EFTec Nanofibrillated Fibers

NANOFIBRILLATED STRUCTURE AND PROPERTIES

Engineered Fibers Technology, LLC (EFT) has developed and is manufacturing a unique product line of nanofibers under the name EFTec™ Nanofibrillated Fibers, which are produced from a wide range of synthetic and natural, sustainable, materials. These fibrillated fibers can have by number count essentially all of the fiber diameters in the range of between 50 to 500 nanometers, which is the same diameter range of fibers produced by electrospinning and melt spinning of nanofibers and nanofiber webs. It is estimated that EFTec nanofibrillated fibers contain between 40-200 Billion nanofibrils / gram. As a comparison, eucalyptus pulp, which is used in papermaking in products requiring fine fibers, have about 14 Million fibers / gram. Combined with these nanofibrils are a small number of longer precursor fibers that function as scaffolding and enable the bridging of the nanofibrils. EFTec Nanofibrillated Fibers are suitable for use in papermaking, wet-laid composites and other wet processes, as well as many types of slurry processed /molded engineered materials.

EFTec Nanofibrillated Fibers address many of the disadvantages of other nanofiber materials. Smaller diameter microfibers than obtainable with melt spun fibers, including splittable bicomponent fibers such as “island in the sea” are produced in the EFTec process. EFTec Nanofibrillated Fibers typically have long lengths for their diameters (aspect ratios over 1000), are produced in metric tons per day so are low cost, and change the value proposition for use of these materials, opening up the potential of their use in large volume applications like specialty / technical papermaking, high efficiency filtration media, consumer wipes /wipers, battery separators, electrical insulation papers, and building material applications, among others. They work just like nanofibers in existing applications but without the limitations of having to apply them as a specific layer to another material, or to produce a nonwoven web. EFTec nanofibrillated fibers can be blended directly as a component in the furnish of wet laid papers, as an example.

EFTec Nanofibrillated Fibers improve and enhance cellulosic paper products. They act as mechanical binders in papers to effectively hold fillers such as calcium carbide, talc, etc. In typical wet laid papers, these nanofibers significantly increase wet web toughness, and increase wet strength properties in high volume paper applications. The inclusion of these materials into papers that will be printed, or into paper coatings, changes the microstructure that the colors are printed on, keeping the inks on the surface of the paper and generating much more vibrant yellow and reds, difficult colors to achieve. The inclusion of these nanofibers also significantly increases sheet opacity, surface smoothness and bulk of the paper. For example, higher
opacity/ higher bulk papers with smooth surfaces for extremely bright and clear photographic papers can be made without chemical additives and coatings.

EFTec Nanofibrillated Fibers can be used to control / enhance porosity, and are currently being used to achieve specific pore sizes in microfiltration papers for potable water, automotive, and analytical filters to improve efficiency and can produce extremely tight, submicron, mean pore radius papers, and in wet friction (transmission) papers to control fluid flow. The tight pore structure of tenths of a micron mean pore diameters created with use of these products results in significant barrier properties and controlled porosity when they are added or coated onto fabrics or papers. They are suitable for applications as varied as medical barrier, environmental protective clothing, fuel cells, barrier packaging. Because of the small diameters and high aspect ratios of these fibers, very low basis weight / caliper (<10 g/m² / 25 micron), with very low mean pore diameters can be produced for applications including membranes, battery separators, etc.

EFTec Nanofibrillated Fibers are effective binders. The nanodiameters of EFTec Nanofibrillated Fibers and their ability to wrap around other furnish mixture components makes them suitable for use as processing aids where wet strength is required. They can also be used as binder systems in papers that are delivery systems for other materials, such as retaining activated carbon particles without blinding the pores. They have been used in place of resinous binders to make brittle fiber nonwovens flexible, and as nano-scale reinforcements. Because of the small diameter and binding mechanism, softness in nonwoven wipes can be increased.

EFTec Nanofibrillated Fiber cost effectiveness allows them to be evaluated in value-added applications such as construction materials where these products would have been historically too expensive. Such markets include building materials (nail pull properties in gypsum board drywall and additional toughness in concrete / cement, for example.

EFTec Nanofibrillated Fibers and can be carbonized in paper form. Both Lyocell and other regenerated cellulose, as well as acrylic (PAN) can also be carbonized (with or without chemical treatment to increase char yields) after being formed into paper, and have been investigated for use in ultracapacitors and other electrical storage devices.

EFTec Nanofibrillated Fibers are being produced in large commercial quantities economically. The ability to produce large scale production quantities of these fibers means that companies developing products using nanofibers now do not have to feel limited by the amount of product that can be produced and can addresses large applications where these materials can bring value. The economics of EFTec Nanofibrillated Fibers and their large scale production availability changes the way that a product designer can approach adding value by allowing them to add many new features economically to new product entries and to add enhancements to existing products.
<table>
<thead>
<tr>
<th>Material</th>
<th>Fineness (Diameter), nm</th>
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</thead>
<tbody>
<tr>
<td>Atom</td>
<td>0.3</td>
</tr>
<tr>
<td>Electrospun Nanofibers</td>
<td>50-500</td>
</tr>
<tr>
<td>EFTec Nanofibrils</td>
<td>100-500</td>
</tr>
<tr>
<td>Melt Blown Microfibers</td>
<td>2,000-5,000</td>
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<tr>
<td>Blood Cell</td>
<td>2,000</td>
</tr>
<tr>
<td>Carbon Fiber</td>
<td>7,000</td>
</tr>
<tr>
<td>Textile Fiber (1.5 Denier)</td>
<td>12,500</td>
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<tr>
<td>Human Hair</td>
<td>30,000</td>
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</tbody>
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EFTec Nanofibrillated Fibers can be dispersed and fibrils opened in water and used with various wet-lay paper machines to obtain specialty nonwovens or papers. In order to obtain maximum performance, the wet lap needs to be dispersed and the nano-fibrils opened in the initial stages of use. The amount of dewatering and compaction in the incoming EFTec Nanofibrillated Fibers has been selected to permit good dispersion in typical high shear production hydrapulpers, refiners, beaters, etc. Pulps can be successfully processed on Fourdrinier, Rotoformer, Inclined wire and Cylinder paper machines, as well as pulp molding machines.

Regardless of the type and concentration of EFTec Nanofibrillated Fibers used, however, specific material quality can be affected by several factors including storage, moisture level, type of paper machine, degree of fibrillation, dispersion, use of retention or dispersion aids, etc. Nanofibrillated Fibers can be readily dispersed and formed in sheet making equipment using recommended procedures.

AVAILABILITY

EFTec Nanofibrillated Fibers are available in a range of standard grades, either as a wet lap (about 20% solids) or as an aqueous slurry (<5% solids). Three types of precursor material are available, and all types can be produced with different fiber lengths and different degrees of fibrillation. All grades are being produced on a commercial scale and can be delivered in truck-load /container load quantities, as well as smaller development /production quantities.

EFTec Nanofibrillated Fiber: Standard Types / Designations

<table>
<thead>
<tr>
<th>Fiber Precursor Chemistry</th>
<th>Type</th>
<th>Degree of Fibrillation, CSF</th>
<th>Length, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lyocell</td>
<td>L</td>
<td>-010 -040 -200</td>
<td>-4 -6</td>
</tr>
<tr>
<td>Lyocell/Cellulose Blend</td>
<td>LC</td>
<td>-010</td>
<td></td>
</tr>
<tr>
<td>PAN (Acrylic)</td>
<td>A</td>
<td>-040 -200</td>
<td></td>
</tr>
</tbody>
</table>

Example
L-040-6 is Lyocell Fiber, 40 ml CSF, 6 mm Starting Length
A-010-4 is Acrylic Fiber, 10 ml CSF, 4 mm Starting Length

Also, it is possible to make customer specific grades of nanofibrillated fibers with specific lengths and fibrillation levels where required. EFTec Nanofibrillated Fibers are provided as a dewatered wet-lap with approximately twenty (20) percent solids content.
ENGINEERED FIBER TECHNOLOGY

Engineered Fibers Technology has a commitment to quality and to providing technical and engineering support to assist customers in the use of EFTec Nanofibrillated Fibers. All EFTec products are manufactured to closely defined conditions, specification and quality standards. Certifications are included with all shipments. Our Development Laboratory in Shelton, CT is available to provide additional information and technical assistance to address specific customer needs. We also maintain an ongoing program related to new product development and applications.

**Nanofiber Definitions / Processes**

Defining the term “nanofibers” is a subject of much discussion. ISO Technical Committee TC 229 is charged with developing standards for “understanding and control of matter and processes at the nanoscale, typically, but not exclusively, below 100 nanometers in one or more dimensions.” This definition most closely describes very short (0.1 mm), high crystallinity, needlelike “nano cellulose” fibers extracted from wood pulp that have high modulus intended for composites reinforcement. Most nonwovens manufacturers who deal with fibers generally understand nanofiber to mean fibers with diameters of less than 1000 nanometers (one micron (µm), and preferably less than 0.5 micron, with longer lengths / high aspect ratios. EFTec Nanofibrillated Fiber characterization is based on this definition.

There are many ways to commercially generate nanofibers of interest for papermaking and nonwoven applications. The oldest process (US Patent 692,631, issued in 1902 to Cooley) is based on electrospinning of polymers dissolved in solvents and extruded into an electrical field that causes the polymer-solvent dope to split into narrower filaments, creating nanofibers left behind as the solvents evaporate. The nanofibers are collected in webs and can be used in multiple applications such as filtration, medical barriers, protective garments, thermal and acoustical insulation, battery separators, and many others.

Nanofibers can also be melt-spun as bicomponent fibers in an “islands-in-the-sea” format, for example. The nanofibers are spun from one polymer as islands that are surrounded with a sea of a dissolvable polymer that is removed down stream as the material is processed further usually into a fabric construction. While both electrospun and melt spun nanofibers can be very uniform in diameter and can produce layers of fiber essentially one fiber diameter thick, these materials are typically very expensive to use as they require extremely specialized manufacturing processes and are generally produced in multiple kilograms per day. They are not high throughput processes by definition so are typically used in applications that are expensive enough to afford them. They are also usually only provided in web form which prevents their use in many applications possible with a dispersible / blendable fiber form. Current technology also permits the direct melt spinning of a nonwoven mat containing a mixture of micron and sub-micron fibers in the range of 0.5 micron diameter.

Depending on the CSF and length, it has been calculated that there can be between 40 million and 200 billion nanofibers /gram. Nanofibrillated fibers can be as small as 0.1-0.25 microns in diameter, which translates to a denier of 0.1-0.7 mg/9000 m. For comparison, the stock / starting fibers have a denier of 1500mg /9000 m and a diameter of 11-12 microns. Therefore, the fiber population can be dramatically increased at relatively low addition rates. Fiber length of the starting fiber, usually 3-6 mm, is selectable, and fiber length of the fibrils can depend on the starting length and the degree of cutting during the fibrillation process. The unique EFTec process does not result in cutting, and fibrils can be as long as the starting fiber, but a special process can be used to shorten the fibers to less than one-millimeter when desired for applications such as coatings.


**CONTRACT US:**

Engineered Fibers Technology invites you to contact us to discuss how and where this new class of materials will be of value in growing your business, or to request samples for evaluation.

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