

Lyocell, The New Generation of Regenerated Cellulose

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Abstract: For the majority of the last century, commercial routes to regenerated cellulose fibres have coped with the difficulties of making a good cellulose solution by using an easy to dissolve derivative (e.g. xanthane in the case of viscose rayon) or complex (e.g. cuprammonium rayon). For the purposes of this paper, advanced cellulosic fibres are defined as those made from a process involving direct dissolution of cellulose. The first examples of such fibres have now been generically designaed as lyocell fibres to distinguish them from rayons, and the first commercial lyocell fibre is Courtaulds' Tencel.

Keywords: cellulose, fibre, lyocell

1 Introduction

The cellulose fibers produced by direct dissolution have the generic name of lyocell.

Cellulose is one of the most abundant natural resources on earth, and there has been extensive research on the films, plastics, and fibers from this material.

The history of cellulose fibers dates back to the 1860s, when the first rayon fibers were commercialized by Courtaulds. But the so-called rayon process includes toxic chemical treatments to block hydroxyl groups of cellulose to prepare a spinnable solution, sometimes causing ecological problems.

Many attempts have been made to invent new solvents to directly dissolve cellulose, and some successful results have been reported [1]. Among these, N-methylmorpholine-N-oxide (NMMO) hydrate turned out to be the best solvent, leading to the commercial success of cellulose fibers under the trade name of Tencel by Courtaulds in 1994 (Figures 1 and 2).

Other lyocell processes include Lenzing Lyocell and TITK Alceru [2]. These processes are advantageous because they are environmentally benign, using

nontoxic NMMO hydrates instead of toxic carbon disulfide, which can be almost totally recycled.

The lyocell fiber has a highly crystalline structure in which crystalline domains are continuously dispersed along the fiber axis. This offers good wet strength as well as excellent dry strength, which makes lyocell water-washable. Further, it shrinks less when wetted by water and dried than other cellulose fibers such as cotton and viscose rayon [3, 4, 5, 6].

Recently, a new lyocell process, the Cocel process [7], was devised, which has some characteristic features similar to the Tencel process. The new process dissolves finely powdered cellulose in molten NMMO hydrate within 5 minutes by means of a pasting stage, which causes much less decomposition of cellulose. Further, this process can use NMMO hydrates with a hydration number (n) greater than 1 because it adopts a plasticating extruder. The value of n plays a significant role in the phase behavior of cellulose solutions [8, 9]. It also affects the physical properties of the fibers spun from the solution [5, 6, 10].

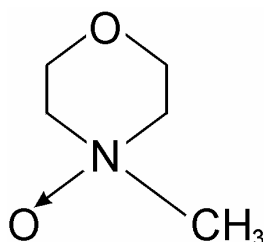


Figure 1
Structure of N-methylmorpholine-N-oxide

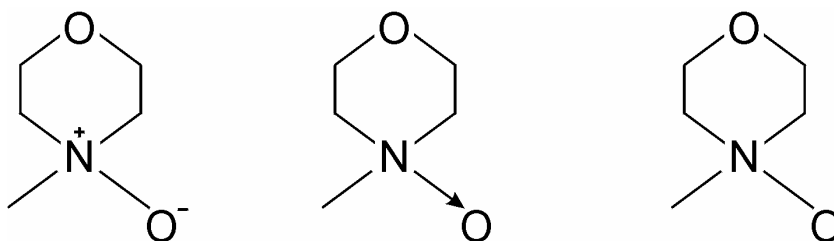


Figure 2
3 Possible Formulas of N-methylmorpholine-N-oxide

2 Direct Dissolution in Amine-Oxide

NMMO emerged as the best of amine-oxides and Neil Franks and Julianna Varga [11] developed a way of making a more concentrated and hence economical solution of cellulose, by carefully controlling the water content of the system. Figure 3. shows that the concentration of water and cellulose where complete dissolution of the cellulose occurs (at 95%), lie between lines B and C. Between lines A and B there can be 95% confidence that the solution would be free from undissolved cellulose fibres are bound to be present. Similarly, between lines C and D there is a 95% chance that crystals will always be present to the left on line D. Figure 4 shows the same information in the more familiar ternary diagram form.

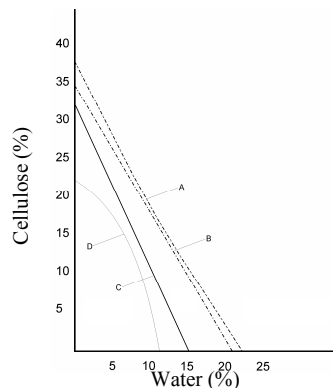


Figure 3

Dissolving Cellulose in NMMO and water mixtures

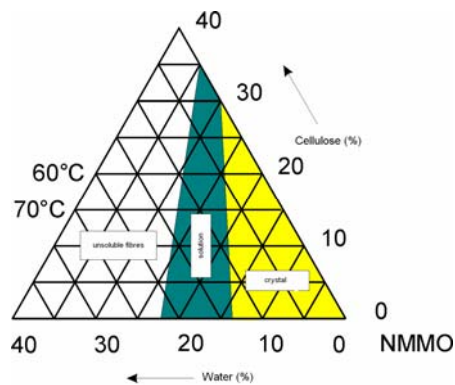


Figure 4

Ternary diagram showing the effect of temperature on the dissolution cellulose in NMMO

3 The Properties of Lyocell

Comparisons of lyocell with viscose in both laboratory and test markets proved that the fibres were sufficiently different to deserve separate marketing strategies.

Lyocell is:

- stronger than any other cellulosic fibres, especially when wet
- easy to process into yarns and fabrics alone or in blends
- easy to blend (unique fibre presentation)
- easy to spin to fine count yarns
- very stable in washing and drying
- thermally stable
- easy to dye to deep vibrant colours
- capable of taking the latest finishing techniques to give unique drape
- comfortable to wear

4 The Courtaulds' Lyocell Process

The Courtaulds' semi-commercial production system is illustrated in Figure 5. Dissolving grade woodpulp is mixed into a paste with NMMO and passes through a high-temperature dissolving unit to yield a clear viscous solution. This is filtered and spun into dilute NMMO, whereupon the cellulose fibres precipitate. These are washed and dried, and finally baled as staple or tow products as required by the market. The spin-bath and wash liquors are passed to solvent recovery systems which concentrate the NMMO to the level required for re-use in dissolution.



Figure 5

Direct Dissolution: Courtaulds' Lyocell

5 Lyocell Conversion

Lyocell is similar in strength to polyester and stronger than cotton and all other man-made staple fibre cellulose. It also has very high dry and wet modulus for cellulose fibre in both the dry and wet states. These properties allow customers great scope for making strong yarns in blend with virtually all the other commercially available staple fibres. They also lead to excellent efficiencies in converting these yarns to woven and knitted fabrics.

All man-made cellulose loses strength and modulus when wetted, but lyocell reduces by much less than others. This is important in determining how properties of the fabric are developed during dyeing and finishing. However, the fibres do fibrillate during abrasion and thus specific techniques are required to achieve the best results, these are discussed later.

Once lyocell fibre has been produced, either as cut staple fibre or continuous tow it will be converted to yarns and fabrics by a range of conventional textile processes. The most common way of using lyocell fibre is as cut staple, with 1.4 and 1.7 dtex fibres being cut to 38 mm and converted into a spun yarn using machinery developed over many years for handling cotton fibres which are similar in linear density and length to lyocell.

The following comments apply to the processing of Tencel fibres. The Lenzing Lyocell is made by a wet cut route and has very different processing characteristics [12, 13, 14].

5.1 Yarn Manufacture

Tencel can be produced via established yarn manufacturing routes, using conventional machinery with few major changes to settings or procedures.

Its processing performance is influenced by the following properties:

- it possesses a non-durable crimp
- it has a high modulus
- there is a little fibre entanglement

Thus lyocell will open easily with little nep. In sliver and roving the fibres pack together, give high cohesion and require high draft forces. It yields yarns with high tensile strength and few imperfections. It blends well with other fibres, especially other cellulose. It adds strength to the final yarns and enhances the performance and aesthetic values of final fabrics.

5.2 Lyocell in Nonwovens

A nonwoven is broadly defined as a textile structure made directly from fibre rather than yarn. The fabric is usually made by producing a web of fibres which is then strengthened by bonding using various techniques, for example:

- Thermal bonding
- Hydroentanglements
- Needle bonding

The key properties of lyocell which make it suitable for nonwovens are:

- high strength
- biodegradability
- easy processing
- absorbency
- potential to fibrillate

Preparation of fibre web can be done in many different ways, however two main methods are carding and wet-laying.

Not all webs are suitable for bonding by all methods, however, both wet-laid and carded webs are suitable for hydroentanglement. This is an area in which work has concentrated on lyocell, owing to the fibres' ability to fibrillate in wet processes. Hydroentanglement produces bonding by entangling the fibres together. This is done by passing the web under rows of high pressure water jets. As this is a wet abrasive process lyocell can be made to fibrillate at high water pressures, producing submicron fibrils, which enhance filtration properties.

Hydroentanglement gives strong lyocell fabrics, which compare well to polyester and stronger than viscose. Lyocell can be bonded using a wide range of other techniques, which will not be discussed in detail here. It is being trialled and developed in nonwovens for a wide range of end-uses including:

- surgical swabs, drapes and gowns
- floppy disc liners
- filtration applications
- semi-disposable workwear
- lining materials

5.3 Lyocell Papers /15/

The ability of lyocell in fibrillate means that it can be processed and made into a paper, like wood pulp. The main steps in paper making are:

- Beating and/or refining – these two processes take a dilute suspension of short fibre – and mechanically treat the fibre in order to fibrillate it. The forces exerted on the fibres cause the fibre to fibrillate and can also cut the fibre.
- Sheet formation, the refined stock is diluted further and then pumped to the paper machine where it is deposited onto a porous metal belt or wire. The water is sucked through the belt, leaving the fibre on top as paper sheet. The paper is then passed through a series of drying cylinders and presses before being wound on a roll.

Lyocell can be processed into a strong paper. The properties depend upon the amount of fibrillation generated, increased fibrillation gives more paper strength, and also affects other properties. In general lyocell papers are strong, with good opacity and low air resistance owing to the circular nature of the fibres and fibrils. The end-uses being explored are therefore mainly filtration applications, and also as an additive to improve the properties of a standard paper made from wood pulp.

References

- [1] C. C. McCorsley, Process for Shaped Cellulose Article Prepared from a Solution Containing Cellulose Dissolved in a Tertiary Amine N-oxide Solvent, U.S. patent no. 4,246,221, January 20, 1981
- [2] Berger, W., Possibilities and Limitations of Alternative Processes for the Dissolution and Forming of Cellulose, *Lenzinger Berichte*, Rudolstadt, Germany, 1994, pp. 11-18, FW16-FW19 (1992)
- [3] Bullio, P. G., *Fibre Tomorrow*, *Am. Textiles Int.* 21(9)
- [4] Anon., Tencel-High Performance Cellulose Fibre, *High Perform. Textiles* 9(7), 1 (1989)
- [5] Davies, S., Courtaulds Tencel-A New Fibre for the Mass Market, *Textile Outlook Int.* 44, 8-18 (1993)
- [6] Hall, M. E., Horrocks, A. R., Seddon, H., The Flammability of Lyocell, *Polym. Degrad. Stab.* 64, 505-510 (1999)
- [7] Lee, W. S., Jo, S. M., Kang, H. J., Kim, D. B., Park, C. S.: Pelletized Pre-dope Granules of Cellulose and a Tertiary Amine Oxide Spinning Solution of Cellulose and the Process for Making Them, U.S. patent no. 5584919
- [8] D. B., Lee, W. S., Jo, S. M., Lee, Y. M., Kim, B. C., Rheological Properties of Spinning Solution of Lyocell Fiber-Effect of Hydrated Level of NMMO, *J. Kor. Fiber Soc.* 37, 681-688 (2000)

- [9] Kim, D. B., Lee, W. S., Kim, B. C., Jo, S. M., Park, J. S., Lee, Y. M., Effects of the Water Level Hydrated in NMMO on the Physical Properties of Cellulose Fiber in Dry Jet-wet Spinning, *Polymer (Kor.)* 22(2), 231-239 (1998)
- [10] Cuculo, J. A.- Hudson, S. M.: US Patent 4 367 191, Research Corporation (1983)
- [11] Franks, N. E., Varga, J. K.: US patent 4 145 532, April 1980, to Akz
- [12] C. C. McCorsley, Process for Shaped Cellulose Article Prepared from a Solution Containing Cellulose Dissolved in a Tertiary Amine N-oxide Solvent, U.S. patent no. 4,246,221, January 20, 1981
- [13] Chun, S. K., Jo, S. M., Lee, W. S., Kim, J. D., The Effect of Water Contents on the Properties of Cellulose Fiber from the Solutions of Cellulose/4-methylmorpholine N-oxide/Water, *J. Kor. Fiber Soc.* 29(6), 44-52 (1992)
- [14] Ingersoll, H. G., Fine Structure of Viscose Rayon, *J. Appl. Phys.* 17, 924-939 (1946)
- [15] P. A. Johnson: Courtaulds Lyocell for Papermaking Applications, TAPPI Nonwovens Conference, Memphis, March 1997