

Rayon

Rayon is a manufactured fiber made from regenerated cellulose fiber. The many types and grades of rayon can imitate the feel and texture of natural fibers such as silk, wool, cotton, and linen. The types that resemble silk are often called artificial silk.

Rayon is made from purified cellulose, primarily from wood pulp, which is chemically converted into a soluble compound. It is then dissolved and forced through a spinneret to produce filaments which are chemically solidified, resulting in fibers of nearly pure cellulose.^[1]

Because rayon is manufactured from naturally occurring polymers, it is considered a semisynthetic fiber,^[2] whereas in precise usage the term synthetic fiber is sometimes reserved for the fully synthetic fibers. Specific types of rayon include viscose, modal and lyocell, each of which differs in manufacturing process and properties of the finished product.

Workers can be seriously harmed by the carbon disulfide used to make most rayon.^{[3][4]}



Play media

When a solution of cellulose in cuprammonium hydroxide comes into contact with sulfuric acid, the cellulose begins to precipitate from the solution. The sulfuric acid reacts with a complex compound of copper and dissolves it. Thin blue fibers of rayon are formed. After some time, sulfuric acid reacts with the complex compound and washes out the copper salts from the fibers. The fibers become colorless.

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Rayon and its variations

Nitrocellulose

The solubility of nitrocellulose in organic solvents such as ether and acetone was the basis for the first "artificial silk" by Georges Audemars in about 1855. Commercial production started in 1891, but the result was flammable and more expensive than cellulose acetate or cuprammonium rayon. Because of this expense, production ceased early in the 1900s. Nitrocellulose was briefly known as "mother-in-law silk".^[5] Frank Hastings Griffin invented the double-godet, a special stretch-spinning process that changed artificial silk to rayon, rendering it usable in many industrial products such as tire cords and clothing. Nathan Rosenstein invented the "spunize process" by which he turned rayon from a hard fiber to a fabric. This allowed rayon to become a popular raw material in textiles.

Acetate method

Paul Schützenberger discovered that cellulose reacts with acetic anhydride to form cellulose acetate. The triacetate is soluble only in chloroform, making the method expensive. The discovery that hydrolyzed cellulose acetate is soluble in more polar solvents, like acetone, made production of cellulose acetate fibers cheap and efficient.

Cuprammonium method

Swiss chemist Matthias Eduard Schweizer (1818–1860) discovered that cellulose dissolved in tetraaminecopper dihydroxide. Max Fremery and Johann Urban developed a method to produce carbon fibers for use in light bulbs in 1897.^[6] Production of cuprammonium rayon for textiles started in 1899 in the Vereinigte Glanzstoff Fabriken AG in Oberbruch near Aachen.^[7] Improvement by the J. P. Bemberg AG in 1904 made the artificial silk a product comparable to real silk.^[8]

Viscose method

English chemist Charles Frederick Cross and his collaborators, Edward John Bevan and Clayton Beadle, patented their artificial silk in 1894. They named their material "viscose", because its production involved the intermediacy of a highly viscous solution. The process built on the reaction of cellulose with a strong base, followed by treatment of that solution with carbon disulfide to give a xanthate derivative. The xanthate is then converted back to a cellulose fiber in a subsequent step. The first commercial viscose rayon was produced by the U.K. company Courtaulds Fibres in 1905. Courtaulds formed an American division, American Viscose, (later known as Avtex Fibers) to produce their formulation in the United States in 1910.^[9] The name "rayon" was adopted in 1924, with "viscose" being used for the viscous organic liquid used to make both rayon and cellophane. In Europe, though, the fabric itself became known as "viscose", which has been ruled an acceptable alternative term for rayon by the U.S. Federal Trade Commission (FTC).



A device for spinning Viscose Rayon dating from 1901

The viscose method can use wood as a source of cellulose, whereas other routes to rayon require lignin-free cellulose as starting material. The use of woody sources of cellulose makes viscose cheaper, so it was used on a larger scale than the other methods. On the other hand, the viscose process affords large amounts of contaminated waste water. Rayon was produced only as a filament fiber until the 1930s, when methods were developed to utilize "broken waste rayon" as staple fiber.

The physical properties of rayon remain unchanged until the development of high-tenacity rayon in the 1940s. Further research and development led to high-wet-modulus rayon (HWM rayon) in the 1950s.^[10] Research in the UK was centred on the government-funded British Rayon Research Association

Industrial applications of rayon emerged around 1935. Substituting cotton fiber in tires and belts, industrial types of rayon developed a totally different set of properties, amongst which tensile strength (elasticity) was paramount.

Lyocell

The Lyocell process relies on dissolution of cellulose products in a solvent, N-methylmorpholine N-oxide. The process starts with woody sources of cellulose and involves dry jet-wet spinning. It was developed at the now defunct American Enka and Courtaulds Fibres. As of 2013, Lenzing's Tencel brand is perhaps the most widely known lyocell fiber producer.

Major fiber properties

Rayon is a versatile fiber and is widely claimed to have the same comfort properties as natural fibers, although the drape and slipperiness of rayon textiles are often more like nylon. It can imitate the feel and texture of silk, wool, cotton and linen. The fibers are easily dyed in a wide range of colors. Rayon fabrics are soft, smooth, cool, comfortable, and highly absorbent, but they do not insulate body heat, making them ideal for use in hot and humid climates, although also making their "hand" (feel) cool and sometimes almost slimy to the touch.^[11]

The durability and appearance retention of regular viscose rayon are low, especially when wet; also, rayon has the lowest elastic recovery of any fiber. However, HWM rayon (high-wet-modulus rayon) is much stronger and exhibits higher durability and appearance retention. Recommended care for regular viscose rayon is dry-cleaning only, HWM rayon can be machine-washed.^[10]

Rayon industrial yarns outperform polyester and are produced for belts in high performance tires (e.g. Cordenka, Germany).

Gallery of textures



A sample of rayon from a skirt, photographed with amacro lens. Another skirt with a different texture.



A blouse with a texture similar to the second.

Physical structure

Regular rayon has lengthwise lines called striations and its cross-section is an indented circular shape. The cross-sections of HWM and cupra rayon are rounder. Filament rayon yarns vary from 80 to 980 filaments per yarn and vary in size from 40 to 5000 denier. Staple fibers range from 1.5 to 15 denier and are mechanically or chemically crimped. Rayon fibers are naturally very bright, but the addition of delustering pigments cuts down on this natural brightness.^[10]

Production method

Regular rayon (or *viscose*) is the most widely produced form of rayon. This method of rayon production has been used since the early 1900s and it has the ability to produce either filament or staple fibers. The process is as follows:

1. **Cellulose:** Production begins with processed cellulose (obtained from wood pulp and plant fibers).
2. **Immersion:** The cellulose is dissolved in caustic soda: $(C_6H_{10}O_5)_n + nNaOH \rightarrow (C_6H_9O_4ONa)_n + nH_2O$
3. **Pressing:** The solution is then pressed between rollers to remove excess liquid
4. **White Crumb:** The pressed sheets are crumbled or shredded to produce what is known as "white crumb"
5. **Aging:** The "white crumb" is aged through exposure to oxygen
6. **Xanthation:** The aged "white crumb" is mixed with carbon disulfide in a process known as Xanthation, the aged alkali cellulose crumbs are placed in vats and are allowed to react with carbon disulfide under controlled temperature (20 to 30 °C) to form cellulose xanthate: $(C_6H_9O_4ONa)_n + nCS_2 \rightarrow (C_6H_9O_4O-SC-SNa)_n$
7. **Yellow Crumb:** Xanthation changes the chemical makeup of the cellulose mixture and the resulting product is now called "yellow crumb"
8. **Viscose:** The "yellow crumb" is dissolved in a caustic solution to form viscose
9. **Ripening:** The viscose is set to stand for a period of time, allowing it to ripen: $(C_6H_9O_4O-SC-SNa)_n + nH_2O \rightarrow (C_6H_{10}O_5)_n + nCS_2 + nNaOH$

10. **Filtering:** After ripening, the viscose is filtered to remove any undissolved particles
11. **Degassing:** Any bubbles of air are pressed from the viscose in a degassing process
12. **Extruding:** The viscose solution is extruded through a spinneret, which resembles a shower head with many small holes
13. **Acid Bath:** As the viscose exits the spinneret, it lands in a bath of sulfuric acid, resulting in the formation of rayon filaments: $(C_6H_9O_4O-SC-SNa)_n + \frac{1}{2}nH_2SO_4 \rightarrow (C_6H_{10}O_5)_n + nCS_2 + \frac{1}{2}nNa_2SO_4$
14. **Drawing:** The rayon filaments are stretched, known as drawing, to straighten out the fibers
15. **Washing:** The fibers are then washed to remove any residual chemicals
16. **Cutting:** If filament fibers are desired the process ends here. The filaments are cut down when producing staple fibers^[1]

High wet modulus rayon (HWM) is a modified version of viscose that has a greater strength when wet. It also has the ability to be mercerized like cotton. HWM rayons are also known as "polynosic". Polynosic fibers are dimensionally stable and do not shrink or get pulled out of shape when wet like many rayons. They are also wear resistant and strong while maintaining a soft, silky feel. They are sometimes identified by the trade name Modal.^[12]

High-tenacity rayon is another modified version of viscose that has almost twice the strength of HWM. This type of rayon is typically used for industrial purposes such as tire cord.^[12]

Cuprammonium rayon has properties similar to viscose but during production, the cellulose is combined with copper and ammonia (Schweizer's reagent). Due to the environmental effects of this production method, cuprammonium rayon is no longer produced in the United States.^[12]

Manufacturing health hazards

See also *Viscose#Pollution and harm to workers*

Highly toxic carbon disulfide is used in the production of viscose, leading to many incidents and legal cases.^[13] However, the volatile carbon disulfide is lost before the rayon gets to the consumer; the rayon itself is basically pure cellulose.^[3] Studies from the 1930s show that 30% of American rayon workers suffered severe effects. Rates of disability in modern factories (mainly in China, Indonesia and India) are unknown.^{[4][14]}

Disposal and biodegradability

The biodegradability of various fibers in soil burial and sewage sludge was evaluated by Korean researchers. Rayon was found to be more biodegradable than cotton, and cotton more than acetate. The more water-repellent the rayon-based fabric, the more slowly it will decompose.^[15] Silverfish can eat rayon.

A recent ocean survey found that rayon contributed to 56.9% of the total fibers found in deep ocean areas, the rest being polyester, polyamides, acetate and acrylic.^[16]

Alternative to cotton

Rising cotton prices in 2010 led clothing makers to begin replacing cotton with rayon in their fabrics. As demand for rayon increases, companies such as Fortress Paper have been investing in pulp mills to increase production. Rayon now sells for as much as \$2.70 per pound, which has led to an increase in the retail price of clothing made with rayon, yet rayon has a price advantage over cotton.^[17]

Mislabelling

See also *Bamboo textile*

In 2010, the U.S. Federal Trade Commission issued letters informing over 100 companies that they were mislabeling products made of rayon as being made from bamboo, deceiving environmentally conscious consumers.^[18] In 2015, the FTC filed complaints against Bed Bath & Beyond, Nordstrom, J.C. Penney, Backcountry.com, and their subsidiaries, for continuing to deceptively sell rayon

mislabeled as bamboo. The four companies were required to pay civil penalties totaling US\$1.3 million for violating the "Textile Act and the Textile Rules" and Section 5(m)(1)(B) of the FTC Act.^[19] Similar action took place in Canada.^[20]

Impact on U.S. textile industry

Rayon contributed partly to the decline of the US textile industry in the 1920s.^[21] It is far cheaper to produce than wool, cotton, or silk. It also requires less processing and hence fewer workers. In addition, it was 50% cheaper than silk during the 1920s in the US.^[21] Then, it was used initially for men's socks but later for lingerie and women's stockings.^[21]

Producers

Trade names are used within the rayon industry to label the type of rayon in the product. Viscose Rayon was first produced in Coventry England in 1905 by Courtaulds.

Bemberg is a trade name for cuprammonium rayon developed by J. P. Bemberg. Bemberg performs much like viscose but has a smaller diameter and comes closest to silk in feel. Bemberg is now only produced in Italy due to United States Environmental Protection Agency regulations in the US. The fibers are finer than viscose rayon.^[8]

Modal and *Tencel* are widely used forms of rayon produced by Lenzing AG. Tencel, generic name *lyocell*, is made by a slightly different solvent recovery process, and is considered a different fiber by the US FTC. Tencel lyocell was first produced commercially by Courtaulds' Grimsby plant in England. The process, which dissolves cellulose without a chemical reaction, was developed by Courtaulds Research.

Accordis was a major manufacturer of cellulose based fibers and yarns. Production facilities can be found throughout Europe, the U.S. and Brazil.^[22]

Visil rayon is a flame retardant form of viscose which has silica embedded in the fiber during manufacturing.

North American Rayon Corporation of Tennessee produced viscose rayon until its closure in the year 2000.^[23]^[24]

Grasim of India is the largest producer of rayon in the world (claiming 24% market share). It has plants in Nagda, Kharach and Harihar – all in India, as well as joint ventures in Canada, Laos and China.^[25]

See also

- Viscose
- Cellophane (sheet-extruded viscose rayon)
- Hilaire de Chardonnet
- Ray P. Dinsmore - pioneered use of Rayon in tires

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Further reading

- For a review of all rayon production methods and markets see *Regenerated Cellulose Fibres* (book – Edited by C R Woodings) Hardback 2001, ISBN 1-85573-459-1, Woodhead Publishing Ltd.
- For a description of the production method at a factory in Germany in World War II, see Agnès Humbert (tr. Barbara Mellor) *Résistance: Memoirs of Occupied France* London, Bloomsbury Publishing PLC, 2008 ISBN 978-0-7475-9597-7 (American title: *Resistance: A Frenchwoman's Journal of the War*, Bloomsbury, USA, 2008) pp. 152–155
- For a complete set of photographs of the process see *The Story of Rayon* published by Courtaulds Ltd (1948)

External links

-  The dictionary definition of *Bemberg* at Wiktionary
 -  The dictionary definition of *rayon* at Wiktionary
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