



(51) International Patent Classification:

D04H 3/013 (2012.01) D04H 3/16 (2006.01)
B01D 39/18 (2006.01) D04H 1/498 (2012.01)

Published:

— with international search report (Art. 21(3))

(21) International Application Number:

PCT/AT2017/000027

(22) International Filing Date:

03 April 2017 (03.04.2017)

(25) Filing Language:

English

(26) Publication Language:

English

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(81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,
AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ,
CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO,
DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN,
HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KH, KN, KP, KR,
KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG,
MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM,
PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC,
SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR,
TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every
kind of regional protection available): ARIPO (BW, GH,
GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ,
UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ,
TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK,
EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV,
MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,
TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW,
KM, ML, MR, NE, SN, TD, TG).

(54) Title: A NONWOVEN MATERIAL DESIGNED FOR USE AS FILTER MEDIA

(57) Abstract: This invention relates to a nonwoven material which has excellent dimensional and thermal stability in a wide variety of liquids, gases and air for use as filter media, containing at least a first cellulosic nonwoven web, characterized in that the cellulosic nonwoven web is made from essentially pure cellulose formed of essentially continuous filaments which are multibonded by merged filaments, hydrogen bonding and physical intermingling of the filaments. It further relates to composite nonwoven materials, where at least one web is characterized by being essentially pure cellulose formed of essentially continuous filaments which are multibonded by merged filaments, hydrogen bonding and physical intermingling of the filaments. The individual layers may, or may not, be designed to have different pore size construction to impart specific filtration performance efficiencies as well as to using of the inventive nonwoven material as a filtration media, or product and using of the inventive nonwoven material for the manufacture of a filter media.



A nonwoven material designed for use as filter media

This invention relates to a nonwoven material suitable to be used as filter media, and, more particularly, to an essentially pure cellulose nonwoven web formed from essentially continuous filaments and multibonded by merged filaments, hydrogen bonding and the physical intermingling of filaments.. This web provides strength, dimensional stability, pore size distribution capable of removing fine particulates and impurities from both liquid and air or gases, a filament size distribution capable of both supplying structural support while still producing fine pore sizes capable of filtering small particulates, capable of holding a sufficient quantity of such particulates to be economically feasible, providing low resistance to fluids passing through the media, and capable of withstanding multiple filtration cycles without losing performance capabilities, and is biodegradable and compostable.

The term “essentially pure cellulose” shall address the fact that cellulosic moulded bodies, e.g. made according to the lyocell process, always contain a small amount of polymers other than cellulose, namely hemicellulose. This does not influence in any way the suitability for the use according to this invention.

Prior Art

The use of nonwoven webs as filter media is well known. U.S. 4,589,894 teaches the use of two separate meltblown polypropylene layers for filtration. U.S. 5,783,011 teaches the use of novel meltblown nonwovens for filter media. U.S. 4,041,203, U.S. 5,073,436, U.S. 5,244,482 and U.S. 5,709,735 disclose the use of spunbond/meltblown/spunbond or SMS composites for filtration. U.S. 5,080,702 teaches the use of two layers, an inner meltblown polypropylene and outer paper layer for vacuum cleaner bag filtration. U.S. 9,309,612 teaches the use of a spunlaid nonwoven with filament diameters between those of spunbond and meltblown nonwovens. U.S. 9,421,294 teaches the use of spunlaid, spunlace airlaid, needlepunch and thermal and carded nonwovens for facemask filtration media. U.S. 9,296,176 discloses a nonwoven composite with layers of spunlaid polyolefin on each side of an

airlaid pulp layer, for filtration media. U.S. 8,021,996 teaches the use of a spunlace nonwoven with partially split bicomponent fibres to maximize small particulate capture while minimizing pressure drop across the media. U.S. 8,668,758 discusses the use of various carded nonwovens for filtration media.

5 U.S. 9,498,932 discloses the use of multilayer meltblown synthetic polymers for filtering liquids, while U.S. 9,487,893 teaches the use of spunlaid polymers to attain needed dimensional stability.

Nonwoven substrates for use as filter media has been the subject of much

10 research, as the requirements are stringent and demanding. A nonwoven used as filter media must be able to filter small size particulates, must be able to hold a quantity of these particulates, must not have significant pressure drops in fluids passed through them, and must be able to withstand multiple cycles of filtering and cleaning. Compostability would be an advantage for

15 such filter media, to simplify disposal.

Many types of nonwovens can be used for filter media, including spunlace nonwovens, needlepunch nonwovens, airlaid nonwovens, wetlaid nonwovens and spunlaid nonwovens. All but the last type employ primarily staple or cut

20 fibres, or wood pulp. The last type consists of continuous filaments (either are not remaining as continuous or cut in the manufacturing process). Spunlaid nonwovens based on polypropylene, polyester or nylon are more expensive and not biodegradable or compostable. Spunlace, needlepunch, wetlaid and airlaid nonwovens can rely on cellulosic fibres, but they all share low strength

25 and dimensional stability in prolonged immersion in some fluids and are not as efficient at removing small size particulates.

The present invention relates to the use of specially designed nonwoven substrates produced using novel variants of the spunlaid nonwoven process,

30 comprising 100% cellulose polymers. There are known methods and products using spunlaid cellulose webs. U.S. 6,358,461, U.S. 7,067,444, U.S. 8,012,565, U.S. 8,191,214, U.S. 8,263,506 and U.S. 8,318,318 as well as WO 98/26122, WO 99/47733, WO 98/07911, US 6,197,230, WO 99/64649, WO 05/106085, EP 1 358 369, EP 2 013 390, WO 07/124521 A1 and WO

07/124522 A1 all teach methods for producing and using spunlaid cellulose webs. None of these teaches production methods for, or products, addressing the specific requirements for filtration media.

5 **Problem**

There are some common problems inherent in all current nonwovens used as filtration media. In order to be commercially useful, filter media must be capable of filtering small size particulates ("filtration efficiency"), in large quantities ("loading") for either multiple cycles (filter, clean filter, filter) or long
10 cycle times ("filter media life") without requiring excessive pressure to force the material to be filtered through the media ("pressure drop"). It must also be capable of enduring long periods of time in various materials to be filtered, as well as potentially high or low temperatures. Biodegradability and/or compostability are also desired.

15 Spunlaid nonwovens can have fine pore size and are dimensionally stable and durable for long times and multiple cycles, but are susceptible to some solvents and high temperatures. They also have high pressure drops across the media and can be expensive. Spunbonds have strength and durability
20 and low pressure drops across media made of them, but large pores which do not filter small particulates well. Meltblowns have fine pore sizes, but are weaker and have high pressure drops. Spunbond/meltblown/spunbond composites or SMS composites combine the filament diameters of coarse, outer layer spunbond with finer diameter inner layer meltblown, with the
25 spunbond contributing strength and coarse particle filtration while the meltblown contributes fine particle and liquid filtration while permitting vapor transmission.

30 Carded, spunlace and airlaid nonwovens usually do not have as fine a pore size distribution as spunlaid, are not as strong or dimensionally stable as spunlaid, nor as durable as spunlaid, but do have lower pressure drops and costs. There are few commercially used solvents which affect cellulose fibres, and these fibres are resistant to higher temperatures than common synthetic fibres or polymers.

Wetlaid nonwovens usually do not have the strength, dimensional stability or durability of spunlaid but do have lower costs.

5 The problem with current technology is that it does not meet all of these needs. The best current technology, the SMS process and products described in U.S. Pats. 5,073,436 and 4,041,203, requires multiple dies and a complicated process, adding cost, and has never been practiced with biodegradable polymers.

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A process and products depending on multiple dies to produce and comingle multiple diameter filaments, as described in U.S. Pat. 5,783,011, is again a very complicated process and is dependent on successfully comingling the multiple diameter filaments uniformly. This process also has never used
15 biodegradable polymers.

A process and products depending on varying process parameters in a process to produce a filament diameter distribution somewhere between that of meltblown and spunbond, as described in U.S. Pat. 9,309,612, produces a
20 product with properties somewhere between meltblown and spunbond nonwoven products. Additionally, no claims for the use of biodegradable polymers are made for this process, nor is filtration mentioned as an end use.

Those processes and products which do use biodegradable polymers,
25 especially those using cellulosic polymers, as described by U.S. Pat. 6,596,033 and U.S. Pat. 7,067,444, do not teach or claim the ability to provide exceptional filtration qualities.

The need for a universal filter media material is for it to have the cost, solvent
30 and temperature resistance and pressure drop profile of a staple cellulose fibre or wood pulp based nonwoven with the pore size distribution, dimensional stability, and durability of a spunlaid nonwoven.

Description

It is an object of the present invention to provide a nonwoven material which has excellent dimensional and thermal stability in a wide variety of liquids, gases and air for use as filter media, containing at least a first cellulosic
5 nonwoven web, wherein the cellulosic nonwoven web is made from essentially pure cellulose formed of essentially continuous filaments which are multibonded by merged filaments, hydrogen bonding and physical intermingling of the filaments.

The nonwoven web is produced using a spunbond or meltblown die or head
10 to form the continuous filaments, in principle known from the prior art cited above.

This material will provide strength, dimensional stability, pore size distribution capable of removing fine particulates and impurities from both liquid and air or gases, a filament size distribution capable of both supplying structural support
15 while still exhibiting fine pore sizes capable of filtering small particulates, capable of holding a sufficient quantity of such particulates to be economically feasible, providing low resistance to fluids passing through the media, and capable of withstanding multiple filtration cycles without losing performance capabilities. Further this material is biodegradable, compostable, made from a
20 sustainable manufacturing process, and is able to qualify for – among others - indirect food contact.

This material is capable of filtering small size particulates (“filtration efficiency”), in large quantities (“loading”) for either multiple cycles (filter, clean filter, filter) or long cycle times (“filter media life”) without requiring excessive
25 pressure to force the material to be filtered through the filter (“pressure drop”). It must also be capable of enduring long periods of time in various materials to be filtered, as well as potentially high or low temperatures.

Compared to nonwoven substrates based on cellulosic fibres, the present invention provides superior strength and dimensional stability, as well a

superior durability to multiple filtration cycles, and the ability to filter small particulates.

Compared to nonwoven substrates based on synthetic polymers and fibres, the present invention provides equivalent strength and dimensional stability, small particulate filtration capability, equivalent durability and superior temperature resistance and is both biodegradable and compostable.

Preferably the nonwoven material according to the invention is further bonded or treated by a hydroentanglement, needlepunch or chemical bonding process to modify the physical properties.

This invention can also exist in a multi-layer structure of the same essentially continuous filaments and multibonded by merged filaments, hydrogen bonding and/or the physical intermingling of filaments. In this multi-layer structure, each layer can consist of different pore size construction by controlling the filament diameter, the degree of merged filaments and the thickness of each layer. In said multi-layer structure it is possible to provide a gradient of decreasing pore size to maximize filtration efficiency and minimize the pressure drop across the filter media. These layers can be produced in a single process where multiple layers are formed on top of one another, or produced in a separate step where the layers are laminated together via bonding processes such as adhesive bonding, hydroentangling, needlepunching and/or chemical bonding.

In particular preferred the first cellulosic nonwoven web of the nonwoven material according to the invention is made according to a lyocell process.

Cellulosic fibres can be produced by various processes. In one embodiment a lyocell fibre is spun from cellulose dissolved in N-methyl morpholine N-oxide (NMMO) by a meltblown process, in principle known from e.g. EP 1093536 B1, EP 2013390 B1 and EP 2212456 B1. Where the term meltblown is used it will be understood that it refers to a process that is similar or analogous to the process used for the production of synthetic thermoplastic fibres (filaments are extruded under pressure through nozzles and stretched to required degree by

high velocity/high temperature extension air flowing substantially parallel to the filament direction), even though the cellulose is dissolved in solution (i.e. not a molten thermoplastic) and the spinning & air temperatures are only moderately elevated. Therefore the term "solution blown" may be even more appropriate here instead of the term "meltblown" which has already become somewhat common for these kinds of technologies. For the purposes of the present invention both terms can be used synonymously. In another embodiment the web is formed by a spun bonding process, where filaments are stretched via lower temperature air. In general, spunbonded synthetic fibres are longer than meltblown synthetic fibres which usually come in discrete shorter lengths. Fibres formed by the solution blown lyocell process can be continuous or discontinuous depending on process conditions such as extension air velocity, air pressure, air temperature, viscosity of the solution, cellulose molecular weight and distribution and combinations thereof.

In one embodiment for making a nonwoven web the fibres are contacted with a non-solvent such as water (or water/NMMO mixture) by spraying, after extrusion but before web formation. The fibres are subsequently taken up on a moving foraminous support to form a nonwoven web, washed and dried.

Freshly-extruded lyocell solution ('solvent spun', which will contain only, for example, 5-15% cellulose) behaves in a similar way to 'sticky' and deformable thermoplastic filaments. Causing the freshly-spun filaments to contact each other while still swollen with solvent and with a 'sticky' surface under even low pressure will cause merged filament bonding, where molecules from one filament mix irreversibly with molecules from a different filament. Once the solvent is removed and coagulation of filaments completed, this type of bonding is impossible.

It is another object of the present invention to provide a process for the manufacture of a nonwoven material consisting of essentially continuous cellulosic filaments by:

- a. Preparation of a cellulose-containing spinning solution
- b. Extrusion of the spinning solution through at least one spinneret containing closely-spaced meltblown jet nozzles

- c. Attenuation of the extruded spinning solution using high velocity air streams,
- d. Forming of the web onto a moving surface [e.g. a perforated belt or drum],
- e. Washing of the formed web
- 5 f. Drying of the washed web

wherein in step c. and/or d. coagulation liquor, i.e. a liquid which is able to cause coagulation of the dissolved cellulose; in a lyocell process this preferably is water or a diluted solution of NMMO in water, is applied to control the merged filament bonding. The amount of merged filament bonding is
10 directly dependent on the stage of coagulation of the filaments when the filaments come into contact. The earlier in the coagulation process that the filaments come into contact, the greater the degree of filament merging that is possible. Both placement of the coagulation liquor application and the speed at which the application liquor is applied can either increase, or decrease, the
15 rate of coagulation. Which results in control of the degree (or amount) of merged filament bonding that occurs in the material.

Preferably the merged filament bonding is further controlled by filament spinning nozzle design and arrangement and the configuration and
20 temperature of filament extension air. The degree of molecular alignment that is present as the solution exits the spinning nozzle has an impact on the coagulation rate. The more aligned the molecules are, the faster the coagulation rate, and conversely, the less aligned the molecules are, the slower the coagulation rate. The spinning nozzle design and arrangement,
25 along with the molecular weight of the cellulosic raw material used will determine the starting coagulation rate at the exit of the spinning nozzle. Additionally, the rate of cooling (temperature decrease) of the solution upon spinning nozzle exit will impact the coagulation rate as well. The slower the cooling rate, the slower the coagulation rate, and conversely, the faster the
30 cooling rate, the faster the coagulation rate. Therefore, configuration of the filament extension air can directing impact the cooling rate and therefore, impact the coagulation rate, which impacts the achievable amount of merged filament bonding that is possible.

In a preferred embodiment of the process according to the invention at least two spinnerets (also known as jets), preferably between two and ten, and further preferred between 2 and 6, each one arranged to form a layer of nonwoven web, are used to obtain a multilayer nonwoven material. By
5 applying different process conditions at the individual spinnerets it is even possible to obtain a multilayer nonwoven material wherein the individual layers have different properties. This may be useful to optimize the nonwoven material according to the invention for different applications. In one
10 embodiment this could provide a gradient of filament diameters from one side of the material to the other side by having each individual web having a standard filament diameter that is less than the web on top, it is possible to create a material suitable for use as an air filter media that will provide a gradient of pore size (particle size capture). This will provide an efficient filtration process and result in a lower pressure drop across the filter media
15 compared to a single web with similar characteristics at the same basis weight and pore size distribution.

Preferably the filaments are spun using a solution of cellulose in an aqueous amine oxide and the coagulation liquor is water, preferably with a content of amine oxide not being able to dissolve cellulose, also referred to as a lyocell
20 process; the manufacture of such a solution is in principle known, e.g. from U.S. 6,358,461, U.S. 7,067,444, U.S. 8,012,565, U.S. 8,191,214, U.S. 8,263,506 and U.S. 8,318,318; preferably the amine oxide is NMMO.

The present invention describes a cellulosic nonwoven web produced via a meltblown or spunbond-type process. The filaments produced are subjected
25 to touching and/or compaction and/or intermingling at various points in the process, particularly before and during initial web formation. Contact between filaments where a high proportion of solvent is still present and the filaments are still swollen with said solvent causes merged filament bonding to occur. The amount of solvent present as well as temperature and contact pressure
30 (for example resulting from extension air) controls the amount of this bonding.

In particular the amount of filament intermingling and hydrogen bonding can be limited by the degree of merged filament bonding. This is the result of a

decrease in filament surface area and a decrease in the degree of flexibility of the filaments. For instance, as the degree of merged filament bonding increase, the amount of overall surface area is decreased, and the ability of cellulose to form hydrogen bonds is directly dependent on the amount of hydroxyl groups present on the cellulosic surface. Additionally, filament intermingling happens as the filaments contact the forming belt. The filaments are traveling at a faster rate of speed than the forming belt. Therefore, as the filament contacts the belt, it will buckle and sway side to side, and back and forth, just above the forming belt. During this buckling and swaying, the filaments will intermingle with neighboring filaments. If the filaments touch and merge prior to the forming belt, this limits the number of neighboring filaments by which it can intermingle with. Additionally, filaments that merge prior to contacting the forming belt will not have the same degree of flexibility as a single filament and this will limit the total area over which the filament will buckle and sway.

Surprisingly, it has been found that high levels of control of filament merging can be achieved by modifying key process variables. In addition, physical intermingling of at least partially coagulated cellulose filaments can occur after initial contact with non-solvent, particularly at initial filament laydown to form the web. It arises from the potential of the essentially continuous filaments to move laterally during initial filament formation and initial laydown. Degree of physical intermingling is influenced by process conditions such as residual extension air velocity at the foraminous support (forming belt). It is completely different from the intermingling used in production of webs derived from cellulose staple fibers. For staple fibers, an additional process step such as calendaring is applied after the web has been formed. Filaments which still contain some residual solvent are weak, tender and prone to damage. Therefore, in combination with controlling degree and type of bonding at this stage, it is essential that process conditions are not of a type which could cause filament and web damage. Initial drying of the washed but never-dried nonwoven, together with optionally compacting, will cause additional hydrogen bonding between filaments to develop. Modifying temperature, compacting

pressure or moisture levels can control the degree of this hydrogen bonding. Such treatment has no effect on intermingling or the merged filament bonding.

In a preferred embodiment of the invention the nonwoven material is dried prior to subsequent bonding/treatment.

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In a preferred embodiment of the invention the percentage of each type of bonding is controlled using a process with up to two compaction steps, where one of these compaction steps is done after step d. of the inventive process where the spun filaments are still swollen with a solvent, and one of these
10 compaction steps is done before or in step e. of the inventive process where all or most of the solvent has been removed and the web has been wet with water. As previously discussed, control of the coagulation of the spun solution is a factor in controlling the degree of merged filament bonding. This preferred embodiment concerns decreasing the coagulation rate to a state where
15 additional compaction steps can be used after filament laydown to further increase the actual amount of merged filament bonding that is achievable. It might be helpful to view the maximum achievable filament bonding as the state where we have merged all filaments into an essentially film-like structure.

20 The present invention describes a process and product where merged filament bonding, physical intermingling and hydrogen bonding can be controlled independently. However, the degree of merged filament bonding can limit the degree of physical intermingling and hydrogen bonding that can occur. In addition, for the production of multi-layer web products, process
25 conditions can be adjusted to optimise these bonding mechanisms between layers. This can include modifying ease of delamination of layers, if required.

In addition to merged filament, intermingling and hydrogen bonding being independently set as described above, additional bonding/treatment steps may optionally be added. These bonding/treatment steps may occur while the
30 web is still wet with water, or dried (either fully or partially). These bonding/treatment steps may add additional bonding and/or other web property modification. These other bonding/treatment steps include

hydroentangling or spunlacing, needling or needlepunching, adhesive or chemically bonding. As will be familiar to those skilled in the art, various post-treatments to the web may also be applied to achieve specific product performance. By contrast, when post-treatments are not required, it is possible to apply finishes and other chemical treatments directly to the web of this invention during production which will not then be removed, as occurs with, for example, a post-treatment hydroentanglement step.

Varying the degree of merged filament bonding provides unique property characteristics for nonwoven cellulose webs with regards to softness, stiffness, dimensional stability and various other properties. Properties may also be modified by altering the degree of physical intermingling before and during initial web formation. It is also possible to influence hydrogen bonding, but the desired effect of this on web properties is minor. Additionally, properties can be adjusted further by including an additional bonding/treatment step such as hydroentangling, needlepunching, adhesive bonding and/or chemical bonding. Each type of bonding/treatment provides benefits to the nonwoven web. For example, hydroentangling can add some strength and soften the web as well as potentially modifying bulk density; needling is typically employed for higher basis weights and used to provide additional strength; adhesive and chemical bonding can add both strength and surface treatments, like abrasive material, tackifiers, or even surface lubricants.

The present invention allows independent control of the key web bonding features: merged filaments, intermingling at web formation, hydrogen bonding and optional additional downstream processing. Manipulation of merged filament bonding can be varied to predominantly dictate the properties of the nonwoven web.

In a preferred embodiment of the invention the nonwoven material comprises a second cellulosic nonwoven web, which is essentially formed of continuous filaments, pulp fiber or staple fiber, is formed on top of the first cellulosic nonwoven web, and subsequently both layers are hydroentangled together.

In another preferred embodiment of the invention the nonwoven material comprises multiple layers of nonwoven webs, suitable for use as filtration media, wherein at least one layer is essentially pure cellulosic material formed of essentially continuous filaments and is bonded by merged fibers, hydrogen bonding and physical intermingling of filaments and subsequently at least two of these layers are hydroentangled together. In a specific embodiment of the invention all layers within the nonwoven material are essentially pure cellulosic material formed of essentially continuous filaments and are bonded by merged fibers, hydrogen bonding and physical intermingling of filaments and subsequently all of these layers are hydroentangled together.

In a preferred embodiment of the invention the individual layers within the two- or multilayer nonwoven material are designed to have different pore size construction to impart specific filtration performance efficiencies.

Most preferably the individual layers in the nonwoven material are assembled in a sequence suitable to provide a gradient of decreasing pore size in flow direction to maximize filtration efficiency and minimize the pressure drop across the filter media.

Another object of the present invention is the use of the nonwoven material according to the invention for filtration as well as the use of this nonwoven material for the manufacture of a filter media.

Another object of the present invention is a filter media which contains a nonwoven material according to the invention.

The invention will now be illustrated by examples. These examples are not limiting the scope of the invention in any way. The invention includes also any other embodiments which are based on the same inventive concept.

Examples

All samples for testing were conditioned at 23°C $\pm$ 2°C and relative humidity 50% $\pm$ 5% for 24 hours.

Example 1

Tensile properties and stiffness of a 50 gsm sample of the product of the invention (single layer) was compared to a commercial product of same basis weight comprising 100% cellulosic staple fiber (lyocell). Tensile properties
5 were measured using standard method DIN EN 29 073 part 3/ISO 9073-3, although a clamping length of 8cm rather than 20cm was used. The product of invention had comparable tensile strength with the commercial sample but the elongation in both MD and CD was 4 times less than the commercial sample.

- 10 Stiffness was measured using a 'Handle-o-meter', using standard method WSP 90.3, with ¼ inch slot width, stainless steel surface, 1000 g beam. Sample size was to 10cm x 10cm. Overall stiffness of the product of the invention was double that of the commercial sample.
- 15 As the product of invention shows less elongation and higher stiffness compared to the commercial sample, it is more able to retain its dimensional structure while under pressure during both liquid and air/gas filtration.

Example 2

- 20 A nonwoven web formed from essentially continuous filaments and multibonded by merged filaments, hydrogen bonding and the physical intermingling of filaments. The spunlaid-like cellulose process, also referred to as solution-blown cellulose, has the capability to produce a range of filament diameters within a single web formation process.
- 25 With this capability, the product of this invention shows a range of pore sizes which enables structural support for the filter media while still exhibiting fine pore sizes capable of filtering small particulates. The media is also capable of holding a sufficient quantity of such particulates to be economically feasible, providing low resistance to fluids passing through the media, and capable of
30 withstanding multiple filtration cycles without losing performance capabilities, and is biodegradable and compostable.

Example 3

A product of the invention comprising multiple layers of the inventive nonwoven in which each layer consists of different filament diameters, and thereby exhibits different pore construction. Layer A is comprised of coarse
5 filaments and coarse filter pores for coarse particle filtration followed by Layer B of fine filaments and fine filter pores for fine particle filtration. This prevents early filter blocking and increases filter lifetime.

Claims

1. A nonwoven material which has excellent dimensional and thermal stability in a wide variety of liquids, gases and air for use as filter media, containing at least a first cellulosic nonwoven web, characterized in that the cellulosic nonwoven web is made from essentially pure cellulose formed of essentially continuous filaments which are multibonded by merged filaments, hydrogen bonding and physical intermingling of the filaments.
2. The nonwoven material of Claim 1, where the filaments show a distribution of diameters.
3. The nonwoven material of Claim 1 that is further bonded or treated by a hydroentanglement, needlepunch or chemical bonding process to modify the physical properties.
4. The nonwoven material of Claim 1 where the first cellulosic nonwoven web is made according to a lyocell process.
5. The nonwoven material of Claim 1 where a second cellulosic nonwoven web, which is essentially formed of continuous filaments, pulp fiber or staple fiber, is formed on top of the first cellulosic nonwoven web, and subsequently both layers are hydroentangled together.
6. The nonwoven material of claim 1 comprising multiple layers of nonwoven webs, suitable for use as filter media, wherein at least one layer is essentially pure cellulosic material formed of essentially continuous filaments and is bonded by merged fibers, hydrogen bonding and physical intermingling of filaments and subsequently at least two of these layers are hydroentangled together.
7. The nonwoven material of claim 4 or 5, where the individual layers are designed to have different pore size construction to impart specific filtration performance efficiencies.
8. The nonwoven material of claim 6, where the individual layers are assembled in a sequence suitable to provide a gradient of decreasing pore size in flow direction to maximize filtration efficiency and minimize the pressure drop across the filter media.
9. Use of the nonwoven material of claim 1 for filtration.

10. Use of the nonwoven material of claim 1 for the manufacture of a filter media.
11. Filter media characterized in that it contains a nonwoven material according to claim 1.

INTERNATIONAL SEARCH REPORT

International application No
PCT/AT2017/000027

A. CLASSIFICATION OF SUBJECT MATTER INV. D04H3/013 B01D39/18 D04H3/16 D04H1/498 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) D04H B01D		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	EP 2 212 456 B1 (CHEMIEFASER LENZING AG [AT]) 22 July 2015 (2015-07-22) cited in the application paragraphs [0006], [0071]; claim 1 -----	1-4,7-11
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* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 23 November 2017		Date of mailing of the international search report 21/12/2017
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Elsässer, Ralf

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