Viscose speciality fibres for filtration applications

Ph. Wimmer*

Viscose speciality fibres are cellulose fibres that are produced from natural cellulose in a chemical process. In the process, the fibre characteristics cannot only be adjusted specifically to match the processes for the production of filter media, but cellulose-containing raw materials of different origin can also be used used for viscose fibre manufacture without altering the properties of the final viscose fibres. Fibres with functional additives influence the result of the filtration not only with their physical properties, but also with the chemical properties of the incorporated additives. Through the openness of the fibres to diffusion in aqueous systems and gases, the full effectiveness of the additives homogeneously distributed inside the fibres is preserved. The incorporation of the finest particles into the fibre matrix allows their inclusion into filtration products without the hazards and problems usually associated with dust. Viscose Speciality Fibres in many different lengths are used as raw material for filter paper production in order to regulate porosity as well as for the production of nonwoven materials and textiles for filters. Filter media for food filtration, for example, are an important field of application for viscose speciality fibres, since the fibres are taste neutral and physiologically as well as hygienically absolutely safe.

1. Introduction

Cellulose is the polymer of beta glucose and thus belongs to the polysaccharides, just like starch. As a component of the cell walls of plants, it is the most widespread (bio-) polymer. Natural cellulose fibres occur in pure form in cotton, for example, but often also as the fibre component of natural composite materials like wood. Due to their different geometrical shapes, these fibres can be processed into a huge number of extremely different products, for example textiles and paper. /1/

Cellulose is biocompatible, physiologically neutral, completely biodegradable and non-allergenic. Therefore it is also suitable for food, medical and hygiene applications. Cellulose can store large amounts of water inside the fibre matrix, since it is extremely hydrophilic and has a high absorbency, but it does not dissolve in water.

Viscose speciality fibres are regenerated cellulose fibres and can be produced from nearly every cellulose-based raw material. They are usually produced from wood in a multistage chemical process, of which the first step is the pulping process known from paper production. In this step the cellulose is separated from other components of the wood, mainly lignin and hemicelluloses.

To be able to spin the cellulose into viscose speciality fibres, an alkali treatment with sodium hydroxide solution is first carried out in the viscose process. In the formed alkali cellulose, a white fibrous powder, the length of the polymer chains is adjusted and afterwards the reactive alkali cellulose is converted with carbon disulfide into cellulose xanthate, a yellowish substance. Through dissolving the freshly formed xanthate in sodium hydroxide solution, a highly viscous liquid with honey-like appearance is obtained, the so-called spinning dope.

While extruding the spinning dope through a spinneret into a sulphuric acid bath, the cellulose xanthate precipitates and coagulates to form viscose fibre filaments (cellulose), while the carbon disul-
phide which is formed in the reaction is re-used in the process. In the following process steps the viscose fibre filaments are stretched, cut into fibres, washed, and dried. 

A further product of the process is sodium sulphate, an important raw material for the glass and laundry detergent industries.

Even though in the viscose fibre manufacturing process cellulose (pulp) is converted into cellulose (viscose fibres), the characteristics of the viscose speciality fibres differ substantially from those of the raw materials used, since the fibre diameters and fibre lengths are adjusted in the viscose fibre process. In addition, the process also allows the controlled chemical modification of the fibres.

2. Fibre modification for the production of filter media

In nature, cellulose fibres occur only in a limited amount of fibre geometries. Differences exist between cellulosics from different fibrous plants, for example cotton, bamboo or wood, but also between cellulosics from the same plant species, but from other geographical growth regions. Seasonal and weather influences also have an influence on the fibre characteristics and unless the viscose fibre manufacturing process many processes to transform fibres into products are unsuitable to completely turn off natural variations.

For the production of textiles and nonwoven materials, for example, much longer fibres are required than for the production of papers. Among the textile and nonwovens fibres longer fibres are better suited for the production of needle felts, whereas shorter fibres are perfectly suitable for the production of hydroentangled nonwovens.

In the viscose process, the fluctuations of the raw material characteristics still present after the pulping process are compensated by adaptation of the process parameters, so that there are always the same product characteristics at the spinning jets. The spinning dope with consistent properties now allows a specific adjustment of the fibre characteristics.

The influence of the following fibre modifications on the characteristics of filter media will be explained more detailed below:
- Changes of the fibre geometry (cross-section, length, thickness)
- Chemical fibre changes
- Embedding of functional additives into a viscose fibre matrix

Unlike thermoplastic fibres like polyesters or polypropylene, viscose speciality fibres allow a quick diffusion of aqueous liquids and gases inside the fibres. Therefore, chemically effective additives that require a direct contact with reaction partners can also be incorporated.

Viscose speciality fibres have a high temperature stability and do not soften or melt. The decomposition point of the cellulose, which often constitutes the upper temperature limit of application, is clearly above the softening point of most thermoplastic fibres.

3. Influence of the fibre geometry on the filter and filtration characteristic

The fibre length primarily has influence on the ability of the fibres to be processed into filters. The influence on the filter characteristics is usually indirect and arises from the fundamental differences between the processing technologies and the products resulting from these. Especially in combination with natural fibres, the adjustability of the fibre length is a big advantage as natural fibres can indeed be shortened with a loss of quality, but in no way can be lengthened. Filter papers are an important market for viscose speciality fibres. Such filter papers are usually made from pulps with fibre lengths of approximately 1 to 10 mm. Viscose speciality fibres are offered as short cut with precise, reproducible cut length in the range of 3 to 12 mm. These short cut fibres are fully compatible with wood pulp and can be dispersed well in the pulper and are hence ready for use for the paper process. In the filter paper itself, the fibre length has only a little influence on the filtration characteristics, but mainly influences the strength of the paper. In particular, the tear strength of the papers increases significantly with increasing fibre length.

Filter papers are not only used in industrial and vehicle filters. In particular, they are used for food and beverage filtration. Due to the positive physiological characteristics of the viscose speciality fibres, even at high temperatures, filter papers suitable for food and beverage applications are an important market for viscose short cut fibres. Common filter papers containing viscose fibres are tea bag and coffee pad papers for liquid filtration and plugwrap papers of cigarettes for gas filtration. During cigarette smoking, these porous papers wrapped around the filter provide lighter smoke by regulating the air flow through the filter side into the smoke stream.

Viscose speciality fibres are added to these papers mainly to increase and control the porosity. The porosity of the filter papers can be influenced by the amount of Viscose speciality fibres used, as well as by their fibre count.

The fibre count is a measure of the diameter of the fibres (considered to be round) and is usually given in the unit dtex (1 dtex = 1 g / 10,000 m of fibre). Viscose speciality fibres are produced in the count range of approx. 0.5 dtex up to well above 10 dtex. This corresponds to fibre diameters of approx. 6 μm to well more than 30 μm.

Fibres with high count lower the paper density and increase the porosity much more significantly than fibres with low count, which, on the other hand, increase the strength of the paper to a certain extent. 

The fibre count/fibre diameter influences the filter characteristics not only in paper filters. The fibre surface in filters, which is available to particles for attachment, or in chemically functionalised fibres is available as "membrane surface" for diffusion into the fibre itself, is directly linked with the fibre count.

For microfibres with < 1 dtex, a particularly large increase of the fibre surface with decreasing fibre count is observed (Fig. 1).

The fibre cross section, which can be regulated in the manufacturing process of the viscose speciality fibres, has a much stronger influence than the fibre count on the fibre surface in the filter. In comparison to the cloud shape of the "round" standard viscose
fibres, the surface can be more than tripled at the same filter weight (Fig. 2).

Other filter properties, for example air resistance, can also be modified by the fibre cross-section. Filters from trilobal fibres have a low air resistance in combination with a high fibre surface area, which is the reason why cigarette filters are usually produced from trilobal cellulose acetate fibres.

Other cross-sectional shapes also significantly influence the filter characteristics. The very deeply fissured, letter-shaped Umberto fibres have numerous hollow cavities well protected from the flow, in which trapped particles are firmly bound. Segmented hollow Bramante fibres are collapsed in the dry state. In contact with water, they swell and store the water in their hollow cavities. The free filter cross-section is significantly reduced by the swelling and thereby the filter resistance is increased. The swelling is reversible and stored liquid water is discharged as humidity. Because the moisture is bound in a hollow cavity inside the fibres, trapped moisture cannot be discharged, even by high flow rates.

The fibre cross-sections also have a big influence on the characteristics of filter papers. As already explained before, round fibres increase their porosity by reducing the paper density, which leads to a lower filter resistance. Trilobal fibres act similarly.

In contrast to round and trilobal fibres, flat fibres increase the filter resistance and the density of the filter papers. The increase of the density is usually linked to a clear increase of the tensile strength of the papers.

4. Chemically modified viscose speciality fibres as an active filter medium

In the preceding section, the influence of modifications of the fibre geometry of viscose speciality fibres on the filter characteristics was introduced, in particular on porosity, filter resistance and surface.

Furthermore, it was shown that viscose speciality fibres can be produced specifically for the requirements of the different filter manufacturing technologies.

In this section, the chemical modification of viscose speciality fibres, as well as application examples for these fibres in filtration, will be discussed. The fibre shape and the type of filter medium can promote the efficiency of the modification, but both are of secondary importance in this context.

The cellulose molecule offers various possibilities for chemical modifications (Fig. 3). If reactions are carried out on the hydroxyl groups of the monomer units, molecules can covalently bind to the polymer chain via electron pair bonds. Such chemical modifications are permanent.

The cellulose molecules of the viscose speciality fibres are bonded to each other through hydrogen bonds. Hydrogen bonds are strong interactions between protons and non-bonding ion pairs of some heteroatoms. If an ideally polymeric substance, which is also capable of forming a large number of hydrogen bonds is incorporated into the viscose fibres, even water-soluble substances can be immobilised in the polymer matrix of the viscose fibres. Due to the high number of hydrogen bonds as well as the steric hindrance of the macromolecules the bonding forces between incorporated molecules and the cellulose chains are stronger than the diffusion forces of the water. This means that even water-soluble incorporated macromolecules cannot be extracted from the viscose fibres.

The cellulose backbone can also be modified, for example by oxidation. These reactions, however, will not be discussed here. In the manufacturing process, the chemical fibre modification is possible both, via the spinning mass before filament formation and after the filament/fibre formation during fibre washing, where the never-dried fibres are much more accessible to reactions than fibres having already been dried.
For use as a reactive filter medium, it is necessary to distinguish between reversible reactions where the filter medium can be regenerated, and irreversible reactions where the filter medium can only be used once, for example as a police filter. Regardless of the reversibility, the viscose fibre can take part as a reactant in the filtration, or it can simply be a carrier for reactive substances.

Viscose speciality fibres that are chemically modified through active ingredients are always highly advantageous when the active ingredients required for filtration cannot be processed into filter media, either because they are water soluble or because the produced filter media have considerable deficits in their physical properties, for example, differential pressure or available filter area. When the active ingredients are part of the carrier material viscose speciality fibres solely the processing and the technical/mechanical properties of the viscose fibres are relevant for filter manufacture but no longer the characteristics of the active ingredients anymore.

The technologies for the distribution of active substances in viscose speciality fibres, as well as for the fibre distribution in filter media, are fully developed and therefore a homogeneous active ingredient distribution is always guaranteed.

Through incorporation of a cationic polyelectrolyte, the rather anionic viscose speciality fibres become cationic. This is associated with an increased affinity both for anions and also Lewis bases. An example of a cationic viscose fibre is Danufil® Deep. Dye with quaternary nitrogen as cation. The application of these fibres as an anion exchanger is obvious. The ion exchange is reversible and the fibre can be loaded at any time with different counter-ions depending on the application. The fibres have a high affinity to PEG (polyethylene glycol), a common active ingredient carrier for pharmaceuticals and cosmetics. PEG can simultaneously bind to several molecules, so that not only anionic pharmaceuticals, but also pharmaceuticals bound to PEG, can be filtered off from water through cationic fibres. An interesting aspect, not only concerning the dyeing of textiles, is the high affinity of the cationic fibres to dyestuffs, which increases with the number of cationic groups (Fig. 4). /5/ The phenomenon of dye transfer in laundry is not only a problem in household laundry, but also in industrial laundry. Cationic viscose speciality fibres can be processed into cloths for household laundry, which catch bleeding dyestuffs from the washing liquor, but they can also be processed into filters for chemical cleaning. The service life of the solvent, used for a longer time in a closed system with solvent filtration, is thereby extended.

As they are made from renewable raw materials, used filters from viscose speciality fibres can be incinerated CO₂ neutrally, or can even be composted if the impurities in the filter allow this.

Anionic viscose speciality fibres, which are produced in analogy to the cationic fibres by incorporation of anionic polyelectrolytes (carboxylic groups), can also be processed into filter media. Polycarboxylates are also used in medicine and hygiene products. These are able to buffer the pH value in the skin-
tral range around approx. pH 5. The buffer effect for the pH is also of interest in the filtration of aquarium water, in particular if fish are kept from tropical waters that are often softened by humic substances in the soil and therefore are slightly acidic. Protons from the anionic viscose speciality fibres replace hardness-forming calcium and magnesium ions from tap water. At the same time, particles and excrements in the water are filtered off.

Like most ion exchangers, the anionic viscose speciality fibres can be loaded with different cations. Especially for pH regulation, different functions can be implemented, from alkaline ion exchangers with alkali metal loading to catch acids, to acidic proton-loaded ion exchangers to catch metal ions. Even ion exchangers with partial proton and metal loading are possible, which then buffer the pH over a wide range.

Cellulosic materials are also used for applications where flame retardant materials are required for safety reasons, for example air filters for motor vehicles. The use of cellulosic fibres is only possible if they are treated with flame retardant chemicals. These often release toxic gases in case of fire. Existing cellulosic solutions often reduce or eliminate the flammability risk but at the same time the risk of intoxication increases as toxic gases are released from the FR chemicals in case of heat and fire exposure.

Through chemical functionalisation of viscose speciality fibres, it is possible to incorporate silicate in the viscose speciality fibres. The Danufil® BF fibre is an alloy of cellulose and silicate which combines the advantageous properties of both materials. The silicate component in the fibre provides heat and flame protection. The LOI of the fibre is above 27. The cellulose component gives the fibre strength and flexibility. Only in direct exposure to flames, the cellulose part will slowly burn away. The silicate framework, however, remains stable and protects the underlying materials from damage by heat and flames.

As only “sand” is used for flame protection no toxic sulphur-containing or phosphorous gases can be released from the fibres.

Water, in particular liquid water, promotes corrosion and is therefore a big problem in many application areas, because the service intervals and the availability of machines are reduced. The ability to absorb and store large amounts of water is a fundamental characteristic of cellulose. The water absorption of viscose speciality fibres, which is especially high in comparison to other cellulose fibres, can be multiplied through chemical modification, which itself can even be combined with a modification of the cross-section (Fig. 5). Viscose speciality fibres in filters reduce the risk of corrosion, because they bind water before it can cause corrosion. The water absorption is fully reversible and there is no risk of bleeding particles during swelling like it is the case for super absorbent particles. At elevated temperature, for example the operating temperature of machines, as well as at low air humidity, viscose speciality fibres release absorbed water in gaseous form so that the original absorption capacity of the filter is restored.

In addition to water absorption, viscose speciality fibres can also prevent corrosion by incorporated corrosion inhibitors, since these remove other corrosive substances from operating media.

The chemical modification of the fibres allows the integration of various further functionalities. A new development is a fluoro- and silicone-free, biodegradable hydrophobic viscose fibre, which, for example, can be used for protection against moisture (Fig. 6). /6/ This fibre is expected to have a higher affinity to oils and fats and therefore should be suitable for the absorption of these media.

5. Use of viscose speciality fibres as a matrix for active particles

Cellulose is known for its openness for diffusion of gases and aqueous liquids. This is also used in filtration, for example for dialysis or ultrafiltration, but also in the food and packaging sector.

Cellophane films or Sausage casings are well-known examples. They allow the drying of the sausages, e.g. Salami, by diffusion of water.

There is no interest of using viscose speciality fibres as membranes because the diffusion through the space between the fibres is always quicker than diffusion through the fibres themselves as it has nearly no diffusion resistance.

The possibility of diffusion inside the fibres is of much greater interest. The fibre diameter of only a few µm allows a very quick diffusion into the fibres. Many different materials, for example resins, activated charcoal, colour pigments and inorganic salts, are resistant to the conditions of the viscose fibre manufacturing process at least for the time required for fibre manufacture and can therefore be incorporated into the fibres. The incorporated particles are distributed homogeneously across the entire fibre cross-section and fibre length (Fig. 7).

In order to be able to be incorporated, the particles must be significantly smaller than the fibre diameter. Finely ground particles have a many times larger surface and therefore usually also a far higher activity than coarse particles. The disadvantage of such fine particles is their tendency to develop fine dust, which increases the health and fire risk. Their incorporation solvles the dust problem, since the particles are permanently embedded inside the fibre matrix. The high diffusion rates through the viscose fibres still allow a high activity of the particles, especially as these are separated from each other and thus are easily accessible from every side.

A very clear example is water softening for coffee and tea preparation using serving machines, where a softening pad is used in addition to the coffee pad for water softening (Fig. 8).

From the simple to the complex
Innovation as a concept

- Mechanical driven knife pleating machines
- Servo driven knife pleating machines
- Mini pleat systems
- Rotary pleating lines

Schlesinger is a global engineering company with more than 90 years of experience in special machines. Schlesinger machines provide technical expertise, product quality, robustness and power.

Our product range includes knife type pleating machines in all standard widths and heights, offered in mechanically and servo motor-driven versions. We also supply rotary type pleating lines and all kind of optional peripheral equipment, such as unwinds, cross cutters or minipleat systems.
temperature microcapsules of creped paper by a suitable design of the nonwoven fabric. The low air resistance for breathing, can be maintained at the level of ion exchangers. Just as it is possible to incorporate ion exchange resins into fibres, also other active ingredients can also be incorporated into the fibres without loss of activity. Certain titanium dioxide particles are suitable for photocatalytic air purification and some metals have an antibacterial effect. Also particles for filter identification, such as luminescent pigments, can be incorporated into filters via viscose speciality fibres.

Through the incorporation of doped, activated charcoal into a fibre matrix, the filter medium can even be utilised as a catalyst for chemical reactions. In the filtration process, there is no risk from charcoal dust.

Through the incorporation of phase change materials (PCM), heat can be exchanged during filtration. The technology of PCM microcapsules is known under the name Outlast®. HME (heat and moisture exchange) filters for ostomy patients are usually made of creped paper and must take over the pre-heating and pre-moistening of the breathed air as a larynx substitute. If nonwoven materials from Outlast® are used, these allow better dust filtration, since, in contrast to creped paper, no flow channels exist. Moreover, the viscose fibres allow an extremely quick and effective moisture management. The PCM microcapsules in the fibres, as a latent heat accumulator, absorb and discharge much more heat than paper alone can do only by temperature change (Fig. 10). The crucial criterion for these filters, the low air resistance for breathing, can be maintained at the level of creped paper by a suitable design of the nonwoven fabric.

Just like the chemical modification of viscose speciality fibres or the adaptation of the fibre geometry, the incorporation of active ingredients in the fibre matrix is also a possibility for the adaptation of viscose speciality fibres to the specific requirements of the most different applications in filtration. It could be demonstrated that viscose speciality fibres are highly suitable as a carrier matrix for particles, in particular for time-critical filter tasks.

6. Summary and Outlook

Viscose speciality fibres are comparable to natural cellulose fibres in their environmental characteristics and their physiological properties, such as the non-allergenic effect, and, just like these, they are also suitable for food and medical applications.

At the same time, in contrast to natural fibres, viscose speciality fibres offer the possibility for the adjustment of the fibre geometry to the specific requirements of filter manufacturers.

Through chemical functionalisation or through incorporation of active ingredient particles, functions that are needed for specific filtration tasks can be selectively incorporated into the fibres. In this context, it could also be shown that Viscose Speciality Fibres allow a quick diffusion of liquids and gases into the fibres, so that molecules and particles incorporated inside the fibres retain their full activity.

The different possibilities for fibre functionalization can also be combined in order to achieve synergetic effects that result from the different functionalities and geometries.

The numerous examples show that viscose speciality fibres are an extremely versatile raw material, suitable for the production of filter media, and suggest that the application possibilities for viscose speciality fibres in the area of filtration have by far not all been exploited yet, just as on the fibre side, not all possibilities for functionalisation have been exhausted yet.

For the development of the filter media of the future, the cooperation between filter manufacturers, to whom the specific requirements of filters are known, and fibre manufacturers, who have the specific knowledge and skills about the functioning of fibres, seem to be the best pathway.

Literature: