NANO WEB™

Advantages Of A New And Advanced Nanofiber Coating Technology For Filtration Media Compared to The Electrospinning Process




John Wertz

Immo Schnieders

Hollingsworth & Vose

Abstract

Research and development of nanofibers has gained significant prominence in recent years due to the heightened awareness of their ability to enhance the performance of various forms of filter media. Nanofiber technology, i.e., the fabrication of very small fibers typically having a diameter of less than 1 micron, has been known and practiced for many years. Currently, the most commonly used process for manufacturing nanofibers is the electrospinning process.

This report highlights the drawbacks of the electrospinning process as compared to a new nanofiber coating process. Further discussed are the advantages of using a nanofiber coating in filtration applications to improve depth filtration and pulse-cleaning ability. Introduced here is a next-generation nanofiber technology specifically designed to enhance filtration media.

Traditional Nanofiber Technology

Among the most prominent methods of producing nanofibers is the electrospinning method. This process involves the use of a hypodermic needle, nozzle, capillary, or movable emitter. These tools provide liquid solutions of the polymer that are then attracted to a collection zone by a high-voltage electrostatic field. As the dissolved polymer and solvents are pulled from the emitter and accelerated through the electrostatic zone, fibers are formed through a process of solvent evaporation.

While electrospinning is effective for producing nanofibers, it has drawbacks. At the outset, electrospinning is a very slow process for producing nanofibers on a commercial scale, which increases manufacturing costs. Electrospinning also produces a largely two-dimensional structure that lacks depth or z-directionality. While this configuration is desirable for surface loading, it has limited capability for depth-loading applications. Electrospun nanofibers tend to be fairly weak and can be easily damaged or dislodged from the substrate. There remains a need for enhanced nanofibers that overcome the deficiencies of current electrospun nanofibers.

New Nanofiber Technology

A newly developed, solvent-free nanofiber coating technology can offer greater flexibility, control, and durability compared to the traditional process of electrospinning. This new nanofiber coating is formed from fibers typically ranging from 0.3 to 0.5 microns in size, but can be increased up to 1 micron. The fiber diameter distribution and layer thickness can easily be varied according to the application requirements. A wide range of filtration media can be improved through the use of this nanofiber technology.

This new nanofiber layer has a thickness in the range of 15 to 30 microns and is applied directly to the macro filtration substrate. When supplied as a standalone substrate, the nanofiber web has a thickness of between 100 to 200 microns. The nanofiber coating can be applied to any nonwoven base material, such as glass, cellulose, or synthetic fibers, while electrospinning is dependent on critical resins for adhesion. A second nanofiber layer of a similar or different polymer can also be applied as a coating. The particular configuration of the substrate will depend on the specific application of the filter media and can be varied to achieve the desired structural properties, including stiffness, strength, pleatability, and temperature resistance.

As indicated, the configuration of the support or base layer can vary depending on the intended use. For heavy-duty air, gas turbine, automotive air, and pulse-cleaning applications, the support is preferably a wet-laid paper, such as cellulose or a synthetic/cellulose blend. In other markets such as HVAC, liquid, cabin air filters, and HEPA filtration, supports can include wet-laid cellulose, glass, synthetic, carded, spunbond, and meltblown nonwovens.

Various nanofiber layers can be positioned at different locations in the filter media according to the application. For example, the nanofiber layer can be positioned upstream, before the macro filtration substrate to enhance surface filtration performance in a gas turbine or heavy-duty air application. The nanofiber layer can be positioned downstream of the macro filtration substrate to improve depth filtration in order to capture particles within the body of the media.

Applications For Nanofiber-Coated Media

Nanofibers can improve the performance of filter media's ability to remove particulates from air streams. This improvement can be seen in air intake streams of vehicles, computer disk drive ventilation, and high-efficiency filtration. In the case of cabin air filters, removing the particulate matter improves the comfort and health of the passengers. Nanofibers offer enhanced filtration performance in both mobile and stationary engines and industrial filtration applications.

With respect to engines, gas turbines, and combustion furnaces, it is important to remove particulate material from the air stream supply that can cause substantial damage to the internal components. In other instances, production gases or off gases from combustion engines and industrial processes may contain damaging particulate material. The removal of this particulate is desirable to protect downstream equipment and minimize pollution discharge to the environment.

This new, durable nanofiber coating can also be used in self-cleaning or pulse-cleaning filter applications. The dust cake formed on the upstream side of the filter media can be removed by back pulsing air through the media to rejuvenate it. As great force is exerted on the surface during the back pulse, nanofiber with poor adhesion to substrates or comprised of delicate nanofibers can delaminate as the shock wave moves from the interior of a filter

through the substrate to the nanofibrous layer. The new nanofiber technology provides excellent adhesion to the substrate as well as durable structural stability of the nanofibers themselves enabling longer life and improved efficiencies in pulse-cleaning applications because of the greater particle collection and overall energy expended during the cleaning process.

A much finer surface structure with decreased pore size is formed with the addition of a nanofiber coating, shown in **Figure 1**, in comparison to a typical cellulose surface shown in **Figure 2.** An electrospun nanofiber coating, shown in **Figure 3**, is also very fine, but so fine that the fibers offer little strength and have little depth. The layered structure and depth of the nanofiber coating is shown in **Figure 4**. The depth of the nanofiber coating illustrates that a nanofiber coating serves not only as a surface filter, but also has a depth filtration aspect that an electrospun coating lacks. The plurality of the nanofiber layers also provides superior durability.

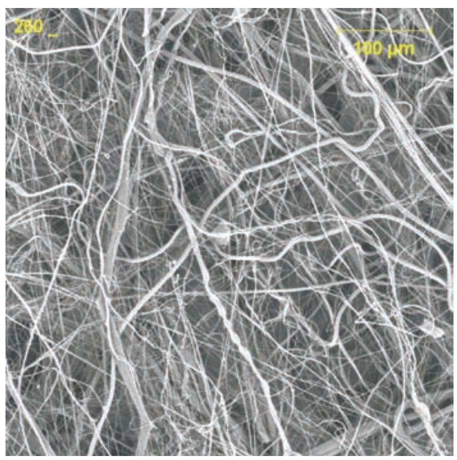


Figure 1. Top View of Nanofiber Coating, 260X

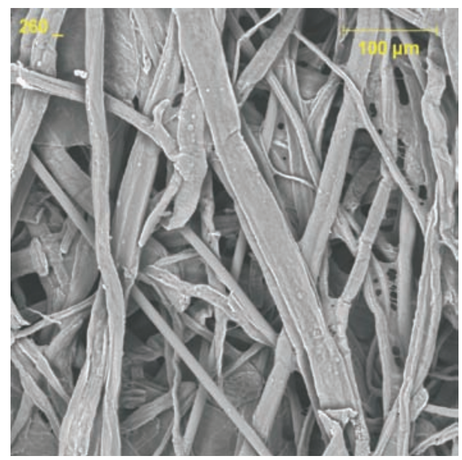


Figure 2. Top View of Standard Cellulose Media, 260X

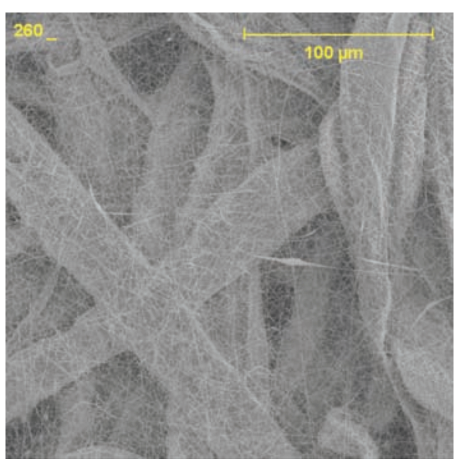


Figure 3. Top View of Electrospun Nanofiber Coating, 260X

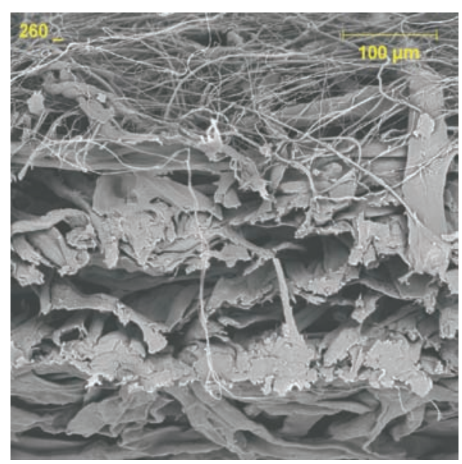


Figure 4. Side View of Nanofiber Coating, 260X

Depth Filtration

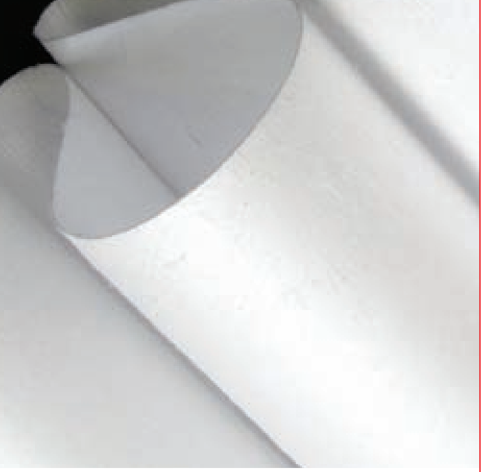
In contrast to heavy-duty air, dust collector, and cleanable media, where the nanofiber is applied upstream, there is a benefit to applying nanofiber layers downstream in applications such as automotive air intake, cabin air, fuel, and lubrication applications where it is important for particulates to be captured and confined within the air filter media. Particle capture efficiency can be greatly improved by adding a nanofiber layer coated substrate downstream while increasing particle-holding capacity. The combination of a more open base sheet with a heavier nanofiber layer results in a composite with not only greater efficiency at the same restriction (or air permeability), but also with significantly improved dust-holding capacity.

The test results of uncoated cellulose, cellulose base media coated with electrospun nanofibers, and a cellulose base media with the new nanofiber coating are compared in **Table I.** Advantages are shown for fine particle efficiency, fine dust efficiency, and panel air efficiency with a light nanofiber coating over a typical auto air media, similar to the impact of applying an electrospun coating. With the ability to add additional fine fiber mass economically, the thickness of the new nanofiber coating can be adjusted, providing 'dial-in' performance. With this added flexibility, the technical specifications of nanofiber composite can be fine tuned to meet application requirements.

Table I Depth filtration comparison of typical uncoated auto air cellulose and electrospinning media to enhanced nanofiber-coated media using flat sheet testing and element testing (panel air).

Auto Air	Uncoated Cellulose	Electrospinning	Nanofiber Coating
Air Permeability (cfm)	89	74	90
NaCl Eff @ 0.3 µm	14	37	40
Initial AC Fine Eff	68	88	77
Collected AC Fine Dust (g/m^2)	112	109	139
Time- AC Fine 1800 Pa (m)	51	46	52
Panel Air Initial Eff%	95	99	99
Panel Air Capture Eff (g/m^2)	210	192	236

Measurements of nanofiber-coated material clearly demonstrate much better cleanability behavior of the material compared to standard cellulose material. Filter media for cleanable applications have two main functions: To ensure no particles penetrate or pass through the media and to have very high-efficiency filtration. For gas turbine applications, high-efficiency material protects the sensitive blades of the turbine from dust particles. In industrial cleaning applications, the clean air should have no contaminants as it is circulated through the building. Based on high dust concentration in industrial cleaning environments or in gas turbines located in desert environments, a high-efficiency depth filter is not the best solution – air passages in the filter will be blocked due to dust cutting off the air flow. Surface filtration is



desired for collecting the dust on the surface of the filter because it creates a homogeneous and high-efficiency dust cake, resulting in a linear rise in pressure drop.

Surface structures, where nearly all particles will be captured on the surface from the beginning, will lead to a much better and more homogeneous dust cake if the filtered particles form a coherent dust cake. A highly efficient nanofiber network on the upstream side of the filter media prevents the dust from penetrating into the media, resulting in permanent air flow restriction.

Ideally, the dust cake should be removed as a whole, indicating that no particles have penetrated into the media. Particles that have penetrated the media cannot be removed effectively. As a consequence, the dust cake will be ripped apart during the cleaning step and the remaining particles will penetrate the media and result in an increase in pressure drop.

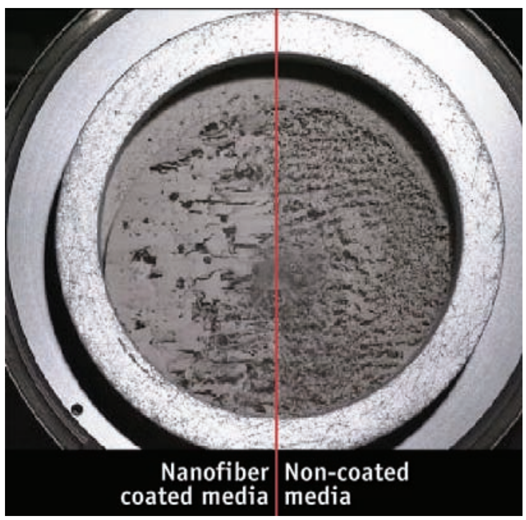


Figure 5. Dust penetrated into the media that will be harder to remove by the pulse jet

Figure 5 demonstrates the improved cleanability of filtration media when coated with nanofibers. The image shows the dust cake release of filter media during the pulse. The media in Figure 5 has had one side coated with this new nanofiber technology. The dust cake on the nanofiber coated left side is removed more effectively with several coherent fragments of the dust cake. In the case of the non-coated side on the right, the dust cake is ripped apart because many particles have penetrated the upper layers and are sticking to the surface of the media.

In surface filtration applications, the new nanofiber technology provides the required high efficiencies as well as improved cleaning behavior resulting in lower energy consumption and higher life times.

Next-Generation Advanced Nanofiber Technology

Hollingsworth & Vose Company (H&V) is one of the world's leading engineered papers and nonwovens producers. With its advanced R&D and pilot manufacturing facilities, H&V has developed an advanced nanofiber technology to drive value in customers' products. H&V's new NANOWEB® technology provides a microporous structure with unparalleled process control and durability. With this proprietary technology, the fiber diameter distribution and layer thickness can be dialed in to deliver greater performance across a wide range of applications.

The benefits of NANOWEB technology can be seen in both air and liquid filtration. NANOWEB coating can greatly improve the performance of filter media's ability to remove particulates

from air streams. This improvement can be seen in air intake streams, dust collectors, gas turbines, cabins of motorized vehicles, HVAC, and high-efficiency filtration. Various nanofiber layers can be positioned at different locations in the filter media according to the application. A NANOWEB coating can be positioned upstream before the macro-filtration substrate to enhance surface filtration performance or downstream of the macro-filtration substrate to improve depth filtration in order to capture particles within the body of the media. The strong nanofiber layer adhesion makes NANOWEB filtration media ideal for pulse-cleaning applications.

NANOWEB technology can also be specifically designed to meet the stringent filtration requirements of many liquid applications. With improved efficiency, NANOWEB media's synthetic composition offers a more durable nanofiber option for fuel and lube filtration. It also addresses the growing need for advanced microfiltration as well as RO and UF membrane pre-filtration in a variety of liquid service applications, including life sciences, food and beverage, and process liquid filtration. H&V's NANOWEB filtration media offers an average of 40% higher porosity for a given micron rating when compared to standard product offerings. With NANOWEB technology, H&V offers flexibility in designing filter media and has the experience to provide quality materials on a global scale.

About H&V

Established in 1843, Hollingsworth & Vose Company is a global leader in developing, manufacturing, and supplying technically advanced engine, high efficiency, and liquid filtration media; battery materials; and industrial nonwovens. H&V adds value to customers' products by inventing next-generation materials with superior performance. H&V's expertise and process capabilities include wet-laid, dry-laid, meltblown, nanofiber, and composite technologies. The company operates manufacturing sites and research centers in the Americas, Europe, and Asia.

Hollingsworth & Vose

Headquarters:
Hollingsworth & Vose Company
112 Washington Street
East Walpole, MA 02032-1008
U.S.A.

Telephone:
Americas +1 (508) 850-2000
Europe +49 6101-98167-0
Asia +86 (512) 6283-8918

Web: www.hollingsworth-vose.com
E-mail: info@hovo.com

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