Polyolefin solutions for filtration applications

Making everyday life easier

BOREALIS

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Borouge

Contents

Introduction

For millennia, humans have used a range of filtration processes to remove contaminants from their surroundings. From the primitive holes dug in the sand along river banks used to clean muddy water, to today's ultramodern, polypropylene-based face masks used to protect the respiratory tract: humankind has come a long way in using innovation and technology to improve filtration. Filtration applications are essential to countless areas of modern life, and in particular for water treatment, air purification, and chemical processing.

Filtration is the process by which solid particles or impurities are separated from a fluid or gas through the use of a porous filter medium. The filter traps and retains unwanted particles while allowing the fluid or gas to flow through the filter. Filter media may be thin barriers (e.g., paper, cloth, screens) or thick barriers (sand, porous metals and ceramics). Nonwovens are becoming increasingly popular filter media because they can be tailored to fulfil technical specifications and stringent regulations in both liquid and air filtration.

This brochure has been created to illustrate relevant aspects of filtration, including mechanisms and methods in air and liquid filtration; important air and liquid filtration applications; and the advanced polyolefin-based solutions offered by Borealis for high-performance nonwovens created through meltblown and spunbond processes.

Air and liquid filtration mechanisms

Filtration separates or removes particles and impurities from fluids and gases. The core requirements for filtration are a filter medium; a fluid or gas with suspended solids; a difference in pressure caused by some sort of driving force; and a device that keeps the filter medium in place and allows force to be applied.

Most Penetrating Particle Size (MPPS) refers to the size of particle that can most easily pass through an air purifier or infiltration system, and which typically is 0.3 microns (μm). As a rough guide, particles of around 0.3 μm include automotive exhaust, dust and dust mites, mold spores, and pet dander. However, depending on the circumstance and type, the size of a particle may range widely. For example, a bacterium particle may range from 0.3 μm to 60 μm, and a pollen particle from 10 μm to 100 μm.

Several values are used to describe filter performance with respect to particle size measurement. For example, Minimum Efficiency Reporting Values (known as MERV) are based on a test method developed by the US industry association ASHRAE (American Society of Heating, Refrigeration, and Air Conditioning Engineers). It reports a filter's ability to capture larger particles between 0.3 μm and 10 μm. The higher the MERV value, the better the filter is at trapping certain types of particles.

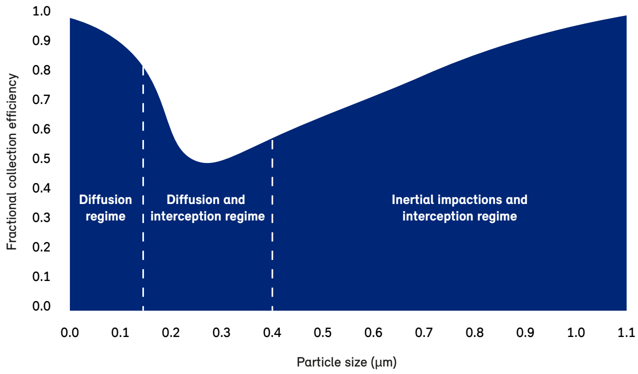
Particle description	Particle size	Typical examples
Ultrafine	<0.1 μm	- Gaseous contaminants - Printer toner exhaust - Viruses
Fine	≤0.1 - <2.5 μm	- Bacteria - Dust mites - Tobacco smoke
Coarse	≤2.5 - 10 μm (less than 10)	- Heavy dust - Fly ash

Image: HVAC filter installation © Borealis

How to improve filtration efficiency

Various filtration techniques are used to capture particles of varying sizes. The commonly-used high-efficiency air particle (HEPA) filter employs several of these mechanisms at once. The HEPA's multiple pleated layers strain and sieve particles by trapping them between layers; intercept particles when they crash into a filter fiber; cause impaction as the momentum of heavier particles causes them to collide straight-on with, then adhere to, the filter fiber; and bring about diffusion, as random collisions with surrounding molecules change the particles' trajectory, causing them to hit the fibers and get stuck. In air filtration, electrostatic attraction has proven to be a very effective mechanism. When used in combination with selected additives, a relatively new treatment, hydrocharging (in a similar way as corona charging), has been shown to improve the capture efficiency of synthetic fibers without increasing pressure drop. The diagram below depicts several of these filtration mechanisms.

Filtration efficiency curve / mechanism



Graph: Typical illustration showing the filtration mechanisms and Filter collection mechanism based on the filtration tester in Borealis Innovation Headquarters in Linz, Austria © Borealis

Filtration mechanisms

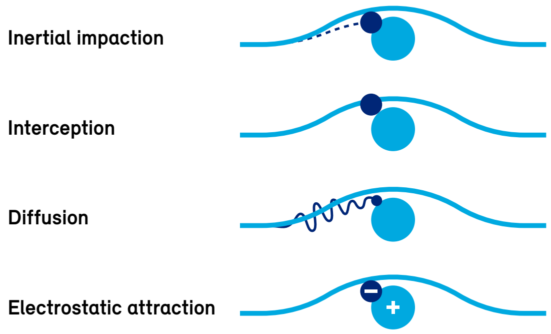


Illustration: General air filtration mechanisms © Borealis

The depth filtration method is employed in water treatment and air purification as well as in many other industries, such as food processing and pharmaceuticals. It is a most effective method due to its adaptability and its effectiveness in capturing a wide range of particle sizes, from ultrafine (<0.1 µm), to fine (≥0.1 - <2.5 µm), and coarse ≥2.5 – 10 µm (less than 10). The chief characteristic of depth filtration is that it employs multiple porous layers with depth. In porous depth filters, particles are retained not only on the surface, but throughout and within the medium itself. Depth filtration enables the capture of a higher load of particles before the onset of clogging. Nonwovens are advantageous for in-depth filtration because particles are captured not only on the surface, but within the matrix itself; the random arrangement of fibers forces particles through tortuous paths from which they cannot escape.

Using the principle of gradient filtration can also improve results. Gradient filtration entails the use of different fiber diameters in layers of filter media with progressively smaller fibers. Larger particles are trapped in the coarser upper layers, and smaller particles in the finer lower ones. In this way, a wide range of particle sizes can be trapped in one single process.

In air filtration, the quality factor (QF) refers to the important balance between pressure drop (Delta P) and filtration efficiency (eta), as shown in the below formula:

$$QF = \frac{-1n(1-\eta)}{\Delta p}$$

The higher the pressure drop, the higher the energy consumption. Thus it is imperative to design a filter that captures unwanted particles while still allowing the easiest possible pass-through for the desired material. However, efficiency and particle holding capacity are no longer the sole properties for consideration: the energy efficiency of the filter system itself has become an increasingly important factor, and exerts a growing influence on modern testing standards. Filters must achieve separation performance with the lowest possible pressure drop: the lower the pressure drop, the higher the energy efficiency of the filter.

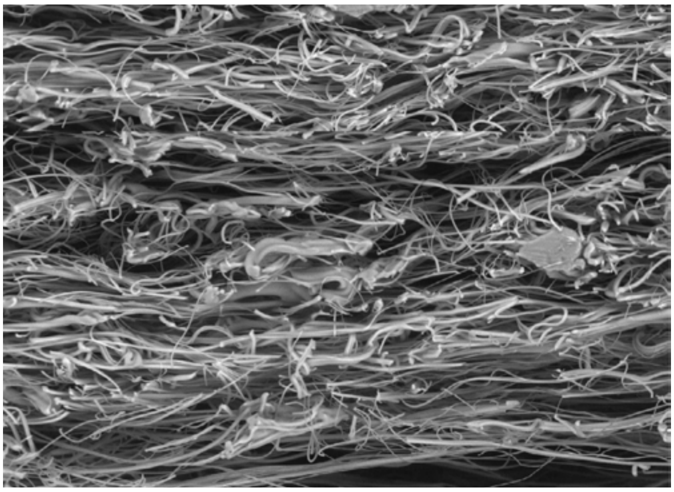


Photo: Course fibres are spunbond and the thinner fibres are meltblown © Norner AS

Nonwovens

As defined according to the ISO standard 9092 and CEN EN 29092, a nonwoven is "an engineered fibrous assembly, primarily planar, which has been given a designed level of structural integrity by physical and/or chemical means, excluding weaving, knitting or paper making." To put it another way: nonwovens are flat sheets which are not in fact woven or knitted, but rather bonded directly from separate fibers.

Nonwovens are not limited by the techniques of traditional textile manufacturing. Each step of the production process (forming, bonding, and finishing) can be customized and modified in order to engineer fabrics for specific applications. Spunbond is a process for making polymer-laid nonwovens and entails the use of air to pull fibers with a diameter of around 15 µm. In contrast, the meltblown process produces microfibers much smaller than conventional textile fibers by using very small die holes and high-velocity hot air to create even finer fibers, in the range of 1 µm.

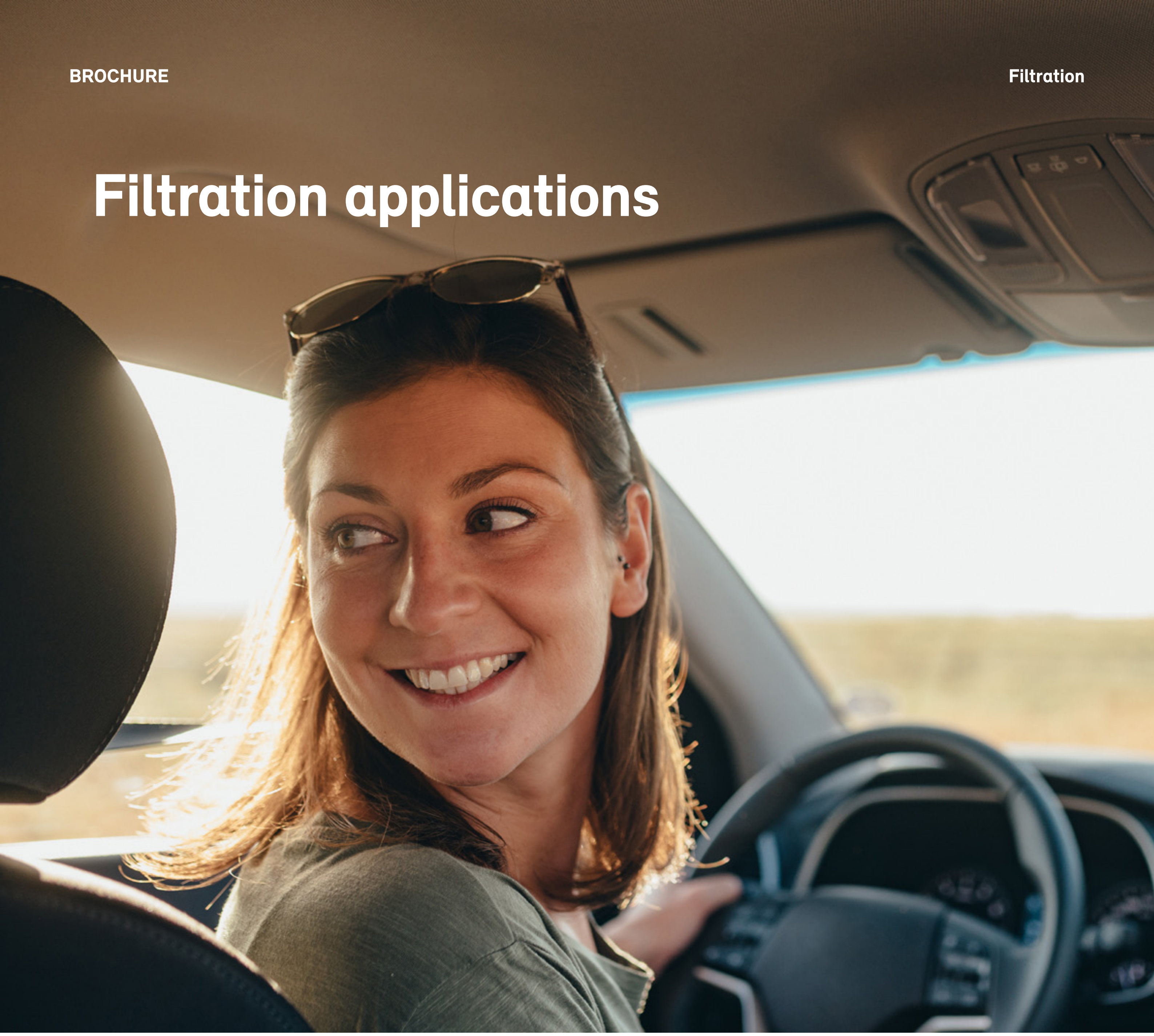
As engineered fabrics made from fibers, nonwovens are used in an ever-growing number of applications across many sectors: from agriculture and horticulture, construction and civil engineering, to healthcare and medicine, but also in apparel, electronics, packaging – and, of course, filtration. Nonwovens have in fact become viable replacements for traditional filter media such as paper, cloth, glass, and carbon, and have become the material of choice for a wide range of air, liquid, and industrial filtration applications.

Photo: Nonwoven material production at the test line in Borealis Innovation Headquarters in Linz, Austria © Borealis

The advantages of nonwovens at a glance

- The high filtration efficiency of nonwovens is due to the dense network created by the random arrangement of fibers which allows air or liquid to pass through easily, yet traps particles very effectively.
- Nonwovens can be designed to have high porosity and air permeability, allowing for efficient airflow or liquid flow during filtration. This characteristic minimizes pressure drop across the filter, reducing energy consumption and maintaining optimal system performance.
- Nonwovens are extremely versatile because they can be engineered to meet specific requirements with respect to particle capture efficiency or air permeability. In manufacturing, varied fiber types, diameters, and density levels can be selected to customize and optimize filter efficiency. They can be engineered to be lightweight and disposable (e.g., hygiene wipes, face masks); or heavyweight and durable (street underlayment).
- Nonwovens facilitate depth filtration, meaning particles are captured not just on the surface but within the fiber matrix itself. Depth filtration results in higher dirt-holding capacity and longer filter life.
- Nonwovens are especially good at particle retention: their fibers create entanglements or electrostatic forces that trap particles and prevent them from being released back into the environment.
- The easy processability of nonwoven materials means that they can be readily formed into various shapes, sizes, and configurations. Nonwovens can be produced as rolls, sheets, or three-dimensional structures, allowing for flexibility in filter design and integration into different filtration systems.
- Nonwovens can be engineered to be resistant to chemicals, moisture, and other environmental conditions. This resistance ensures the longevity and stability of filtration performance, even in demanding filtration applications.
- Nonwovens are a cost-effective solution for many filtration applications. Nonwoven manufacturing processes are efficient and can be scaled up for mass production. Moreover, nonwovens' long service life reduces the frequency of filter replacement and the associated costs.
- Nonwovens can enhance the sustainability of filtration solutions because less energy may be required in their manufacture, and they can be designed for recycling and/or easy disposal at end-of-life.

Filtration applications



Air filtration

As nations grapple with the effects of climate change and global warming, air quality has become a major public health issue. In 2023, the World Bank reported that pollution is the greatest environmental cause of disease and premature death; seven million premature deaths around the globe each year are attributed to air pollution. Improving air quality both outdoors and indoors delivers significant benefits for human health. In the US alone, the consumer market for air purifiers and filters doubled in size from 2019 to 2020, during the first year of the Covid pandemic. The combined effects of the outbreak, longer allergy seasons, and exposure to extreme climate events such as wildfires are likely to drive demand for air filtration systems in many parts of the world.

Automotive

Automotive filtration involves removing contaminants that cause damage to vehicle parts, and ensuring clean air for the vehicle's passengers.

The function of an engine air filter is to trap and remove airborne particles and contaminants found in incoming air, including dust, dirt, pollen, debris, and any other pollutants that can potentially damage the engine or affect its performance. Engine air filters must strike a balance between efficient filtration and optimal airflow maintenance for the engine.

A cabin air filter cleans the air entering the passenger compartment, thus improving and freshening it to ensure a more pleasurable driving experience. Cabin air filters that incorporate activated carbon media absorb and trap odor-causing molecules, thus removing unpleasant odors like external pollutants, exhaust fumes, and odors flowing through the vehicle ventilation system.

Photo: Air filters for cars help rid smoke, dust, pollutants, and other respiratory irritants from the cabin © Borealis

Cleanrooms

Cleanrooms are designed to provide an environment that contains an extremely low level of airborne contaminants. A commonly used filter is the HEPA filter, which can remove particles as small as 0.3 µm at an efficiency rate of 99.975% or greater. HEPA filters are designed to prevent unwanted particles from passing through the filter, which is typically made of dense fiber media, by trapping particles through straining, intercepting, impacting, and diffusing them in the filter fibers.

Consumer Air Filtration Products

Air purifiers sanitize indoor air by eliminating pollutants (such as mold) and allergens (e.g., pet hair and dander, pollen, dust) through a combination of a fan and one or more filters. The fan sucks in the air; filters then capture and neutralize pollutants and particles before recirculating clean air back into the living space. High-efficiency filters are best at trapping the smallest particles, such as pet dander. Studies have demonstrated that the use of HEPA cleaners in indoor ventilation systems can lower the exposure to airborne infectious particles (such as the Covid-inducing SARS-CoV-2), even if they cannot prevent transmission altogether.

Cooker hoods (also called range hoods) help reduce food odors and prevent smoke from spreading. Many hoods function according to the conventional extraction method, in which a grease filter traps the fats from the air drawn into the hood and releases the remaining fumes outside, through a vent. However, hoods that use the recirculation method are becoming increasingly popular. This is thanks in part to the design flexibility and lower costs made possible by ductless installation. Many leading recirculation hood systems feature an easy-to-clean metal mesh filter that removes grease. This is paired with another HEPA filter that removes fine particles by way of an integrated carbon filter. These advanced filters are far more effective in removing particles from the air. They also help enhance energy efficiency by keeping warm air within the home rather than venting it outdoors.

The filtration system is an integral component of most vacuum cleaners. The suction generated by the vacuum cleaner's motor draws in dust and air. These particles are propelled into the bag, a specially designed, porous container often made using a combination of synthetic fibers and paper. The multiple filter layers in the bag exhibit various degrees of porosity: large-pore outer layers prevent clogging, and denser inner ones provide finer filtration. The system thus traps particles while ensuring that the air released back into the environment is clean. Like most industrial vacuum cleaners, some household appliances are equipped with HEPA filters capable of removing the finest particles and allergens.

HVAC (Heating, Ventilation, and Air Conditioning)

HVAC comprises the technologies, systems, and equipment used to provide heating and cooling as well as to maintain indoor air quality in buildings. Commonly found in residential, commercial, and industrial settings, HVAC systems are crucial in creating comfortable and healthy indoor environments.

Industrial HVAC systems are designed specifically for large-scale industrial facilities such as factories, warehouses, data centers, manufacturing plants, and other industrial settings. These systems often include advanced filtration systems that are tailored to the unique requirements and challenges of industrial environments: high heat loads, specialized processes, and stringent environmental monitoring of air quality. They often incorporate high-efficiency filters to remove dust, particulate matter, chemicals, and/or hazardous substances from the air to maintain clean and safe working environments.

The current European standard for filters used in HVAC is EN 1822:2019. ASHRAE publishes relevant HVAC standards applicable to the US, such as Standard 52.2-2017 ("Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size"). The comparable European test standard is ISO 16890 ("Air filters for general ventilation").

Photo: Vacuum cleaner filters © Borealis

Liquid filtration

Liquid filtration is the process of separating solid particles or impurities from a liquid medium. The choice of filtration media depends on the specific requirements of the respective processing application. Liquid filters are central to processes like water treatment and mining, and to the medical, pharmaceutical, and food and beverage industries, among others. The type of filter selected for use varies according to the liquid, the desired performance, and the type of particle to be removed.

Food & Beverage

Liquid filtration helps maintain the integrity, quality, and safety of liquid ingredients and products in the food industry. It is an essential step in ensuring that the final food or beverage product meets the desired standards and specifications.

Pharmaceutical & Medical

Liquid filtration is used to remove unwanted particles so as to prevent blockages in medical devices, provide correct and consistent doses, and improve the safety and appearance of the liquid.

Water

Clean, potable water is in short supply in many areas of the world. Water-borne diseases such as shigella, cholera, and typhoid fever are spread through water which is contaminated with pathogenic microbes. By removing such pathogens and other biological contaminants, water filtration plays a crucial role in improving public health, hygiene, and sanitation.

Nonwovens are especially effective at removing particulates from water and other fluids. According to the nonwovens trade association EDANA, the global market for nonwoven filter media used in water filtration is rapidly growing, particularly in the Asia-Pacific region. Other key applications for nonwovens in water filtration include swimming pool filters, rain water capture, and tap water filtration.

Water filters used by end consumers are classified by their micron (μm) rating; as a unit of measurement, the micron describes the size of the filter's pores. The lower the micron rating, the finer the filtration, with ratings commonly ranging from 0.5 μm to 100 μm.

Photo: Pool water filtration © Borealis

Personal protective equipment (PPE)

In many countries, personal protective equipment (PPE) was once used primarily by frontline healthcare workers and those in construction and industry. Yet PPE became an inescapable feature of daily life for most of the world's citizens after the Covid-19 outbreak. While face masks and respirators may be the most visible types of PPE, the category also encompasses booties, eye protection, face shields, gloves, gowns, and wipes.

Face masks are designed to contain particles as the wearer breathes, coughs, or sneezes. Closely-fitting face masks provide some protection against particles spread by others, including viruses. Respirators protect the wearer by filtering the air. A closely-fitting respirator filters out particles, including the virus that causes Covid-19, while containing the particles in the same way that a face mask does.

Nonwovens are an essential component of face masks. Along with the mask's ear loops or straps, and the optional nose wire, a typical face mask consists of three nonwoven layers:

- **An outer layer lends structural integrity to the mask and repels moisture and liquids. It is often made of spunbond PP**
- **A middle filter layer filters out particles. In masks fulfilling the highest standards, this layer is often made using electric charged, PP meltblown webs. These nonwovens are able to capture tiny particles**
- **An inner layer rests against the skin and should therefore be soft and comfortable to the touch. This layer is frequently made of PP spunbonded webs.**

FFP2 and N95 are specialized, strenuously tested filtering masks made of PP fibers. They use the processes of interception, diffusion, impaction, and electrostatic deposition to filter at least 94% (FFP2) or at least 95% (N95) of airborne particles sized 0.3 µm. The efficiency of removal is influenced by filter characteristics (such as fiber diameter); aerosol characteristics (particle size, charge); and environmental conditions (such as temperature).

In Europe, EN 14683:2019+ AC:2019 governs requirements and test methods for medical face masks; EN 149:2001+ A1:2009 covers requirements, testing, and marking for filtering half-mask-type respiratory devices. In North America, the ASTM F3502-23a is one current standard specification for barrier face coverings.

Photo: Facemasks safeguarding our health © Borealis

The Borealis portfolio of meltblown and spunbond grades

Two main fiber spinning processes, meltblown and spunbond, use synthetic polymers to manufacture filtration applications.

Meltblown is a one-step, granulate-to-web process. PP granulate is fed into an extruder and melted. The melt is spun out through a die tip consisting of several hundred die holes. High-velocity hot air flows out on both sides of the die tip, transforming the polymer streams into fine filaments (typically from 1.0 to 2.0 µm). The hot air draws the filaments on to a conveyer belt, where a self-bonding web is formed.

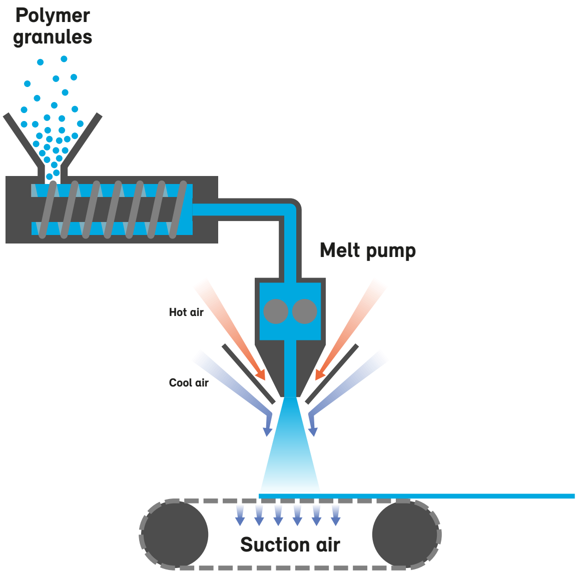


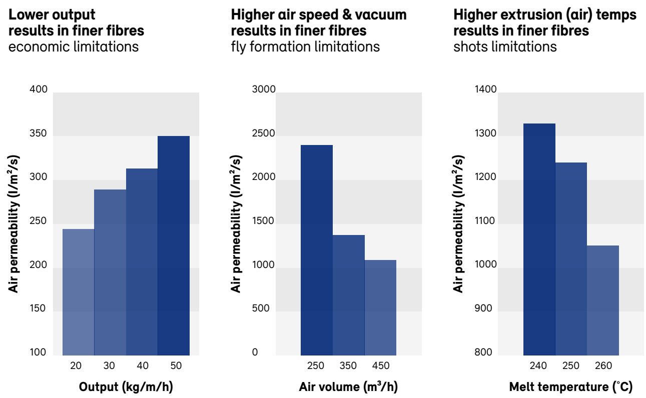
Illustration: Scheme of a typical meltblowing line

The meltblown process requires grades with a high melt flow rate (MFR) and narrow molecular weight distribution (MWD). Using high MFR grades with low elongational viscosity makes it easier to draw in the air, and reduces the necessary air speed, temperature, and volume. Because the hot air makes up the largest share of energy consumption in the meltblown process, using high MFR grades helps improve energy efficiency.

When used for filtration applications, the meltblown process can produce very fine fibers. The fine fiber diameter of meltblown creates a large filter media surface area. This improves filtration efficiency and dust holding capacity. To prevent clogging and build-up, the filter can be composed of layers. The first layer, which consists of coarse fibers, captures the large particles, while another finer layer captures the smaller particles.

The three general ways to achieve finer fibers are illustrated in the table below. The first approach is to reduce the line output of filaments leaving the die. This obtains a smaller diameter and subsequently finer fibers after stretching. However, reducing the output is less economical. The second method is to increase the velocity of the hot air and the vacuum to produce finer fibers. One limitation to this approach is that the vacuum may fail to keep the filaments on the belt, setting off fiber fly. In the third approach, increasing the melt temperature results in reduced melt elasticity, thus producing finer fibers. However, a limiting factor for this approach is shot formation, a possible result of too-high temperatures.

How to achieve finer fibres



Graph: Process parameters impacting meltblown fibre diameter © Borealis

Meltblown nonwovens are an entirely synthetic product. Borealis meltblown PP resins can be used to produce a variety of filter media and filtration products for key industries and sectors, including consumer appliances, mobility, and healthcare. Depending on temperature and air volumes applied in the process, using meltblown resins like Borealis HL708FB and HL712FB produces very fine fibers. However, to provide support and create a more open structured web, or to maintain shape and edges (such as in a pleated filter), a lower MFR meltblown resin like HL504FB may be used.

Among the range of Borealis PP homopolymer grades for filtration is Borealis HL912FB, a grade specifically developed to broaden the processing window. It enables the production of even finer fibers while also reducing energy consumption in the meltblown process. Borealis HL912FB is less sensitive to shot formation. It can be produced at temperatures of up to 20° C higher than HL712FB, and deliver significantly finer filaments. When processed at the same temperature as Borealis HL708FB, the air volume can be reduced significantly, thus resulting in significant energy savings.

Grade name	MFR 230°C/2,16 kg (g/10 min)	Molecular Weight Distribution (N M B)	Applications
HK060AE	125	N	Filtration media and absorbents. Excellent processing on multirow/Biax meltblown lines.
HL504FB	450	N	Filtration media, Oil adsorbents, flow enhancer for moulding and extrusion as carrier for master-batch and carrier applications.
HL708FB	800	N	Hygiene (SMS structures), Filtration (air, liquid), flow enhancer for moulding and extrusion as carrier for master-batch and carrier applications.
HL712FB	1200	N	Hygiene (SMS structures), Filtration (air, liquid) Ultra fine fibres for filtration media and absorbents, flow enhancer for moulding and extrusion, carrier for master-batch compounds.
HL912FB	1200	N	Wide processing window which allows production of even finer fibres, Hygiene (SMS structures), Filtration (air, liquid) Ultra fine fibres for filtration media and absorbents.Can be used for higher filtration classes.

Table: Borealis meltblown portfolio © Borealis

In many filtration applications, a support layer may be used to filter out bigger particles. The coarser fibers in these layers may be produced using staple fibers, carded webs, or using the spunbond process, one of the most common ways to make polymer-laid spunbond nonwovens. In this process, filaments are created by melting polymer and processing it through spinnerets. The filaments are then cooled, stretched, and swirled by air before being deposited on a perforated conveyor belt.

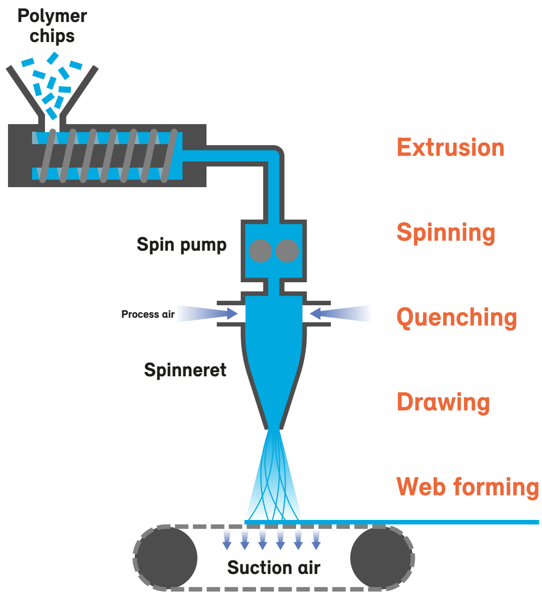


Illustration: Spunbond process

Grade name	MFR 230°C/2,16 kg (g/10 min)	Molecular Weight Distribution (N M B)	Applications
HE370FB	12	M	Staple fibre dry laid thermobonded hygiene applications.
HF420FB	19	N	Geotextiles & technical nonwovens. Excellent mechanical properties.
HG475FB	27	N	Excellent spinning performance suitable for high speed lines. Good mechanical properties.
Borstar Nextension HG485FB	27	N	Extremely broad processing window, fine fibres high web strength, downgauging, less spinning fumes.
HH450FB	37	N	Suitable for high speed lines.
RH414FB	35	N	Random PP grade suitable for spunbond process and excellent in high loft side/by/side combined with HG475FB.

Table: Borealis spunbond and staple fibres portfolio © Borealis

Our partners can benefit also from the Bornewables™ and Borcycle™ C version of all our filtration grades (for more information, please refer to page 13).

Accelerating action on circularity with the Bornewables™ and Borcycle™ C

ISCC PLUS-certified polyolefins

Meet your sustainability targets with renewable or chemically recycled feedstocks, offering the same material performance and regulatory compliance as virgin filtration grades.

The Bornewables

The Bornewables offer polyolefins with a reduced carbon footprint and are produced with renewable feedstock derived entirely from waste and residue streams.

Borcycle C

Borcycle C is the chemically recycled line of polyolefins and renews plastic back to plastic, giving polyolefin-based, post-consumer waste another life and delivering on PPWR requirements in contact sensitive applications.

Borealis innovation and expertise

Borealis is committed to supporting our customers and value chain partners in all activities related to filtration.

Laboratory capabilities

We operate a small Reicofil meltblown line at the Borealis Innovation Headquarters in Linz, Austria. It is equipped with an electret charging beam with which we carry out trials for our partners and customers as well as for our own in-house R&D.

Our Linz facilities boast new filtration test equipment, the Palas PMFT 1000, for the development of face mask webs and other filtration applications, such as for HVAC, automotive, and others.

Our experienced and knowledgeable application marketing team is here to provide support to our customers and value chain partners in all matters related to new and existing business development, circular economy solutions, and more.

Photo: Meltblown pilot line in Borealis Innovation Headquarters in Linz, Austria © Borealis

"Our customers know that they can depend 100% on the excellent quality of Borealis resins and the comprehensive support provided by the experts in our technical team. Our polymers expertise and equipment know-how expand the boundaries of the possible when it comes to high-end filtration applications. Together with our customers and partners, we work continuously to turn innovation into value creation in order to meet their filtration needs. We are making everyday life easier."

Peter Voortmans
Borealis, Global Commercial Director Consumer Products Flexibles

Borealis and Borouge consumer products solutions are making everyday life easier

date of issue: **November 2024**

Borealis is one of the world's leading providers of advanced and sustainable polyolefin solutions. In Europe, Borealis is also an innovative leader in polyolefins recycling and a major producer of base chemicals. We leverage our polymer expertise and decades of experience to offer value-adding, innovative and circular material solutions for key industries such as consumer products, energy, healthcare, infrastructure and mobility. .

With operations in over 120 countries and head offices in Vienna, Austria, Borealis employs around 6,000 people. In 2022, we generated a net profit of EUR 2.1 billion. OMV, the Austria-based international oil and gas company, owns 75% of our shares. The Abu Dhabi National Oil Company (ADNOC), based in the United Arab Emirates (UAE), owns the remaining 25%.

In re-inventing essentials for sustainable living, we build on our commitment to safety, our people, innovation and technology, and performance excellence. We are accelerating the transformation to a circular economy of polyolefins and expanding our geographical footprint to better serve our customers around the globe. Our operations are augmented by two important joint ventures: Borouge (with ADNOC, headquartered in the UAE); and Baystar™ (with TotalEnergies, based in the US).

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