickly, and dries quickly. Quick drying gives a cooling effect, which makes cotton a comfortable fiber to wear in hot weather. It has a 10 percent increase in strength when wet, which makes it completely launderable. It is dry cleanable and has no static or pilling problems. It has fair drape and a soft hand, and it is inexpensive.

Figure 3.3a and b
The Seal of Cotton (a) is a registered servicemark/trademark of Cotton Incorporated for products made of 100% (U.S. Upland) cotton. Natural Blend (b) is a registered servicemark/trademark of Cotton Incorporated for blended products containing a minimum of 60% (U.S. Upland) cotton with approved performance characteristics. *(Cotton Incorporated)*

Unfavorable Cotton has little luster and has poor elasticity and resiliency. It is attacked by mildew and silverfish. It is weakened by resin chemicals used in finishing and by acids, but is highly resistant to alkalies. Cotton fabrics form lint because the short fibers are able to come out of the fabric easily.

End Uses

The end uses of cotton include a wide range of products in the apparel, interior furnishings, and industrial areas. Examples include blouses, jeans, jackets, towels, sheets, trousers, T-shirts, belts, and sneakers.

FLAX

Flax comes from the stem or stalk of the flax plant and is harvested by pulling the entire plant from the ground. When the fiber is processed into fabric, it is called linen. It is generally considered to be the oldest textile fiber, having been used in the Stone Age. The largest producer is France, with most of the other leading producers—including Poland, the Ukraine, Belgium, and Russia—located in Europe. Northern Ireland and Belgium are leading exporters of linen cloth.

Flax is raised for both its fiber and seed. The seeds contain linseed oil, used primarily in paints and varnishes. The long fibers are used to make fabric, and short fibers are used for twine, rope, and rug backings (see Figure 3.4).

Because it is a plant fiber, flax is composed mainly of cellulose. It is a medium-weight fiber of naturally light tan color with a fiber length between 2 and 36 inches (5.08 to 91.44 cm). The average is from 6 to 20 inches (15.24 to 50.8 cm). The fiber, when viewed under a microscope, is shaped like bamboo.

Properties

Favorable The fiber has excellent strength. It is the strongest of the plant fibers. Flax is also 10 percent stronger when wet. Its hand is good and the fiber has good luster. It is more hydrophilic than cotton (12 percent moisture regain), absorbs moisture quickly, and also dries quickly. These properties make it a good fiber for hot weather wear, because quick drying has a cooling effect. Flax is completely washable and drycleanable. Sometimes, however, dry cleaning is mandated due to finishes applied to the fabric or the construction of the product. It has the highest safe-ironing temperature (450°F≈232°C), and it has no static or pilling

Figure 3.4
A field of flax plants.

Figure 3.5
Silk cocoons on fabric made of silk.

problems. Linen fabrics are lint free because they contain no very short fibers.

Unfavorable Flax has only fair resistance to abrasion, making it less durable than cotton. It has poor drape, elasticity, and resiliency, and it is vulnerable to mildew and silverfish.

End Uses

The principal end uses of flax include dresses, suits, sports jackets, and luxury tablecloths and napkins.

SILK

Silk is said to have been discovered in 2640 B.C. by a Chinese princess. It is a continuous strand of two filaments cemented together, which forms the cocoon of the silkworm. The silkworm secretes silk by forcing two fine streams of a thick liquid out tiny openings in its head. On contact with air, the fine streams of liquid harden into filaments. The worm winds the silk around itself, forming a complete covering (cocoon) for protection while changing from a worm into a moth. As much as 1,600 yards (1,463 meters) of fiber are used to make the cocoon.

Silkworms are usually cultivated and are raised under controlled conditions of environment and nutrition; this is called sericulture. The food for sericulture silkworms consists solely of mulberry leaves. These worms produce the finest, silkiest fibers (see Figure 3.5). To keep the silk in one continuous length, the worms in the cocoons are subjected to heat before they are ready to leave. Some moths, however, are allowed to mature and break out of their cocoons to produce the eggs for the next crop of silk. Sericulture is a very labor-intensive enterprise.

The other type of silk commercially practical for textile manufacture is a wild, uncultivated type called tussah silk. The worms that produce this silk feed on the leaves of other trees, such as oak and cherry. The brown fiber produced is flat, very nonuniform, and much thicker and less lustrous than the triangular, thin, cultivated silk fiber. Tussah silk is used for heavier, rough-textured fabrics.

At times, two silk worms nest together and form one cocoon made of a double strand. The fibers are not separated, and the resulting yarn has a varying thick and thin appearance. This type of silk is called duoppioni or dupion silk.

Spun silk yarn can be made of short fibers taken from pierced cocoons, from the first and last part of the cocoon, which is of poorer quality, from waste silk that accumulates around the machines during the various operations, or from a combination of these sources. Staple silk fibers are made from waste silk.

China is the leading silk producer in the world. Other producers include India, Thailand, and Brazil.

Silk is composed mainly of protein because it is an animal fiber. It is a medium-weight fiber of naturally white color. The fiber may look gray or yellow because that is the color of sericin, which is the gummy substance that makes cocoons hard. Silk that has not had the sericin removed is called raw silk. Silk is the only natural filament fiber. When viewed under a microscope, silk has a rounded, triangular shape with an uneven diameter.

Properties

Favorable The fiber has excellent drape and a luxurious hand. It is the thinnest of the natural fibers. It is lustrous and hydrophilic (11 percent moisture regain). Silk has very little problem with static, and no pilling occurs. Silk fabric can be washed or drycleaned, although sometimes the dye or finish used necessitates drycleaning only.

Unfavorable Silk has only fair resiliency and abrasion resistance. Its strength is good; it loses about 15 percent strength when wet, but recovers when dried. The fiber has poor resistance to prolonged exposure to sunlight and can be attacked by moths. It is also expensive and turns yellow if washed with chlorine bleach. It is weakened and made harsher by alkalies such as those found in strong soaps. Silk also degrades over time by exposure to atmospheric oxygen, which makes it especially difficult to preserve, even in climate-controlled museum settings.

End Uses

The principal end uses of silk include dresses, ties, scarves, blouses, and other apparel. Silk is also used in home furnishings, particularly decorative pillows, and can be found in washable sheets for the luxury market.

WOOL

Wool is the fiber that forms the covering of sheep. It is also an old fiber, known to have been used by the people at the end of the Stone Age. Approximately forty different breeds of sheep produce about two hundred types of wool fiber of varying grades. Examples of well-known breeds of sheep raised in the United States are Merino and Debouillet (fine-wool grade), Southdown and Columbia (medium-wool grade), and Romney and Lincoln (coarse-wool grade). Grading is the process of judging a whole fleece for fiber fineness and length. Sorting is the process of breaking up an individual fleece into its different qualities. The best-quality wool comes from the sides and shoulder; the poorest comes from the lower legs.

A numerical count system is used to indicate the fineness or coarseness of wool fibers. Numbers range from 36's for coarse wool up to 80's and beyond for the very fine, high quality wool used in the luxury suiting market. These numbers correspond to an average fiber diameter in microns, with 80's being less than 20 microns and 36's being more than 40 microns (see p.45). The numerical terms also relate to the fineness that yarn can be spun. The menswear market utilizes these fiber notations to indicate the fabric fineness and quality.

The grades of wool vary widely, depending on the breed and health of the sheep and the climate. The thinner the fiber diameter, the better the properties of the wool. Merino wool is considered the best grade of wool. It has the most crimp, best drape, most strength, best resiliency, best elasticity, softest hand, and most scales on its surface.

Shorn wool is called fleece wool or clipped wool. Lamb's wool is wool taken from a sheep younger than one year (first clip); it is desirable because it is fine in diameter, which can make a very soft product.

Leading producers of apparel-class wool include Australia, New Zealand, South Africa, and the United States (see Figures 3.6 and 3.7). Leading producers of carpet-class wool include, China, Argentina, and Turkey.

Wool is mainly composed of protein (similar to human hair) because it is an animal fiber. It is a medium-weight fiber of a natural cream, brown, or black color, it has much natural crimp, and it has a fiber length between 1 and 18 inches (2.54 to 45.72 centimeters). When viewed under a microscope, its shape is round and it has a scaly surface.

Properties

Favorable The fiber has good resiliency when dry, but poor when wet. Wrinkles come out if the garment is hung in a moist atmosphere. Its hand is fair to

PURE WOOL® a

WOOL BLEND® b

Figure 3.6a and b
The Woolmark (a) is a registered trademark of The Wool Bureau, Inc., the U.S. Branch of the International Wool Secretariat, for fabrics made of 100% wool and meeting specifications of the Wool Bureau, Inc. The Woolblend mark (b) is used where the fabric is a quality-tested material made predominantly of wool. *(The Wool Bureau, Inc.)*

AMERICAN WOOL™

Figure 3.7
The logo of the American Wool Council, Division of American Sheep Industry Association. The logo is colored red, white, and blue. *(American Wool Council)*

excellent, depending on the quality of the wool fiber. Wool has good drape and elasticity and is hydrophilic (13 percent moisture regain). Wool has very little problem with static, but its abrasion resistance is good only if it is coarse.

Wool makes warm fabrics for two reasons. First, it absorbs moisture slowly and dries slowly, thus having no cooling effect and resulting in feeling warm when worn. Second, wool fabrics have an excellent insulation property because the fibers have a natural crimp, which prevents them from packing together and so forms dead air spaces (trapped air). The trapped air is the insulating barrier. Wool's crimpy fibers also allow bulky fabrics to be made.

Unfavorable Although wool is a weak fiber, its high crimp allows it to be pulled with great force without breaking. It has fair to good abrasion resistance, depending on its thickness—fair for the finer wool used for apparel, and good for the coarser wool used for carpets. It loses about 25 percent strength when wet. It has poor luster.

Wool garments usually must be dry cleaned because the fabric felts and shrinks greatly if washed at elevated temperatures with agitation. **Felting** occurs in the presence of heat, moisture, and agitation, which cause the fiber surface scales to interlock with one another; this leads to a tangled mass on the fabric surface that cannot be combed or brushed out. With these scales snagging adjacent wool fibers, the fibers cannot return to their original positions in the fabric. Wool fiber surface scales can be either chemically removed or covered with a resin to create a washable fabric in which no felting and only a little shrinkage occur. There are certain applications in which felting is desirable for specific end uses such as hats and banners.

Wool is vulnerable to moths, but can be mothproofed. Wool has problems with pilling, it turns yellow if washed with chlorine bleach. It is also weakened and made harsher by alkalies, such as those found in strong soaps. However, wool is highly resistant to acids. Wool is an expensive fiber due to the limited quantities available and the cost associated with production.

End Uses

The principal end uses of wool include overcoats, suits, sweaters, carpets, and felt fabric.

OTHER NATURAL FIBERS

Specialty Hair Fibers

Specialty hair fibers are rare animal fibers that possess special qualities of hand, fineness, or luster. They are usually stronger, finer, and more expensive, but lower in abrasion resistance, than most wool fibers.

Alpaca comes from the alpaca of South America. It is durable, silky, and very lustrous. Alpaca is frequently used in sweaters and ponchos.

Camel hair comes from two-hump camels of Mongolia, Tibet, and other areas of Asia. It is a weak fiber with a wool-like texture. Its scales are not as defined as wool, so it does not felt rapidly. Camel hair is mainly used for overcoats.

Cashmere comes from the inner coat hair of an Asian Cashmere goat (the outer coat hair is coarse and of little use). It is extremely fine and is noted for its outstanding softness. Pashmina is the Persian for cashmere. China is the world's leading exporter of cashmere fiber. Principal end uses include scarves, sweaters, suits, and coats for the luxury market.

Llama comes from the llama of South America. It is weaker than camel hair and alpaca, but still fairly strong. Uses include sweaters and blankets.

Mohair comes from the Angora goat, found mainly in Turkey, South Africa, and the southwestern United States (see Figure 3.8). It is the strongest of the specialty animal fibers, with very good abrasion resistance. It is the most resilient natural textile fiber. It possesses little crimp and its scales are flat, resulting in a slippery, smooth hand and high luster. The fiber can be dyed bright colors and is often used in fashionable specialty clothing, luxury throws, and velvet fabric for furniture sold in the contract market.

Vicuna comes from the vicuna of South America. It is the finest and softest of all wool and specialty fibers, but it is also weak. Its very fine scales result in a smooth hand and high luster. The fiber is lightweight. Vicuna fiber is the rarest and most costly of the specialty fibers because attempts to domesticate the animals have not

Figure 3.8
The logo for the Mohair Council of America. *(Mohair Council of America)*

been successful. The export of Vicuna, in fiber form and fabric form, is controlled by the Peruvian government. Because vicuna is so rare, the cost of a vicuna coat is more than the cost of a high-end fur coat.

Bast Fibers

Bast fibers are those that grow in the stem section of the plant and thus are cellulosic in content. Flax is the most important of these fiber types, with hemp, jute, and ramie also having commercial importance.

Hemp is a yellowish-brown fiber that grows in many parts of the world. Russia, India, Hungary, Romania, and Poland are leading producers of hemp. The fiber resembles flax in appearance but is coarser and harsher. It is strong and lightweight and has very little elongation. Its principal end use is twine, rope, and cordage. Hemp has recently gained popularity as a specialty fiber for the apparel market. It has been used for jeans, shirts, hats, and other items. This unique alternative to cotton or flax has even been used by a noted designer in a tuxedo for men.

Jute is a yellowish-brown fiber that grows mainly in Bangladesh, India, and Pakistan. It is coarse and harsh, with good resistance to microorganisms and insects. The fiber has moderate dry strength but low wet strength. It has low elongation, which helps it retain its shape when made into items such as sacks. Jute is shorter than most bast fibers and is inexpensive to produce. It also has fair abrasion resistance. Its main end uses include burlap fabric for bagging, fabric for interior furnishings, carpet backing, and cordage.

Ramie is a white fiber that is also known as China grass. Although China is the major producer, ramie is also grown in other countries, such as the Philippines and Brazil. It is a fine, absorbent, and quick-drying fiber. It is the most resistant to mildew and rotting of all plant fibers, and it is the strongest. Ramie is slightly stiff and has high natural luster and low elongation. It is similar to flax, and its end uses include apparel for the mass market, some interior furnishings, ropes, and industrial threads.

Micron System

The micron system is used to measure the diameter of natural fibers. The **micron** is equal to 1/1000 of a millimeter, or 1/1,000,000 of a meter, or 1/25,400 of an inch. The following is the average diameter of specific plant and animal fibers.

vicuna	6–10 microns
alpaca	10–15 microns
silk	11–12 microns
flax	12–16 microns
merino sheep	12–20 microns
angora rabbit	13 microns
cashmere	15–19 microns
cotton	16–20 microns
camel	16–25 microns
mohair	25–45 microns
llama	30–40 microns

Manufactured Fibers

The era of manufactured fibers began in the early 1900s with the commercial production of rayon fiber. It was helped along by the introduction of acetate, the second manufactured fiber, in 1924. Both fibers contain mostly cellulose because the technology was insufficient to produce a fully synthetic fiber entirely from chemicals.

The delay in the development of manufactured fibers was largely due to the inability to look into the structure of a fiber to see how it was constructed. Without this knowledge, scientists did not know how to go about making a manufactured fiber. With the advent of X-ray technology in the 1920s and 1930s, the obstacle was removed. The discovery was then made that the basic building blocks, or molecules, that make up a fiber are long and narrow (or fibrous) themselves. By 1938, nylon was ready to be presented to the marketplace (by E.I. DuPont de Nemours & Company). The development of the manufactured fibers industry is an amazing success story resulting in many consumer-recognizable advancements in textiles, such as spandex, microfibers, and products such as Gore-Tex®, and Teflon®.

The most significant advancements in the textile industry for apparel and home furnishing applications come from innovations within the textile fibers sector. Many of these advancements have been developed after careful analysis and the exploration of potential needs within the marketplace. These advancements are as innovative and provocative as the initial conception and introduction of the first commercial manufactured fiber from wood pulp over a hundred years ago or as simple as Teflon® moving from a protective covering for pots to a protective covering for pants.

GENERIC NAMES

The generic names and definitions in this section are from the Rules and Regulations of the Textile Fiber Products Identification Act (TFPIA). All manufactured fibers used for consumer articles of apparel or textile articles customarily used by the consumer in home furnishings appliation have been placed into the generic categories listed in this federal act. The Federal Trade Commission establishes the generic names and definitions for manufactured fibers (see Table 3.2).

Table 3.2
The FTC Recognizes the Following Generic Names and Generic Fiber Subclasses of Manufactured Fibers

- Acetate
  - Triacetate
- Acrylic
- Anidex
- Aramid
- Azlon
- Elastoester
- Fluoropolymer
- Glass
- Metallic
- Melamine
- Modacrylic
- Novoloid
- Nylon
- Nytril
- Olefin
  - Lastol
- PBI
- Polyester
  - Elasterell-p
- Rayon
  - Lyocell
- Rubber
  - Lastrile
- Saran
- Spandex/Elastane
- Sulfar
- Vinal
- Vinyon

To receive a new generic classification, a fiber producer must spell out how the physical properties and chemical composition radically differ from other classified fibers. The commercial use must be explained as well as its importance to the marketplace of the public.

To meet the criteria for granting application for a new generic fiber subclass name, a fiber must have the same general chemical composition as an established category and have distinctive properties, which lead to the distinctive features that set it apart from the original recognized classification (Table 3.3). Thus, subclass designations are used when a textile fiber technically falls within a generic classification but is commercially distinguishable due to significant enhancements or differences. For example, a fiber which is a polyester, but has stretch characteristics similar to spandex.

MARKETING OF MANUFACTURED FIBERS

Manufactured fibers are marketed as commodity fibers, as trademark fibers, as controlled trademark fibers, or under a certification mark. Each is briefly explained in the following sections.

Commodity Fibers

Fibers marketed as commodities are used without identification of source and are sold to any buyer in the open market. A shirt labeled 100 percent polyester has been made with commodity polyester fibers. This is the cheapest way to purchase manufactured fibers.

Fiber Trademarks

Manufactured fibers are often identified by trademarks. The fiber producer spends promotion money to establish a trademark and expects manufacturers, wholesalers, and retailers down the line to take advantage of it. The fiber producer receives a slightly higher price from mills than if the fiber were sold without a trademark.

A fiber **trademark** is a word or words used by a fiber supplier or producer to distinguish its fibers from fibers of the same generic class produced or sold by others. It is intended to attract the attention of potential customers, both industrial (e.g., textile mills) and consumer. Trademarks appear on product labels and promotional material.

Table 3.3
Comparison Chart of the Most Commonly Used Manufactured Fibers

Fiber	Durability		Comfort	Appearance	
	Abrasion Resistance	***Strength***	***Absorbency***	***Resiliency***	***Pilling Resistance***
Cellulosic					
Acetate	Poor	Poor	Fair	Good	Good
Viscose rayon	Fair	Fair	Excellent	Poor	Good
Lyocell	Fair	Excellent	Excellent	Fair	Good
Manufactured					
Acrylic	Fair	Fair	Poor	Good	Fair
Nylon	Excellent	Excellent	Poor	Excellent	Poor
Olefin	Excellent	Excellent	Very poor	Excellent	Good
Polyester	Excellent	Excellent	Poor	Excellent	Very poor

A person or company first using the trademark in commerce usually constitutes ownership of the mark. The letters ™ accompany the mark initially. If the user elects to apply for registered ownership of the trademark with the United States Patent and Trademark Office and the application is approved, the symbol ® is used instead of the ™ to indicate registered ownership.

Companies usually promote their trademarks widely to ensure benefits by its use. The use of the mark is carefully monitored, and unauthorized use of the trademark is illegal. Such well-known registered fiber trademarks include Dacron® (polyester, INVISTA™), Anso® (nylon, Honeywell Nylon, Inc.), and Creslan® (acrylic, Sterling Fibers, Inc.). See specific fibers for additional trademark names.

Recently, there has been a shift in ownership for fiber trademark names. Well-known producers such as DuPont have strategically moved closer to the chemical business and entrusted much of their brand recognition to INVISTA™ Inc. Additionally, chemical companies are creating partnerships with commodity producers such as Dow Cargill to develop new markets. It is expected that these changes and alliances will continue to create new companies and opportunities for the global textile industry.

Controlled Trademarks

The controlled-trademark approach enables the fiber maker to rigidly control the selling and subsequent use of the fiber. Relationships are established with specific textile mills and fabric users that will use the fiber properly. A quality control program of the fiber producer ensures that only products that have satisfactorily passed various tests related to the end use are allowed to use the fiber brand name. Unfortunately, consumers are usually unable to distinguish between a controlled trademark fiber and an uncontrolled trademark fiber.

Certification Marks

Various fiber producers, such as INVISTA™ (formerly E. I. DuPont de Nemours & Company), also have certification programs. The following is an explanation from DuPont promotional material:

> Certification marks are marks licensed by INVISTA™ for use by manufacturers of products in which a INVISTA™ fiber or other material is used and which meet specified performance quality standards. It is important to distinguish between trademarks and certification marks. Trademarks appear on products made by INVISTA™. Certification marks, on the other hand, may not be used on products made by INVISTA™, for, under U.S. trademark law, a mark may not be a trademark and a certification mark at the same time.

Thus INVISTA™ uses two types of marks: the trademark that identifies its fibers, such as Dacron® polyester, and the certification mark that identifies a product not made by INVISTA™ but that contains its fibers. An example of the latter is Thermolite® (formerly ThermaStat®) which is used for thermal underwear made of a special INVISTA™ fiber (see Figure 3.9) and that meets specified performance quality standards. (It is a hollow polyester fiber that provides thermal insulation, wicking of perspiration away from the body, and softness.) Both marks are registered to INVISTA™ and, therefore, cannot be used by other companies.

Descriptions of Principal Manufactured Fibers

The following sections present the properties and characteristics of each principal generic category of manufactured fibers. The generic names and definitions in this section are from the Rules and Regulations of the TFPIA.

ACETATE

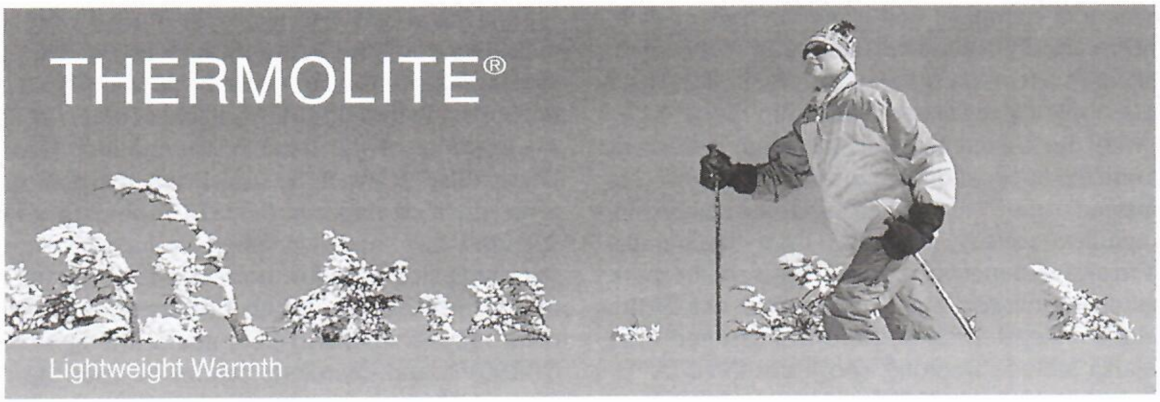
The first commercial production of **acetate** fiber in the United States was in 1924 by the Celanese Corporation. In 1952 the Federal Trade Commission made acetate a generic category, separating it from the rayon fiber family.

Acetate is a manufactured fiber in which the fiber-forming substance is cellulose acetate. It has a round shape with striations on the surface.

Properties

Favorable Acetate is a medium-weight fiber with excellent drape and a luxurious hand. It has fair resiliency and fair absorbency (6½ percent moisture regain). It has no pilling problem and very little static problem, and it is inexpensive.

Unfavorable Acetate has poor strength; it becomes about 30 percent weaker when wet, but recovers original strength when dried. It has poor abrasion resistance and poor elasticity. It should be drycleaned or carefully laundered. Washing by machine should be avoided because the wet strength of acetate is very low, and the garment may be damaged. Hot water and dryers cause significant loss of strength at about 195°F≈90°C. Thus casual creases may become permanent or excessive shrinkage may occur from the heat. Acetate is also subject to gas fading from pollutant gases in the air that tend to easily fade or change the color of fabric. (See p. 337.) This can be a problem par-



a

b

c

Figure 3.9a–c
Thermolite® (formerly ThermaStat®) is an INVISTA™ certification mark for thermal wear fabric of hollow-core polyester fiber meeting its quality standards and results in a more thermally-efficient Thermolite® fabric (a and b) (© INVISTA™ 2005). Gortex® rainwear combines elegance with practicality (c).

ticularly for deep blue and navy lining material, which can change to purple and then red from exposure.

End Uses

The principal end uses for this fiber include lining fabric, lingerie, graduation gowns, backing fabric for bonded materials, and cigarette-filter material.

Producers and Trademarks

Celanese Acetate: Celanese®

Eastman Chemical Co.: Estron®, Chromspun® (solution dyed)

ACRYLIC

The first commercial production of **acrylic** fiber in the United States was in 1950 by E. I. DuPont de Nemours & Company. The fiber soon began to replace wool, initially in sweaters and blankets and then later in other items. Consumers responded well to acrylic because it was less expensive than wool and washable (see Figure 3.10).

Acrylic is a manufactured fiber in which the fiber-forming substance is any long-chain synthetic poly-

Figure 3.10
The logo of the Acrylic Council. *(Acrylic Council, Inc.)*

mer composed of at least 85 percent by weight of acrylonitrile units. Acrylic has a round shape with a smooth surface.

Properties

Favorable Acrylic is a lightweight fiber with good drape. It creates fabrics that are warm yet lightweight. It has good resiliency and elasticity and has excellent resistance to sunlight and weathering. It may be washed or dry cleaned.

Unfavorable Acrylic has only fair strength; it becomes about 20 percent weaker when wet, but recovers when dry. It is a hydrophobic fiber (1 1/2 percent moisture regain), and static and pilling are frequent problems. Its abrasion resistance is fair.

End Uses

The principal end uses for this fiber include sweaters, blankets, carpeting, children's garments, and outdoor products, such as awnings, market umbrellas and tents.

Producers and Trademarks

Solutia, Inc.: Acrilan®, Pil-Trol® (low pilling)

Sterling Fibers, Inc.: Creslan®, Micro Supreme®, WeatherBloc™

LYOCELL

The Federal Trade Commission approved the **lyocell** generic fiber name as a subclass under Rayon in 1996. The fiber was developed by Courtaulds Fibers Ltd. (Great Britain) and took ten years and $100 million to produce.

Lyocell is a manufactured fiber composed of solvent-spun cellulose. The self-contained solvent-spun process used to produce this fiber creates less water and air pollution. The fiber has a round cross-section with a smooth surface.

The process used to produce lyocell, has less negative impact on the environment than the process used to produce rayon because a different spinning technique is used. Difficulties relating to environmental standards for air and water pollution have become a concern for most producers in the textile industry.

Properties

Favorable Lyocell is stronger than all other cellulosic fibers and has less shrinkage. It is launderable with an 11.5 percent moisture regain and is stronger when wet. It is noted for creating fabrics with great luster, soft hand, and good drape.

Unfavorable Fabric wear and tear may cause the fibers to splinter on the surface. This may result in fuzziness and pilling over the life of the product. Color changes can occur, as well as changes in hand from splintering. It can be washed or dry cleaned, but laundry agitation can accelerate surface change. It is also vulnerable to mildew and some insects.

End Uses

End uses for this fiber include dress slacks, shirts, blouses, Hawaiian shirts and dresses.

Producers and Trademarks

Tencel Inc.: Tencel®

NYLON

The first commercial production of **nylon** fiber in the United States was in 1939 by the E. I. DuPont de Nemours & Company. It is the second-most-used manufactured fiber in the United States, behind polyester. The two major types of nylon today are nylon 6,6 and nylon 6.

Nylon is a manufactured fiber in which the fiber-forming substance is a long-chain synthetic polyamide in which fewer than 85 percent of the amide linkages are attached directly to two aromatic rings. The fiber has a rod-like shape with a smooth surface.

Properties

Favorable Nylon is a lightweight fiber with excellent strength and abrasion resistance. It is about 10 percent weaker when wet. It has very good elasticity, good resiliency, and good drape. It can be washed or drycleaned.

Unfavorable Nylon is a hydrophobic fiber ($4^{1}/_{2}$ percent moisture regain). Static and pilling are problems. It has poor resistance to prolonged and continuous exposure to sunlight, thus usually making this fiber unsatisfactory for use in draperies or outdoor furniture (unless modified to improve its resistance).

End Uses

The end uses include a wide range of products in the apparel, interior furnishings, and industrial areas (for example, lingerie, swimwear, exercise wear, hosiery, jackets, bedspreads, carpets, upholstery, tents, fish nets, sleeping bags, rope, parachutes, and luggage). (See Figure 3.11.)

Producers and Trademarks

The following is only a partial list of nylon producers and trademarks:

Honeywell Nylon, Inc.: Anso®, Caprolan®

INVISTA™: Antron® (trilobal), Supplex®, TACTEL®

OLEFIN

The first commercial production of an **olefin** fiber in the United States in a textile-grade multifilament form was in 1961. It was a polypropylene type. Today a polyethylene-type olefin fiber is commercially produced.

Olefin is a manufactured fiber in which the fiber-forming substance is any long-chain synthetic polymer composed at least 85 percent by weight of ethylene, propylene, or other olefin units, except amorphous (noncrystalline) polyolefins qualifying as a rubber fiber. The fiber has a rod-like shape with a smooth surface.

Figure 3.11
One of the wide range of textile products made of nylon is luggage.

Properties

Favorable Olefin is a very lightweight fiber. It has very good strength and abrasion resistance. This fiber also has excellent sunlight resistance and weatherability. Olefin is almost completely hydrophobic (less than 0.1 percent moisture regain). Spills and staining liquids can be readily wiped up, making for favorable use of this fiber in indoor/outdoor carpeting, bathroom and kitchen floor covering, and upholstery. Olefin can be washed and dry cleaned. Although this fiber is hydrophobic, it possesses excellent wicking action when very thin. It also has excellent resiliency.

Unfavorable The almost completely hydrophobic nature of this fiber makes it unfavorable for most clothing. Blended with other fibers, its hydrophobic nature and excellent wicking action make olefin a practical component of fabrics used for running clothes and other high-performance applications. Static occurs and pilling is a problem at times. Ironing, machine laundering, and machine drying must be done at low temperatures (about 150°F≈65°C) because the fiber has a very low softening point.

End Uses

Important apparel end uses are athletic clothes, exercise suits, and underwear because of its excellent wicking action. Significant uses are nonwovens (see p. 156) and carpet face yarns. The fiber is also used in upholstery, auditorium seating, industrial fabrics (e.g., filter cloth, bagging, cordage), and geotextiles (see p. 159).

Producers and Trademarks

The following is only a partial list of olefin producers and trademarks:

American Fibers and Yarns Co.: Essera®

Hercules, Inc.: Herculon®

LASTROL

A subclass for olefin, called lastrol, was approved by the Federal Trade Commission in January 2003. It is an olefin fiber with a cross-linked polymer network. It has stretch and recovery properties that far exceed olefins and can withstand a wide range of temperatures, thus finding applications in easy care stretch apparel.

PLA

PLA is a new generic fiber classification approved by the Federal Trade Commission in February 2002. It is a manufactured fiber in which the fiber forming substance is composed of at least 85 percent by weight of lactic acid ester units derived from naturally occurring sugars. The polylactic acid or poly lactate comes from sugars found in corn or sugar beets. Cargill Dow applied for this new classification for their Nature Works™ fiber. Cargill Dow developed a way to capture the carbon that plants use during photosynthesis. The carbon and natural sugars found in the plants are used to make a polymer called polylacide (PLA). Cargill Dow believes a fiber based on annually renewable agricultural crops offers environmental soundness missing in the marketplace.

Properties

PLA has excellent resiliency, outstanding crimp retention, and good wicking ability. It offers good thermal insulation, breathability and absorbency. It also has excellent hand and drape.

End Uses

It is found in the marketplace in pillows, comforters, and mattress pads and is suitable for performance active wear and fashion apparel.

Producers and Trademarks

Cargill Dow LLC: Nature Works™

POLYESTER

The first commercial production of **polyester** fiber in the United States was in 1953 by E. I. DuPont de Nemours & Company. It is the most used manufactured fiber in the United States.

Polyester is a manufactured fiber in which the fiber-forming substance is any long-chain synthetic polymer composed of at least 85 percent by weight of an ester of a substituted aromatic carboxylic acid, including, but not limited to, substituted terephthalate units and parasubstituted hydroxy-benzoate units. The fiber has a rod-like shape with a smooth surface.

Properties

Favorable Polyester is a medium-weight fiber with very good strength and abrasion resistance. It can be washed and drycleaned. The fiber has excellent resiliency and is the best wash-and-wear fiber. It also possesses good elasticity.

Unfavorable Polyester is almost completely hydrophobic (0.4 percent moisture regain). It is difficult to get water and detergent into the fiber to remove

Figure 3.12
A sleeping bag made with Polarguard® hollow-core polyester fibers. *(Hoechst Celanese Corporation)*

stains. Visa® finish helps release soil from polyester fibers (see p. 228). Static and pilling are also major problems. In addition, polyester is oleophilic (absorbs oil easily).

End Uses

The end uses include a wide range of products in the apparel, interior furnishings, and industrial areas. Suits, skirts, career apparel, perfomance fabrics, curtains, carpeting, sails, tire cord, fiberfill used to stuff pillows, and comforter threads are some examples of its uses (see Figure 3.12).

Producers and Trademarks

The following is only a partial list of polyester producers and trademarks:

INVISTA™: Dacron®, CoolMax®, ESP®

KoSa: Microtherm®, Polarguard®, Stretch-Aire®

Wellman, Inc.: Fortrel®, EcoSpun® (recycled plastic), Sensura®

ELASTERELL-P

The Federal Trade Commission approved a new subclass of polyester called elasterell-p in November 2002. This fiber consists of two substantially different forms of polyester that offers significant stretch and recovery. Given the unique structure and characteristics of this fiber, the existing generic name (polyester) would not be suitable. It exhibits low shrinkage, excellent shape retention, and is chlorine resistant. It is utilized in products that require moderate stretch such as stretch denim, shirt fabric, and socks. INVISTA™ will market this as a new class of fiber under the Lycra® umbrella to offer brand recognition from a variety of sources.

Producers and Trademarks

INVISTA™: Lycra®

RAYON

The first commercial production of **rayon** fiber in the United States was in 1910 by the American Viscose Company. It was the first manufactured fiber. Because it is largely cellulose in content, it greatly resembles cotton in its chemical properties.

By using different chemicals and manufacturing techniques, two basic types of rayon were developed: viscose rayon and cuprammonium rayon. Only viscose rayon is now being produced in the United States. Cuprammonium rayon is produced in Europe and is frequently called "cupro," its shortened generic name. Cuprammonium rayon and viscose rayon have nearly identical physical and chemical properties. Cupro, however, can be produced in much finer (thinner) filaments than viscose, which may then translate to finer, sheerer and/or to softer, more drapable fabrics than can be achieved with viscose. Fabrics of cupro are most frequently used in higher-priced lines (cupro is more expensive than viscose) for coat linings and sheer, lightweight dresses.

Rayon is a manufactured fiber composed of regenerated cellulose, as well as manufactured fibers composed of regenerated cellulose in which substituents have replaced not more than 15 percent of the hydrogens of the hydroxyl groups. Because it is a cellulosic fiber, it shares many of the same properties as other cellulosic fibers, such as cotton and flax. The fiber has a serrated, round shape.

Properties

Favorable Viscose rayon is a medium-weight fiber with fair to good strength and abrasion resistance. It is hydrophilic (11 percent moisture regain). The fiber is washable under proper care conditions and is drycleanable. There are no static or pilling problems, and it is also inexpensive.

Unfavorable Viscose rayon loses 30 to 50 percent of its strength when wet, thus requiring great caution in laundering. It recovers strength when dry. (The modified type of rayon, HWM rayon [see the next section], does not require this caution.) Rayon has very poor elasticity and resiliency. It also shrinks appreciably from washing and is attacked by mildew and silverfish.

End Uses

The end uses for viscose rayon include a wide range of products in the apparel, interior furnishings, and industrial areas (for example, dresses, shirts, lingerie, jackets, draperies, medical products, nonwoven fabrics, hygiene products).

Producers and Trademarks

Lenzing: Lenzing Viscose®

HWM RAYON

A variation of rayon is classified as **HWM (high wet modulus) rayon,** or high-performance rayon. HWM rayon was developed in 1951 in Japan and is also referred to as polynosic rayon. This type of rayon is completely launderable. Although it loses strength when wet, its wet strength is significantly higher than that of regular viscose rayon. In addition, this type of rayon can be shrink-resistant when treated by compressive shrinkage methods (see p. 226). It can also be mercerized (see p. 228). The hand of HWM rayons is similar to that of high-quality cotton.

Producers and Trademarks

Lenzing: Lenzing Modal®

SPANDEX

The first commercial production of **spandex** fiber in the United States was in 1959 by E. I. DuPont de Nemours & Company. It is an elastomeric manufactured fiber (able to stretch at least 100 percent and snap back like natural rubber). Spandex is used in filament form exclusively because elastomeric properties are available only in filament form. Elastane is the generic fiber name used outside the United States and Canada.

Spandex is a manufactured fiber in which the fiber-forming substance is a long-chain synthetic polymer composed of at least 85 percent of a segmented polyurethane. The fiber is extruded as a monofilament or in many very fine filaments that immediately fuse together to form a monofilament.

Properties

Favorable Spandex is a lightweight fiber with excellent stretch and recovery properties (over 500 percent elongation) and good durability. It can be washed or drycleaned, although chlorine bleach causes yellowing of the fiber. There are no pilling or static problems.

Unfavorable Spandex has poor strength, but this is not critical because it has so much stretch. It is a hydrophobic fiber (1 percent moisture regain). White spandex becomes yellowed from prolonged exposure to air. This is not a problem, however, in covered yarns or in dyed spandex, in which the yellowing effect is masked. Ironing should be done quickly, with a low-temperature setting. Spandex is an expensive fiber; however, as little as 1 percent is needed in fabric to achieve desirable stretch.

End Uses

The principal end uses include undergarment, support products, ski pants, swimwear, athletic apparel, and other articles where stretch is required.

Producers and Trademarks

INVISTA™: Lycra®

Radici Spandex Corp.: Glospan®

Dorlastan fibres LLC: Dorlastan®

Hysosung Corp.: Creora®

PROPERTIES OF MAJOR TEXTILE FIBERS

Textile fibers are categorized into three broad types: natural, manufactured cellulosic and manufactured non-cellulosic. Each exhibits different properties and are used in a variety of applications depending on the desired properties requried of the finished goods. Table 3.4 highlights the fibers and specific properties.

MICROFIBERS

Microfibers, also called microdenier fibers, are manufactured fibers that are much finer (thinner) than normal fibers. The fibers that may be produced as microfibers are acrylic, nylon, polyester, lyocell, and rayon.

The microfiber was invented in Japan in the early 1980s. The first such fiber was made of polyester. It was next produced in Europe by Hoechst A. G. of Germany in 1986, and finally in the United States by DuPont in 1990. In 1991, DuPont and BASF began producing a nylon microfiber, and American Cyanamid Corporation began to make an acrylic microfiber in the United States. Courtaulds Fibers and BASF were first to produce a rayon microfiber in the United States.

There are two major processes used to produce microdenier fibers. The first is to extrude very fine filaments from the spinnerette and then further reduce the fiber size by drawing the yarn. The second method is to produce filament fibers of two different polymers. After the fabric is made, the fibers are made to split apart into much finer filaments through a finishing process (see Figure 3.13).

Properties

The physical and chemical properties of a fiber in microdenier form are not different from those of the same fiber in normal thickness. However, many important characteristics are improved in microfiber form. The hand becomes softer, the drape becomes more fluid, and the wicking effect is greatly improved. Also, fabrics made with microfibers produce more vivid color contrasts in the print design (when printed) because there are more fibers per unit surface area.

Microfibers can be used in blends, with wool, cotton, or other manufactured fibers. Using microfibers alone or as a large percentage in a blend creates a silk-like fabric. When used in smaller percentages in a blend, microfiber provides a softer hand and better drape. Blends with wool are very effective because the result is a wool fabric that feels and looks like a better-quality, more expensive wool fabric (softer, better drape, and increased durability).

Although microfibers can be used to make many fabric types such as velvet, chiffon, brocade, and gabardine, there are various drawbacks in using these fibers. Microfibers are much more costly than the regular generic manufactured fibers. The weaving costs of fabrics with

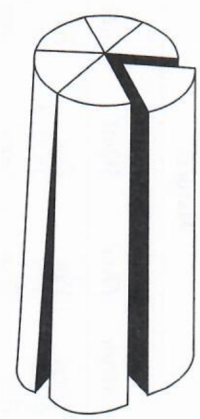


Figure 3.13
A filament fiber composed of two incompatible polymers is extruded from the spinnerette and then separated into microfibers.

Table 3.4
Properties of Major Textile Fibers

	Natural				Manufactured Cellulosic			Manufactured Non-cellulosic					
Properties	***Cotton***	***Flax***	***Wool***	***Silk***	***Acetate***	***Lyocell***	***Viscose Rayon***	***Acrylic***	***Glass***	***Nylon***	***Olefin***	***Polyester***	***Spandex***
Abrasion resistance	Good	Fair	Fair	Fair	Poor	Fair	Fair	Fair	Poor	Excel.	Excel.	Good	Good
Absorbency (% M.R.)	8½ %	12%	13 ½ %	11%	6.5%	11%	11%	1.5%	0%	2.8–4.8%	0.01–0.1%	0.4%	1%
Flexibility	Fair	Poor	Good	Excel.	Excel.	Fair	Good	Good	Poor	Good	Fair (*when thin*)	Fair	Good
Elasticity @ 70 F, 65% R.H.:													
% elongation at break	3–10	3	20–40	20	25–45	13–15	15–30	35–45	3–4	16–75	30–100	19–55	400–700
% recovery	75	65	99	90	48–65	—	95	92	100	82–100	96	81	99
from % strain	2	2	2	3	4	—	2	3	3	3	5	3	50
Environment:													
Mildew resistance	Poor	Fair	Good	Good	Excel.	Fair	Fair	Excel.	Excel.	Excel.	Excel.	Excel.	Excel.
Renovation (wash or dry clean)	W or DC	W or DC	DC	W or DC	DC	W or DC	W or DC	W or DC	W–hand	W or DC	W or DC	W or DC	W or DC
Safe iron limit (°F°)	400	450	300	300	325	400	350	300	—	350	250	325	300
Sunlight resistance	Fair	Good	Good	Poor	Good	Good	Fair	Excel.	Excel.	Poor	Good	Good	Fair
Hand	Good	Fair	Fair–Excel.	Excel.	Excel.	Excel.	Good	Good	Poor	Fair	Fair	Fair	Poor
Pilling resistance	Good	Good	Fair	Good	Good	Good	Good	Fair	Excel.	Poor	Good	Very poor	Excel.
Resiliency	Poor	Poor	Good	Fair	Fair	Fair	Poor	Good	Excel.	Good	Excel.	Excel.	Excel.
Specific Gravity	1.54	1.52	1.32	1.30	1.32	1.56	1.48–1.54	1.14–1.19	2.54	1.14	.91	1.38	1.21
Static resistance	Good	Good	Fair	Fair	Fair	Good	Good	Poor	Excel	Poor	Good	Very poor	Excel.
Strength dry, (grams/denier)	3.0–5.0	3.5–6.0	0.8–2.0	2.4–5.1	1.2–1.5	4.5–5.0	1.2–3.0	2.0–3.5	9.5	2.5–7.3	2.5–5.5	3.0–6.0	.07–1.0
	Good	Excel.	Poor	Good	Poor	Good	Poor–Good	Fair	Excel.	Excel.	Excel.	Excel.	Very poor
Strength loss when wet (approx. %)	+10%	+10%	20%	15%	30%	11%	30–50%[b]	20%	0	10	0	0	0
Thermoplastic	No	No	No	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes

[a] Compensated by high fiber stretch.
[b] HWM (high wet modulus) rayon has much higher wet strength than viscose rayon.

microfibers are higher (slower weaving speeds), as are the dyeing costs (much more dye is required to produce a color due to the increase of surface area).

The impact of microfibers in the marketplace is across the board. From luxury applications to mass markets, microfibers can be found in almost every application in which manufactured fibers are utilized.

End Uses

Microfibers have a significant presence in a broad range of end uses, including blouses, slacks, tailored suits, lingerie, dresses, raincoats, upholstery, sheeting, running clothes, undergarments, nonwovens, and industrial products.

Producers and Trademarks

The following is only a partial list of microfiber producers and trademarks:

Acrylic:
- Sterling Fibers, Inc.: MicroSupreme®

Nylon:
- INVISTA™: Supplex® Micro
- Honeywell Nylon Inc.: Silky Touch®

Polyester:
- Wellman, Inc.: Fortrel MicroSpun®
- KoSa: Microtherm®

Rayon:
- Lenzing: Micro Modal®

NANOTECHNOLOGY

Microfibers come from the first generation of technology in the 1980s that produced extremely fine filaments. Microfibers are filaments that measure less than 1 denier per filament. The term denier becomes impracticable when referring to a fiber finer than1 denier. When fiber diameter is less than 1 denier it is measured in microns. A 1 denier fiber has the diameter of approximately 10 microns. The term nanometer is used when the fiber is finer than 0.5 of a micron. A nanometer is one billionth of a meter or 10^{-9}. A single grain of sand is about 100,000 nanometers. Thus, micro technology has led to nanotechnology.

Nanotechnology is the ability to manipulate individual atoms to significantly enhance products. The ability to utilize polymer chemistry and molecular engineering on a nano scale has made a huge impact on the textile industry. Many advanced performance characteristics are used in fabrics created for major manufacturers and sold at Eddie Bauer, Lands' End, Gap, Old Navy, Brooks Brothers, and Lee Jeans. Since these enhancements are done in nano size the fabric preserves its original hand and comfort. NANO-TEX™ is a company that licensees its innovation to textile makers and manufacturers. NANO-TEX™ has developed technologies which improve fabric performance (Figure 3.14). These improvements include the following enhancements:

- provides water and oil repellency and wrinkle resistance to fabrics of cotton fibers.
- provides advanced moisture control for greater comfort for fabrics of manufactured fibers.
- provides water and oil repellency for fabrics of a range of fibers types.
- wraps a cotton-like covering around a core made of a manufactured fiber to create notable comfort and luxury.

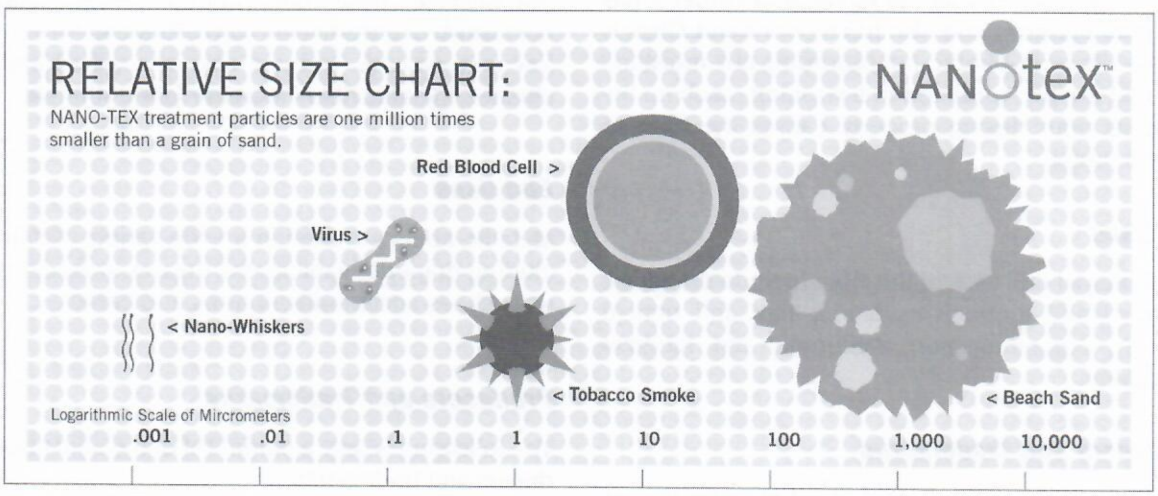


Figure 3.14
NANO-TEX™ treatment particles are one million times smaller than a grain of sand.

Secondary Manufactured Fibers for Consumer Use

This section presents the properties and characteristics of generic categories of the secondary manufactured fibers for consumer use. These fibers are more specialized than the principal manufactured fibers and are used in apparel or products for the home. The generic names and definitions in this section are from the Rules and Regulations of the TFPIA.

GLASS

The first commercial production of **glass** fiber in the United States was in 1936 by the Owens-Corning Fiberglas Corporation.

Glass is a manufactured fiber in which the fiber-forming substance is glass. The fiber has a round, rod-like shape with a very smooth surface.

Properties

Favorable Glass has excellent strength. It is a stiff fiber and requires no ironing. It suffers no effect from exposure to sunlight, even over extended periods, which makes glass an excellent fiber for curtains and drapes. Also, glass does not burn, but it melts at 1500°F≈815°C.

Unfavorable Glass is a heavy fiber with poor drapability. Its abrasion resistance is extremely poor, which makes it unusable for clothing or other items that involve significant movement of fibers or fabric. Additionally, the glass fragments would cause skin abrasion on a person who came in direct contact with it. Therefore, it is not used for clothing or carpet. It has very poor elasticity and also has a poor hand. Glass is completely hydrophobic, not absorbing any moisture. It should not be laundered in a washing machine because its poor flexing property causes the fiber to crack or break.

End Uses

The principal end uses of this fiber include draperies, electrical and thermal insulation, tires, and optical fiber for communication, electronic, and medical equipment.

Producers and Trademarks

The following is only a partial list of glass producers and trademarks:

Owens-Corning Fiberglas Corporation: Fiberglas®

PPG Industries, Inc.: PPG™

METALLIC

The earliest **metallic** fibers were strips of real gold and silver. These can be seen in ancient saris, carpets, and tapestries. Later, less expensive metals such as steel, copper, and aluminum were used. The first commercial production of metallic fiber in the United States was in 1946.

Metallic fibers are now commonly made by laminating, using a roll of aluminum foil and two rolls of transparent plastic film, which are joined together with the aluminum foil sandwiched between the two sheets of plastic. An adhesive binds the three layers together. Sometimes, instead of two sheets of plastic, a resin coating is used to protect both sides of the aluminum foil or metallized plastic film. Color can be added (e.g., gold, silver, blue) by applying pigments on the foil or in the adhesive or lacquer coating. The roll is then cut into narrow strips to form a length of metallic yarn equal to the length of the roll.

Metallic is a manufactured fiber composed of metal, plastic-coated metal, metal-coated plastic, or a core completely covered by metal. The width of the metallic yarn can be measured in millimeters and the thickness in microns. Metallic film can be made of an iridescent plastic that has been dyed with fluorescent dyes to create new looks and markets.

Properties

Metallic fibers are used primarily for decorative effects, although when placed in carpeting (as little as 2 percent) the functional effect is to lessen the accumulation of static. These fibers (not completely metal) do not tarnish or cut adjacent yarns. They can be ironed at low temperatures and can also be washed and drycleaned. Metallic fibers increase fabric stiffness.

End Uses

Metallic fibers are used in a wide variety of items, including draperies, tablecloths, dresses, sweaters, swimwear, shoes, accessories, ribbons, and carpet.

Producers and Trademarks

The following is only a partial list of metallic fiber producers and trademarks:

Lurex Co. Ltd.: Lurex™

MODACRYLIC

The first commercial production of **modacrylic** fiber was in 1949 by the Union Carbide Corporation in the United States. The word modacrylic comes from the term *modified acrylic.*

Modacrylic is a manufactured fiber in which the fiber-forming substance is any long-chain synthetic polymer composed of fewer than 85 percent but at least 35 percent by weight of acrylonitrile units. The fiber has a circular shape with a smooth surface.

Properties

Favorable Modacrylic is a medium-weight fiber with fair strength and abrasion resistance but good elasticity and resiliency. It has good drape and is highly resistant to sunlight. It may be washed or drycleaned. This fiber has excellent resistance to chemicals and flame. It has fair resistance to pilling and little static problem.

Unfavorable Modacrylic is hydrophobic (0.4 to 3 percent moisture regain). It can be ironed, but only at a low temperature (about 225°F≈107°C or less).

End Uses

The principal end uses include fake-fur fabrics, wigs, children's sleepwear, fleece fabric for stuffed animals, upholstery, and drapery and industrial fabrics.

Producers and Trademarks

Solutia Inc.: SEF®

TRIACETATE

The first commercial production of **triacetate** fiber in the United States was in 1954 by the Hoechst Celanese Corporation. It is a subclass of acetate.

Production of this fiber was discontinued in the United States in 1986 because of its limited market and high cost relative to other manufactured fibers. It is still being produced in Europe.

Triacetate is a manufactured fiber in which the fiber-forming substance is cellulose acetate, not less than 92 percent of the hydroxyl groups being acetylated. The fiber has a lobular, round shape with a smooth surface.

Properties

Favorable Triacetate is a medium-weight fiber with a luxurious hand and excellent drape. It has good resiliency and excellent pleat and crease retention when heat-set. The fiber may be washed and drycleaned. There is no pilling problem and only occasionally a static problem.

Unfavorable Like acetate, triacetate also has poor strength, becoming about 30 percent weaker when wet but regaining its original strength when dry. It is hydrophobic (3 1/2 percent moisture regain). It also has poor abrasion resistance and poor elasticity.

End Uses

The principal use for this fiber is various forms of apparel in which good pleat or crease retention is needed (e.g., pleated dresses and skirts) as well as in knitted sleepwear and robes.

Secondary Manufactured Fibers for Industrial Applications

This section presents the properties and characteristics of generic categories of the secondary manufactured fibers for industrial applications. These fibers are not typically recognized by the consumer but may have significant industrial applications in various markets. Others are referenced to complete the generic fiber classification recognized by the TFPIA.

ANIDEX

The first commercial production of **anidex** fiber in the United States was in 1970 by the Rohm & Haas Company.

Anidex is a manufactured fiber in which the fiber-forming substance is any long-chain synthetic polymer composed of at least 50 percent by weight of one or more esters of a monohydric alcohol and acrylic acid. Commercial manufacture of this fiber was discontinued.

ARAMID

The **aramid** generic fiber name became effective January 1974. The first commercial production of this fiber was by E. I. DuPont de Nemours & Company.

Aramid is a manufactured fiber. The fiber-forming substance is a long-chain synthetic polyamide in which at least 85 percent of the amide linkages are attached directly to two aromatic rings.

Properties

The unique properties of aramid fibers include high levels of tensile strength, abrasion resistance, stretch resistance, toughness, and heat resistance. Aramid does not melt; it chars and degrades above 700°F≈371°C. It has a 5 1/2 percent moisture regain.

End Uses

The end uses for this fiber include heat-protective clothing, cables, tires, combat helmets, and ballistic protective vests. Its use in race car drivers' suits has saved lives.

Producers and Trademarks

E. I. DuPont de Nemours & Company: Kevlar® and Nomex®

AZLON

Azlon is a manufactured fiber in which the fiber-forming substance is composed of regenerated, naturally occurring proteins. It was made from proteins found in nature, such as peanuts, corn, and casein from skimmed milk.

Production of this fiber has been discontinued in the United States.

LASTRILE

Lastrile is a manufactured fiber in which the fiber-forming substance is a copolymer of acrylonitrile and a diene (such as butadiene) composed of not more than 50 percent but at least 10 percent by weight of acrylonitrile units. It is a subclass of rubber.

Lastrile fibers have never been commercially produced.

NOVOLOID

The **novoloid** generic fiber name became effective February 1974. Although this fiber is not being produced in the United States, it is being imported and used.

Novoloid is a manufactured fiber containing at least 85 percent by weight of a cross-linked novolac.

Properties

Its most unique properties are excellent flame and chemical resistance.

End Uses

End uses for this fiber include protective apparel for fire fighters, liners in aircraft seats, and fire-protection curtains.

Producers and Trademarks

American Kynol, Inc. (distributor): Kynol™

NYTRIL

Nytril is a manufactured fiber containing at least 85 percent of a long-chain polymer of vinylidene dinitrile in which the vinylidene dinitrile content is no less than every other unit in the polymer chain.

Production of this fiber has been discontinued in the United States.

PBI

The **PBI** generic fiber name became effective in June 1986. The first commercial production of this fiber was by Hoechst Celanese Corporation.

PBI is a manufactured fiber in which the fiber-forming substance is a long-chain aromatic polymer having recurring imidazole groups as an integral part of the polymer chain.

Properties

Its most unique property is its excellent flame resistance. This fiber does not burn or melt, and it has low shrinkage and low smoke emission when exposed to flame. Even when charred, PBI fiber remains relatively supple and intact. Its moisture regain is high, about 15 percent.

End Uses

End uses for which this fiber are suitable include heat-resistant apparel (e.g., for fire fighters and industrial workers), race car driver apparel, rescue gear, hazmat suits, and space suits.

Producers and Trademarks

Celanese Advanced Materials, Inc.: PBI Gold®

RUBBER

The first commercial production of synthetic **rubber** fiber was in 1930 by the U.S. Rubber Company, now Uniroyal, Inc. Lastex™ was a major trade name for the fiber.

Rubber is a manufactured fiber in which the fiber-forming substance comprises natural or synthetic rubber. The manufacturing process consists of extending the natural rubber latex into a coagulating bath to form filaments. The material is cross-linked to obtain fibers that exhibit high stretch.

Properties

Very little rubber fiber is used today, having been mostly replaced by spandex fiber for products requiring stretch properties, because the latter has superior elastic properties (i.e., greater stretch, higher recovery force, greater resistance to aging). Rubber has low resistance to perspiration but is much less expensive than spandex.

End Uses

End uses of this fiber include elastic bands and tapes.

SARAN

The first commercial production of **saran** fiber was in 1941 by the Firestone Plastics Company (now Firestone Fibers and Textiles Company) in the United States.

Saran is a manufactured fiber in which the fiber-forming substance is any long-chain synthetic polymer composed of at least 80 percent by weight of vinylidene chloride units.

Properties

Saran has good strength and abrasion resistance. It is highly resilient as well as very resistant to the effects of sunlight and weather. It is easily washed and, if it burns, is self-extinguishing. The fiber is stiff and has a very low safe-ironing temperature. It is a heavy fiber with a poor hand (slippery) and 0 percent moisture regain. Saran is used in monofilament form.

End Uses

End uses for saran include upholstery in transportation vehicles (e.g., cars, trains), outdoor garden furniture, filters, and doll hair.

Producers and Trademarks

Dow Chemical Co.: Saranex®

SULFAR

The **sulfar** generic fiber name became effective in June 1986. The first commercial production of this fiber was by Phillips Fibers Corporation.

Sulfar is a manufactured fiber in which the fiber-forming substance is a long-chain synthetic polysulfide in which at least 85 percent of the sulfide linkages are attached directly to two aromatic rings.

Properties

This fiber is highly resistant to acids and alkalies and has excellent resistance to heat.

End Uses

End uses for sulfar include hot gas filtration (e.g., coal-fired industrial boilers), electrical insulation, papermakers' felt, and rubber reinforcement.

VINAL

Vinal is a manufactured fiber in which the fiber-forming substance is any long-chain synthetic polymer composed of at least 50 percent by weight of vinyl alcohol units and in which the total of the vinyl alcohol units and any one or more of the various acetate units is at least 85 percent by weight of the fiber.

Production of this fiber has been discontinued in the United States.

VINYON

The first commercial production of **vinyon** fiber in the United States was in 1939 by the American Viscose Company. Production of this fiber was discontinued in the United States in 1990. It is still being produced in Japan, however.

Vinyon is a manufactured fiber in which the fiber-forming substance is any long-chain synthetic polymer composed of at least 85 percent by weight of vinyl chloride units.

Properties

Vinyon fibers have a high resistance to chemicals, which makes them very desirable for certain industrial uses. Their low softening temperature also makes them useful as bonding agents for nonwoven fabrics. The fiber is hydrophobic (0.5 percent moisture regain).

End Uses

End uses for vinyon include industrial uses, bonding agent for nonwoven fabrics, and fishing nets.

Other Generic Fiber Categories

Other generic fiber categories are industrial fibers which have unique end uses. Examples include carbon, fluorocarbon, and heterogeneous fibers.

CARBON FIBERS

Carbon fibers are manufactured by pyrolysis of organic precursor fibers (e.g., rayon, polyacrylonitrile, or pitch) in an inert atmosphere at 1000°–3000°C. The result is a fiber from which all the elements except carbon have been removed. Carbon fibers are black in color, are stiff, possess high strength, and are lightweight. Their main application is in plastics reinforcement in industrial uses. Carbon fiber reinforced with plastic provides high strength and is lightweight and therefore is ideal for use in bridge components, aircraft structures, sporting goods (e.g., golf club handles), and brake discs.

Carbonized fiber is also very thermal protective and has been used in the heat shields of space shuttle wings.

FLUOROCARBON FIBERS

Fluorocarbon fibers are formed from long-chain carbon molecules in which all available bonds are saturated with fluorine. These fibers are exceptionally resistant to heat and chemicals, are completely hydrophobic (0 percent moisture regain), and possess very good resistance to abrasion, sunlight, aging, and mildew. Their main application is industrial uses, such as protective clothing, hot gas filters, and chemical and heat-resistant threads. Producers and trade names of this fiber include W. L. Gore & Associates, Inc. (Gore-Tex®) and INVISTA™ (Teflon®). The material formed into fibers can also be formed into sheets or applied as a coating to other substances. Thus Gore-Tex® fabrics have a thin membrane covering for water resistance and Teflon® is used as a coating for cooking items as well as rainwear.

HETEROGENEOUS FIBERS

So far only homogeneous fibers (i.e., fibers composed mainly of a single chemical substance) have been discussed. Another fiber category is the **heterogeneous fibers** (see Figure 3.15). These fibers are prepared from two or more chemically or physically distinct components. Each component, if separately extruded into a fiber, would be classified as one of the generic fibers of the TFPIA. Fiber properties that are not obtainable with the normal generic fiber types previously described in this chapter can be achieved with these special fibers. These additional categories are bicomponent or multicomponent fiber and matrix or matrix-fibril fiber.

Bicomponent or Multicomponent Fiber

Bicomponent or **multicomponent** fiber is a manufactured fiber that is a combination or mixture of two or more chemically and/or physically different components combined at or prior to the time of extrusion. Each component, although possessing some different properties, if separately extruded into a fiber, could be classified in the same generic category of textile fiber. Thus, if the fiber is composed of two different types of nylon, the industry might label this fiber 100 percent bicomponent nylon, although, according to the TFPIA, 100 percent nylon is all that is necessary.

The fiber could also be composed of two different generic categories. This fiber would be referred to as a bicomponent bigeneric fiber. The label for such a fiber might read as follows:

100 percent bicomponent bigeneric fiber

(60 percent polyester, 40 percent nylon)

The most used bicomponent fiber type is side-by-side, where each fiber component is formed along the length-wise axis. The different polymers are fed separately to the spinnerette opening, but exit through the hole together, side-by-side. Because the two sections of the fibers are composed of slightly different chemicals, a cross-sectional microscopic view of the fiber shows two different areas, with a line of separation easily observed.

The other large usage for bicomponent fibers is the sheath/core type. This type is produced by having one polymer (sheath) surround the other polymer (core) as both are being extruded from the spinnerette opening.

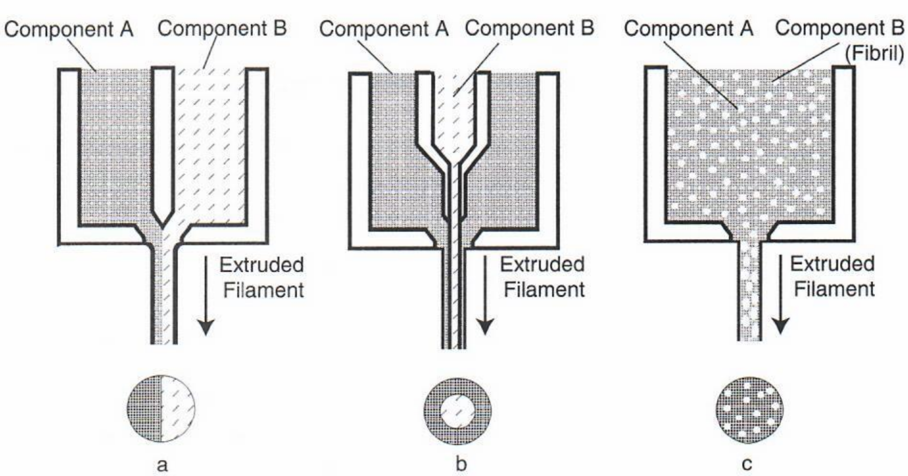


Figure 3.15a–c
Three ways to form an extruded heterogeneous fiber: side-by-side type (a); sheath-core type (b); and matrix-fibril type (c).

Wool can be considered a natural bicomponent fiber because it contains two types of cells. One is nearer the outside and the other is further inside. Because they have somewhat different chemical compositions, they react differently to changes in temperature and humidity. This response to environmental conditions helps give wool its crimped, curled structure.

Various effects are obtainable in bicomponent or multicomponent fibers, three of which are the following:

1. Self-crimping effect: Self-crimping occurs when one component shrinks more than the other in processing or fabric finishing and so pulls the yarn into a helical, crimped shape. Bulk, cover, and elasticity are better in this case than in mechanically induced crimp.

   An example of a bicomponent fiber is Creslan® acrylic (Sterling Fibers, Inc.) which is a self-crimping bicomponent fiber used to make high-bulk yarns for knitwear.

2. Cross-dyeing effect: If each of the two parts of the bicomponent fiber reacts to a different dye, then a two-color fabric can be created because each fiber part can be a different color. This can be accomplished with a single dye bath containing one dye for one fiber type and a second dye for the other fiber type. Each type is dyed with only one of the dyes and is not affected by the other. Carpet yarn can be dyed in this manner to create heather effects.

3. Heat-bonding application: KoSa produces a fiber (Celbond®) with a sheath-core structure. The core is polyester for toughness and resiliency. The sheath, which is one-third to one-half of the fiber, is a special low-melting polymer. After exposure to heat, it is designed to form a solid bond with adjacent fibers. The fiber is used as the binding fiber when producing such materials as nonwoven fabric (see p. 156) and high-loft batting. Binder fibers are normally from 10 to 40 percent of the material, depending on the required characteristics.

When the sheath and core are made from different polyester polymers (Type K54), the fiber is a polyester bicomponent fiber. When the sheath and core are made from different generic fiber polymers (e.g., polyester core and polyethylene olefin sheath), as with Type K56, the fiber is a bicomponent bigeneric fiber.

Antistatic Fibers The antistatic fibers now being produced contain a section of carbon. Because the quantity of carbon is small, these fibers are identified by the generic name of the major fiber component and not as a bicomponent fiber. Two such examples are Solutia's Ultron® nylon (side-by-side type) and DuPont's Nega-Stat® polyester (sheath-core type). The former is used primarily for antistatic floor coverings, and the latter is used primarily for clean room apparel as required in the aerospace and computer chip industries. Another example is BASF's Resistat® nylon, which has carbon chemically saturated into the entire outer skin of the nylon fiber. Its uses include the aforementioned as well as antistatic conveyor belts, gloves, and conductive brushes.

Matrix or Matrix-Fibril Fiber

Matrix or **matrix-fibril** fiber is a manufactured fiber composed of two or more chemically distinct components in a matrix-fibril configuration. Each component, if separately extruded into a fiber, would be classified in a different generic category of textile fiber.

A matrix-fibril fiber form is one in which very fine short filaments (the fibril) are embedded in the rest of the fiber (the matrix). The fibril and matrix are made of different generic substances.

The process is similar to that of mixing oil and water and then freezing the solution. The drops of oil are embedded in the resulting ice. If the drops of oil elongated upon freezing, then the resulting configuration would resemble the matrix-fibril fiber. Although the fiber-forming process does not use a freezing technique to obtain solidification, the example is a simple way of expressing the formation of the fiber with its two physical components, one embedded in the other. UltraSuede® is an example of a bicomponent fiber made of polystyrene and polyurethane used in a matrix configuration.

Fiber Innovation

Innovation and technology are the controlling forces that can accelerate the growth or retard the decline of a product. They have played an important role in the growth of the manufactured fiber industry. Textile chemists initially modified the shape of the manufactured fibers. Then, chemical changes were made to the fiber to meet specific industry and consumer needs. Today, fiber innovation enhanced by technology has cut across the entire fiber to fabric pipeline. From this a wide range of products have exploded onto the marketplace. Many are marketed as high performance products that have been engineered to address a specific need for the consumer. They may be crafted by a high performance fiber, yarn, fabric, finish, or combination. They are designed to manage moisture, regulate heat, inhibit the growth of bacteria, or other identified requirements. The following are examples of such products.

Therma-Pore™ is a polyethylene product produced by Therma-Float Ltd. It is an ultra thin material (1millimeter thick) for maximum warmth with minimum bulk. Uses include skiwear, military clothing, and ultra light sleeping bags.

SportwoolPro™ is a lightweight composite fabric for extreme sports such as free style skiing or competitive cycling. It utilizes a layer of merino wool next to the user's body and a layer of manufactured fiber on the other side. This allows moisture removal plus it helps reduce post-exercise chill.

Weather Bloc™ is an acrylic fiber that resists fading, is color fast to chlorine bleach, stain resistant, and inhibits the growth of mildew. It is used in fabric for protective clothing and fabrics for outdoor furniture, market umbrellas, and awnings.

Holofiber™ works with the body to increase circulation, build strength, and accelerate muscle recovery. It is used in athletic wraps, shoe insoles, snowboard gloves, and performance-based layer underwear.

The **A.M.Y.™** yarn has antimicrobial properties engineered into the yarn to build permanent odor control along with bacteria fighting capabilities. It is used in performance apparel, uniforms, bedding, and other applications.

DOW XLA™ is an olefin-based elastic fiber that offers stretch performance with excellent heat resistance from home laundering and ironing and chemical resistance, such as exposure to chlorine bleach. Used in shirting, denim, and other bottoms weight fabrics.

Innova® AMP is an anti-microbial additive to olefin fibers before extrusion through the spinnerette. The product is incorporated into the fiber while it is still in a molten state. Thus the antimicrobial additive is locked into the fiber structure to protect from order causing bacteria, fungi, molds, and mildews.

Lycra® is being marketed with a collection of products that addresses specific needs of the body. For instance:

- a textile treatment that traps odor and releases it in the wash
- a treatment that offers a cooling effect for the skin
- a yarn that regulates the body temperature by cooling or heating when needed
- products that moisturize when worn
- products that utilize graduated compression to energize the wearer

Successful and continual innovation requires a company to have not only a large research and development staff, but also sizable financing. Few are able to afford the expense associated with innovation and technology. Strategic alliances and partnerships have been the answer. Companies have reshaped their focus and established new joint ventures to continue creating innovation in fibers, yarns, fabric, and finishing.

Study Questions

1. List differences and similarities between the following natural fiber types and their manufactured fiber substitutes:
   a. cotton and HWM rayon
   b. wool and acrylic
   c. silk and acetate
2. Why are some fabrics made from two different fiber types and others made completely from one fiber type?
3. Compare a fabric made with polyester filament microfiber with a similar fabric made of filament silk fibers.
4. Differentiate between a generic fiber name and a fiber trademark.
5. You have determined that your line of fitted blouses would benefit from stretch and have three different generically classified fibers to choose from. What are they and what advantage might each one offer?
6. You have purchased pillows, comforters and mattress pads made of PLA for your store. What unique aspects of PLA will you highlight to market these products to your customers?
7. Why are microdenier fibers so popular for lingerie?
8. Nylon is used for each of these end uses. What fiber property modification would be beneficial for each?
   a. Carpet
   b. Rope
   c. Fiberfill for quilt
   d. Pajamas
   e. Drapery
9. Because wool fibers readily form pills, why is pilling not less of an aesthetic problem on a fuzzy surface fabric verses a flat surface fabric?
10. A cross-country skier must choose between a 100 percent wool jacket and a 100 percent polyester fleece jacket of similar construction. Which jacket would you advise as a better choice? Why?

Assignment 3.1

To Determine the Major End Uses for Textile Fibers

For at least three weeks, read the advertisements for consumer textile products in the daily newspaper. Record the following information for each of the advertisements:

a. Fiber content (record all generic fiber names if there is more than one fiber used).
b. Manufactured textile product.

After you have obtained information, make a chart for each of the generic fibers, indicating for what articles the fiber has been used.

Finally, on a separate sheet, state for at least ten different generic fibers the major markets for each. The generic fibers chosen should include both natural and manufactured types.

Assignment 3.2

To Determine Why Certain Fibers Are Used for Specific Consumer End Products

Cut out ten advertisements from newspapers, magazines, or catalogs. The ads must be for consumer textile products (e.g., dresses, suits, drapes) and indicate the fiber content of the item. Underline the fiber content in the advertisement.

Write two reasons why you believe each of the fibers was used for the textile product in each ad.

Do not duplicate any blend (i.e., two or more fibers mixed together) or single fiber, although a single fiber can be repeated in a blend (e.g., 100 percent cotton and 65 percent polyester/35 percent cotton can be used once).

Assignment 3.3

To Determine Applications of Nanotechnology

Cut out five advertisments from magazines or catalogs that illustrate performance characteristics achieved through nanotechnology. List the product manufacturer and explain what enhancement is being marketed.