Water filtration media: Talking about a revolution?

Rod Komlenic, VP Business Development at Ahlstrom Filtration, believes that their new Disruptor™ technology is a revolution in filtration. Here, we take a look at the new product and see if it really has the potential to change the (filtration) world.

Introduction

Developments in any field of endeavour are nearly always evolutionary, not revolutionary. It is normal to expect advances in manufacturing equipment, process control and chemical science to facilitate product improvements. In the field of liquid filtration there is frustration at the seemingly unbreakable linkage that exists between increasing pressure drop and lower flow rates as gains are made in retention. This is clearly exemplified by the development of smaller diameter synthetic fibres. Manufacturers continue to improve extrusion equipment and develop new polymers to produce ever-smaller diameter fibres.

However, the fundamental problem with finer fibres is that they are just finer fibres. Very little about their composition, shape or ability to be formed into a web alters the aforementioned relationship that exists between pressure drop, flow rate and retention. If anything it makes it worse since smaller fibres in a web results in smaller interspatial void volume (pores) with the media becoming more of a highly retentive surface filter with limited loading capacity, reduced flow rate and increased pressure drop.

Ahlstrom's Disruptor™ technology is capable of shattering the relationship between increased pressure drop and decreased flow rate as retention is increased. This is possible because Disruptor™ technology represents a breakthrough in materials science that synergistically combines the best aspects of charged and mechanical filtration in one media. The patented technology behind Disruptor™ is was invented by Fred Tepper and Leo Kaledin [1] of the Argonide Corporation and is manufactured and sold by Ahlstrom under an exclusive, global license.

Truly unique?

The active "ingredient" in Disruptor™ is nanoalumina fibres composed of the mineral boehmite AlO(OH). These fibres are typically 2nm in diameter and 200 – 300nm in length, and have dense electropositive charges that have been measured to reach up to 1um from the fibre. With surface areas of up to 500 square meters per gram of nanoalumina fibres, a typical 2.5" x 10" pleated cartridge will have more than 10,000 square meters of active surface area. In the manufacturing process, nanofibres are attached to 0.65 µm mean diameter microglass fibres. Figure 1 is a TEM that clearly shows the structure of the nanofibres. The microglass/ nanoalumina fibres are then blended with other fibres to create a matrix where the pore or interspatial opening size can be controlled during web formation.

The mean pore size of Disruptor™ is designed to be somewhat less than 2 µm. This size allows the entire volume of a 2-µm pore to be affected by the charge radius of the nanofibres to effect (or disrupt) the natural path a particle would take in traversing the thickness of the media. With a media thickness of 0.8 mm, a particle will have to pass through approximately 400 pores before traversing the cross section of the sheet, thereby creating a statistical meaningful interaction horizon between the contaminant and the charged fibres.

Being a depth filter that is a synthesis of charged and mechanical media, Disruptor™ can have comparatively large pores with high porosity and permeability thereby creating many conduits for free flow of fluid. These large pores are what facilitate high flow at low pressure drop.

The potential

The electrical potential can be altered between –32 mV to +32mV by controlling the packing density of the nanoalumina fibers on the glass fibres. This effect can be seen from zeta potentials (See Table 1) that were derived from streaming potential measurements. The charge potential was measured on a single layer of media, the MS2 virus retention was obtained using two layers (1.6 mm thickness) of media. The computed zeta potential is compared to the retention of MS2 phage when a 25 mm diameter disc is challenged at a flow rate of 50 ml/min. Testing has shown that the optimum value

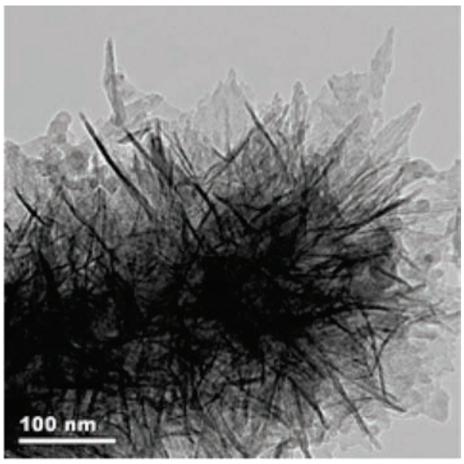

Figure 1: Nanoalumina fibres. Photograph by R.Ristau, IMS, UCONN

Table 1: Zeta Potential as a Function of Nanoalumina		
% Nanoaluminaon Glass	Zeta Potential mV	Percent MS2 Retention
0 %	-35	8
5 %	-10	29
10 %	7	94
15 %	12	>99.9999
25 %	32	>99.9999
40 %	29	>99.9999
50 %	23	>99.9999

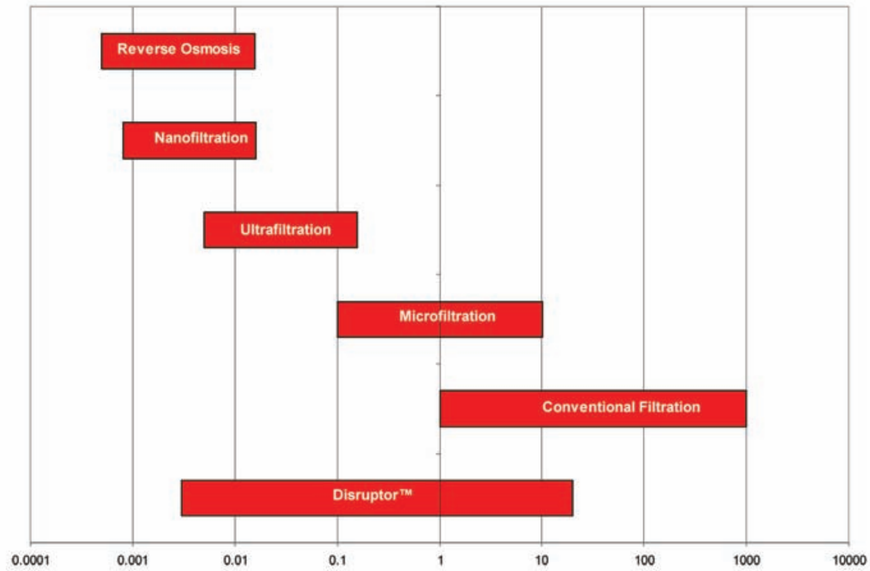

Figure 3- Filtration Spectrum of Disruptor

relationship between cost and performance is realized with a nano alumina content between 22-35 percent by weight. With Disruptor™ technology it is now possible to selectively manipulate the filtration efficiency through pore size and electrical charge.

With the charge being inherent to the media, not a result of chemical modification of the surface of the fiber, its charge capability is sustained in use. Its isoelectric point is approximately pH 9.4, outside the recommended use range of pH 4 to 9. The charge is maintained in fresh, brackish or seawater. Figure 2 is a comparison between Disruptor™ and a leading

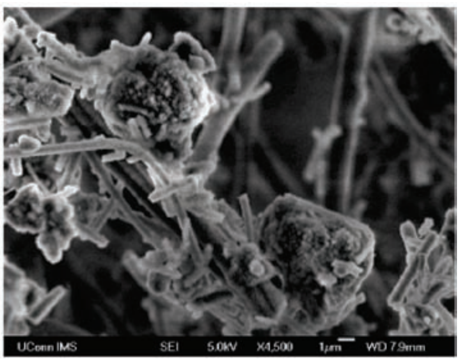

Figure 4 – Powdered Activated Carbon in Disruptor. Photograph by R.Ristau, IMS, UCONN

charge-modified media in the removal of MS2 virus (~25 nm)

The important distinction to note between Disruptor™ and conventional polymeric nanofibre is that the latter is purely a mechanical media, filtering with very small diameter fibres. These fine fibres create a media that has very small interspatial openings, making it primarily a surface filter media with correspondingly low permeability.

Filtration/Adsorption Capability

Having the features of both electrical and mechanical media, Disruptor™ brings new capability to the entire range of water filtration markets for the removal or reduction of:

- Particulates – As a general rule all particles tend to become more electronegative as the particle size diminishes. Therefore filtration efficiency of Disruptor ™ technology improves against ever finer particles. This is why the media efficiently removes contaminants below about 0.5 μm to a few nm, having low mass and negative electrical potential such as: virus, many particulate metals, bacteria, cysts, gram positive and gram negative bacteria, cells, proteins, endotoxins, DNA and RNA.
- Colloids – Testing has indicated the ability to remove or reduce many colloidal substances including silica.
- Dissolved Metals – Varying removal capability can be demonstrated for iron, tin, copper, lead, aluminium and silver.

The large surface area of the nanoalumina fibers and the pore structure of the web create loading capacity that is 1.5-7 times its weight depending on the challenge contaminant. Third party testing shows that Disruptor™ is very effective at clarifying water. When tested against ASTM D 4989-95 for SDI, results were <0.5 or below measurable limits.

Although Disruptor™ technology will remove virus, bacteria and pathogens from water streams it does not inactivate, kill or suppress the growth of biologic materials. The media can be made to inactivate biological material removed from the water through the addition of appropriately regulated products.

Disruptor™ technology allows wet laid nonwoven media to have filtration capability that rivals UF and MF membranes but with a pressure drop of 0.1 bar in a typical Disruptor™ pleated cartridge, having 0.3 square meters of media. Figure 3 illustrates the filtration retention range achievable with non woven media.

Having high structural integrity, the base nanoalumina media can be used as is or can be laminated to a variety of prefiltration or structural materials to improve performance or processing characteristics.

A variety of spunbond PET or PP webs can be laminated to increase strength for high speed pleating, to act as a pleat support or to enhance burst strength. A prefilter material such as meltblown PP, microglass, paper or needle felt can also be laminated to the upstream side of Disruptor™ to prevent premature blinding.

Disruptor™ media is easily processed on conventional converting equipment into all types of filter configurations. It can be used as die cut sheets in plate and frame presses or in stack disc filters, or be pleated or spiral wound for use as cartridge filters.

Adding functionality

Due to its large surface area, powerful electroadhesive charge and available hydroxyl groups Disruptor™ can be functionalized by chemical modification or through the addition of particulates to create affinity for specific compounds. Development work has shown promise in enhancements that will remove metals such as lead and arsenic.

Many different nanopowders can also be added to the media. Powdered activated carbon with a mean particle size of 25 μm has been added up to 60% by weight. Disruptor ™ is capable of retaining the ultra fine powdered activated carbon to significantly increase the adsorption

Table 2

Media	Thick-ness,mm	Basic weight, g/m2	Challenge water			MS2 removal, %		
			pH	TDS g/L	MS2, PFU/ml	0-10 ml	60-70 ml	130-140 ml
Disruptor™	0.8	200	7.2	0	3•105	99	98	94
			9.2	0	6•105	90	90	
			7.2	30	5•105	97	97	
			9.2	30	4•105	96	88	
Other Electro positive filter	0.8	210	7.2	0	6•105	99	92	62
			9.2	0	3•105	60	13	
			7.2	30	5•105	4	6	
			9.2	30	4•105	0	0	

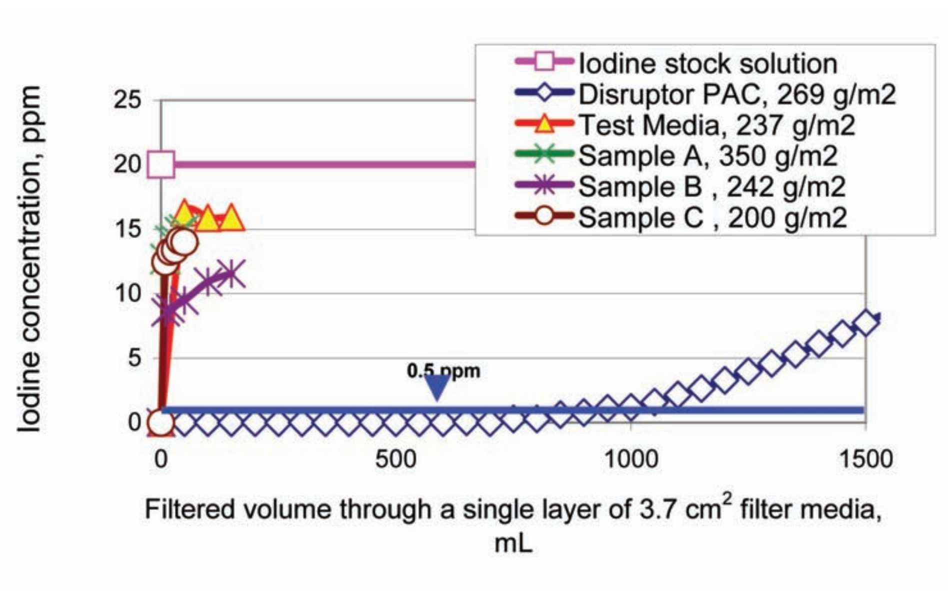

Figure 5 – Iodine Breakthrough Curves for Various Media

kinetics (or speed of adsorption if you prefer). By increasing the external surface to volume ratio, the path for diffusion of the solute into the particle is significantly reduced as well. This increase in surface area significantly increases the rate of adsorption, as compared to the typical granular activated carbon media that is tens if not hundreds of microns in size. Figure 4 is a TEM of retained carbon after being washed in ethanol to remove enough carbon to show the underlying fibre structure.

With so many active adsorption sites, any challenge to the media is very effectively addressed. Figure 4 shows a comparison of the reaction kinetics between Disruptor™ and several web-based carbon products purchased from a large retail distributor.

Each media was challenged by a dynamic stream containing a 20 ppm iodine solution, to a detectable level of 0.5 ppm in the effluent.

Other nanopowders such as catalysts and nano oxides have also been successfully added to the media. Figure 6 is a TEM showing fumed silica, again after washing in ethanol to show the underlying fibrous structure.

If antimicrobial effects are required, appropriately registered products can be added to the powdered activated carbon or tethered to the nanoalumina structure itself, through electroadhesion. Such additions can provide contact remediation of many organisms, reducing their proliferation on the media once removed from the water.

Filtration opportunities

With optimum performance capability in polar liquids, the water market offers the broadest opportunities in both Point of Use (POU) and Point of Entry (POE) filters. Key market segments include: Potable Water, Food and Beverage, Pharmaceutical Manufacture, Commercial Water and Waste Water.

Potable Water POE/POU – For home, restaurant, small industrial, pharma and other smaller volume applications Disruptor ™ makes an excellent stand-alone media for the removal of contaminants such as biological particulates, iron, colloidal silica and other particulates that contribute to turbidity. Since these contaminants also contribute to biofouling of RO membranes and reduce the life of carbon and deionization resins by blocking active sites on the media, their removal will improve membrane flux rates and increase the life of downstream media such as reverse osmosis membranes, deionization resins and carbon blocks.

Food & Beverage – Many of the benefits presented above also apply to for this use category. Improved water quality through turbidity and contaminant reduction will produce purer, better tasting products such as bottled water, juice, soda, coffee, etc.

Pharmaceutical Manufacture – Removal of previously mentioned contaminants as well as cell debris, proteins, DNA, RNA and endotoxins will allow for the production of cost-effective, high purity make-up water. The filter will also be effective in handling many contaminants in pharmaceutical waste, including many endocrine disruptors.

Commercial Water – Encompasses a broad range of industrial applications where removal of iron and biologic material is critical. Disruptor ™ can be used to control the iron and biologic content in heat exchangers, chillers, robotic welding cooling systems and boilers to provide more effective heat exchange and reduce the amount of chemical remediation needed to keep the systems clean and control biologic growth.

Waste Water – Disruptor™ media is cost effective post filter to hollow fibre UF membrane systems. Although very effective in removing high contaminant loads on a day in, day out basis, these membranes have been known to develop micro fractures that can lead to influent bypassing into the effluent stream. By using Disruptor™ as a post filter to UF membranes it becomes a reliable safety filter to remove by-pass influent from micro fractures or broken tubes. Effluent quality can now be sustained to meet quality standards with influent bypass until scheduled maintenance can be performed on the membrane system.

Disruptor™ filters must be replaced once all the active sites are used and/or the pore volume filled. In typical use, it is not been practical to wash or back flush the filter to extend its useful life. Disruptor™ is most effectively utilized as a disposable filter for those applications that require high dirt holding capacity and efficiency in removing sub-micron particles.

In high volume applications having a high contaminant load but requiring low NTU or SDI for clarification, Disruptor™ will be most cost

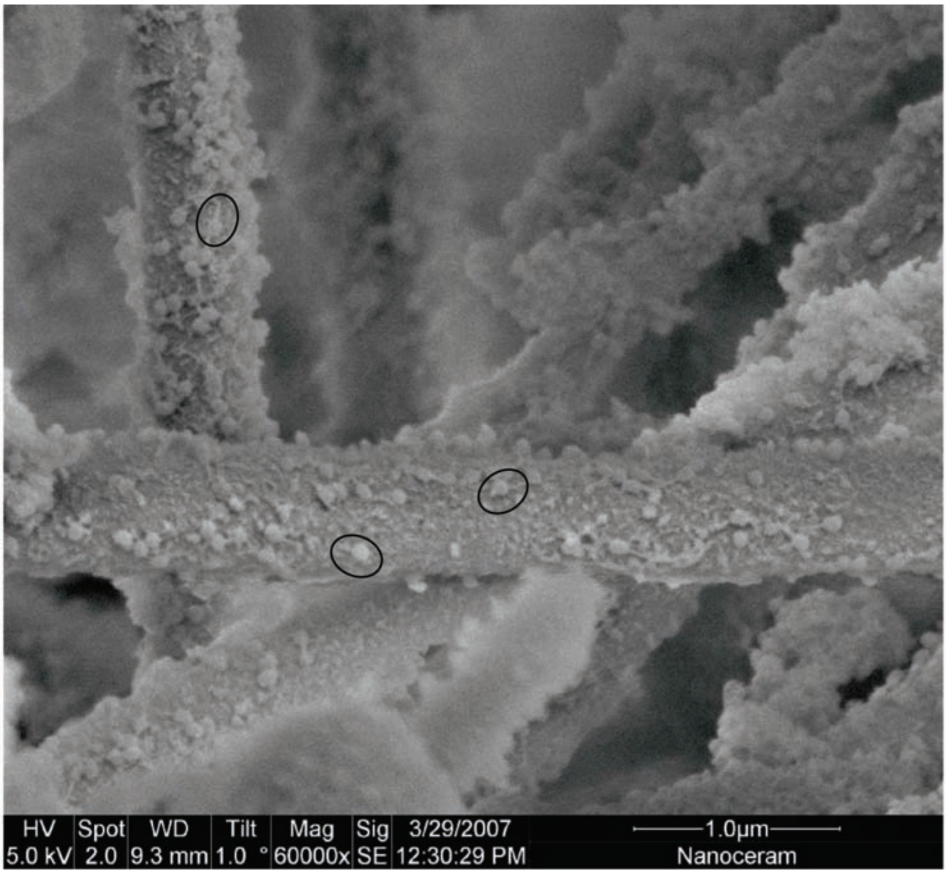

Figure 7: T4-Phages are seen attached to the Disruptor™ fiber. For preparation of the raster electron microscopy (REM) image the filter material was placed for 4 h in a highly concentrated T4-phage solution and dried afterwards. Three phages are encircled as examples, where the icosahedral head and the tail are easily visible

effective as a polishing cartridge filter installed down stream of the primary filter press or UF membrane filter.

Health and Safety

All the materials used in Disruptor™ other than the nanoalumina have been used extensively and for many years in the manufacture of air and water filter media.

The nanoalumina itself is composed of the mineral boehmite AlOOH, the monohydrate of aluminium oxide. Aluminium is very abundant, making up 8.1 percent of the earth's crust and is the third most common element after oxygen and silicon. Compounds suitable for reduction to the metal are not common in nature, so sources are the oxide, alumina with the principal source of alumina being bauxite, a mixture of the mineral gibbsite, Al(OH)3, with lesser amounts of the denser and harder boehmite and diaspore, AlOOH. [2,3]

Bugosh [4] suggests the use of fibrillated AlOOH for treating peptic ulcers, as a thickener in food products and as a food dye carrier. More recent publications show that fibrillar boehmite is used as an analgesic in the treatment of peptic ulcers [5,6]. Testing the dissolution of nano alumina aggregates in simulated stomach acids (pH 3.5 with pepsin added) found that 80% was dissolved in 18 hours. An inspection of the ingredients in nearly all stomach analgesics show they contain high amounts of aluminium hydroxide "gels" that are believed to be boehmite or pseudo boehmite as previously cited in the literature.

With extensive experience related to several bacteria (E coli, K. terrigina, B. globiggi, B. diminuta) Argonide has found the nanoalumina not to be bioactive. In fact bacteria tend to proliferate on the media making it a very effective substrate for fermentation and in biocatalytic processes.[1]

Collaboration between Argonide Corporation and Purdue University aimed at developing bone growth cements, found [7] that nanoalumina substrates could serve as scaffolding for the growth of human bone cells (osteoblasts). The nanoalumina, blended into biodegradable (e.g.-lactic acid based polymers) was found to facilitate the proliferation of such cells.

Vector Research Centre of Virology and Biotechnology Institute (Novosibirsk, Russia) evaluated the toxicity of both nanoalumina fibres and filter media. They measured toxicity towards E. coli; Staphylococcus aureus; Bacillus subtilis; Bacillus pumilis; and Candida albicans with no toxic effects noted for any of the cultures with the exception of the controls.

Since it is naturally occurring and not found to be harmful to bacteria, discharge of nanoalumina to the environment would not affect natural bacteria or the bacteria used in municipal plant filtration systems. The boehmite sols and nanoalumina in Disruptor™ are less chemically persistent in nature [8] as compared to other mineral fibers such as single or multi-walled carbon nanotubes, asbestos, titanium dioxide, alpha alumina (Al2O3) and SiC. Figure 7 shows attachment of viable T4 phages to the nanoalumina media.

As with particulate or granular carbon media and many other filters, flushing of the filter media prior to use is recommended to remove manufacturing debris. Recent tests by a third party laboratory measured both the soluble and insoluble aluminium present in both the flush water of a new filter and after flushing. Results in both cases were at less than detectable (100 μg/L) amounts of aluminium, within the drinking water standard.

Conclusions

Ahlstrom's Disruptor™ technology produces a hybrid filter media that works through a synergistic effect of naturally electroadhesive nanofibres and mechanical filtration. The media has a very large surface area and two micron pore size which creates a depth filter media having high loading capacity and fine particle retention at very low pressure drop as compared to any traditional fibrous or polymeric filter media of similar efficiency.

Disruptor ™ has been proven to remove nano sized particulates, bacteria, virus, colloids and dissolved metals from water. With such retention capability at low pressure drop, Disruptor™ is a worthy competitor against products such as meltblown, microglass, resin bonded or cellulosic depth filter media as well as UF and MF membranes in many applications. ●

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