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(54) **FILTRATION MEDIA FOR FILTERING PARTICULATE MATERIAL FROM GAS STREAMS**

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(57) **ABSTRACT**

A filtration medium is disclosed for use in air filters used in heating, ventilating and air conditioning systems. The medium contains at least one nanofiber layer of fibers having diameters less than 1 μm and at least one carrier layer, each nanofiber layer having a basis weight of at least about 2.5 g/m^2, and up to about 25 g/m^2. The medium has sufficient stiffness to be formed into a pleated configuration.

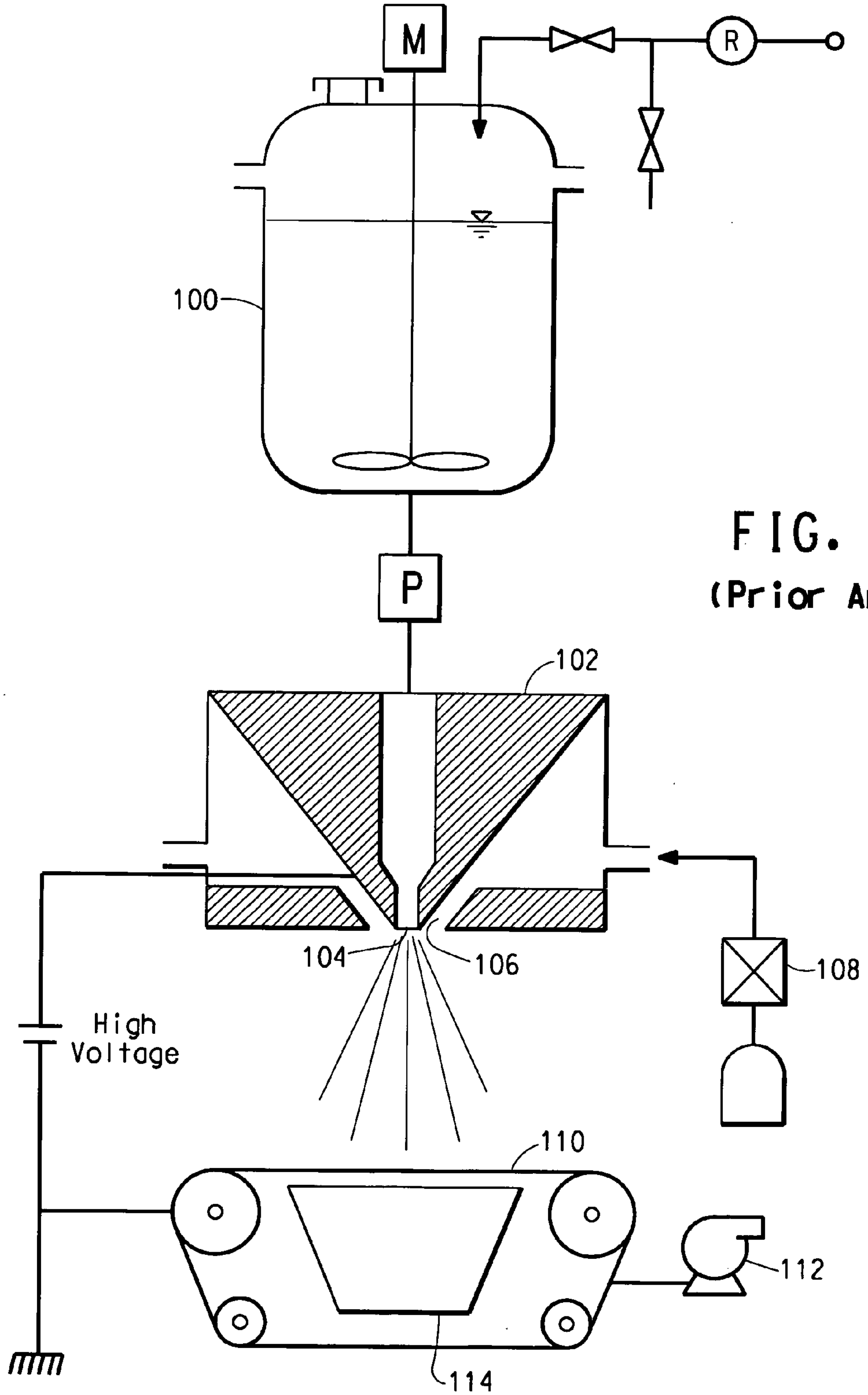

FIG. 1
(Prior Art)

FILTRATION MEDIA FOR FILTERING PARTICULATE MATERIAL FROM GAS STREAMS

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to air filtration media, for filtering particulate material from gas streams.

[0003] 2. Description of the Related Art

[0004] Filter media typically utilized for HVAC air filters that perform at efficiencies less than 99.97% at a 0.3 micron challenge are either glass, cellulose or polymer based. Filters made with media in this performance range are typically referred to as "ASHRAE filters" since the American Society of Heating, Refrigerating and Air-Conditioning Engineers writes standards for the performance of filter media in such applications. Polymer based filter media are typically spunbond or meltblown nonwovens that are often electrostatically enhanced to provide higher filtration efficiency at lower pressure drop when compared to glass or cellulose media manufactured by a wet laid paper-making process.

[0005] Electrostatically enhanced air filter media and media manufactured by the wet laid process, more specifically with the use of glass fibers, currently have limitations. Electrostatically treated meltblown filter media, as described in U.S. Pat. Nos. 4,874,659 and 4,178,157, perform well initially, but quickly lose filtration efficiency in use due to dust loading as the media begin to capture particles and the electrostatic charge thus becomes insulated. In addition, as the effective capture of particulates is based on the electrical charge, the performance of such filters is greatly influenced by air humidity, causing charge dissipation.

[0006] Filtration media utilizing microglass fibers and blends containing microglass fibers typically contain small diameter glass fibers arranged in either a woven or nonwoven structure, having substantial resistance to chemical attack and relatively small porosity. Such glass fiber media are disclosed in the following U.S. patents: Smith et al., U.S. Pat. No. 2,797,163; Waggoner, U.S. Pat. No. 3,228,825; Raczek, U.S. Pat. No. 3,240,663; Young et al., U.S. Pat. No. 3,249,491; Bodendorf et al., U.S. Pat. No. 3,253,978; Adams, U.S. Pat. No. 3,375,155; and Pews et al., U.S. Pat. No. 3,882,135. Microglass fibers and blends containing microglass fibers are typically relatively brittle and can break when pleated, and produce undesirable yield losses. Broken microglass fibers can also be released into the air by filters containing microglass fibers, creating a potential health hazard if the microglass were to be inhaled.

[0007] It would be desirable to provide a means for achieving ASHRAE level air filtration while avoiding the above-listed limitations of known filtration media.

SUMMARY OF THE INVENTION

[0008] In a first embodiment, the present invention is directed to a filtration medium comprising at least one nanofiber layer of continuous polymeric fibers having diameters less than about 1000 nanometers, each nanofiber layer having a basis weight of at least about 2.5 g/m^2, and at least one scrim layer, wherein the medium has a filtration efficiency of at least about 20% when challenged with particles having an average diameter of 0.3 μm in air flowing at a face velocity of 5.33 cm/sec, and a Handle-o-meter stiffness of at least about 45 g.

[0009] A second embodiment of the present invention is directed to a process for filtering particulate matter from an air stream comprising passing an air stream containing particulate matter through a filtration medium comprising at least one nanofiber layer of continuous polymeric fibers and at least one scrim layer, wherein the continuous polymeric fibers of the nanofiber layer have diameters less than about 1000 nanometers and wherein each nanofiber layer has a basis weight of at least about 2.5 g/m^2 and a thickness of less than about 100 μm, and wherein the filtration medium has a Handle-o-meter stiffness of at least about 45 g, and filtering up to about 99.97% of particles having an average diameter of 0.3 μm in an air stream moving at a face velocity of 5.33 cm/sec.

[0010] Another embodiment of the present invention is directed to a process of forming a filtration medium comprising providing at least one scrim layer having a Handle-o-meter stiffness of at least about 10 g on a moving collection belt, and depositing nanofibers on the scrim layer to form a single nanofiber layer having a basis weight of at least about 2.5 g/m^2 to form a filtration medium having a Handle-o-meter stiffness of at least about 10 g and a pressure drop of less than about 30 mm H_2O.

DEFINITIONS

[0011] The term "nanofibers" refers to fibers having diameters of less than 1,000 nanometers.

[0012] The term "filter media" or "media" refers to a material or collection of materials through which a particulate-carrying fluid passes, with a concomitant and at least temporary deposition of the particulate material in or on the media.

[0013] The term "ASHRAE filter" refers to any filter suitable for use in heating, ventilation and air conditioning systems for filtering particles from air.

[0014] The term "SN structure" refers to a multilayer nonwoven material containing a spunbond (S) layer and a nanofiber (N) layer.

[0015] The term "SNS structure" refers to a multilayer nonwoven material containing a nanofiber layer sandwiched between two spunbond layers.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] **FIG. 1** is an illustration of a prior art electroblowing apparatus for forming nanofibers suitable for use in the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0017] The invention relates to a filter medium comprising at least one nanofiber layer and at least one scrim layer. The nanofiber layer comprises a collection of substantially continuous organic polymeric nanofibers in a filtration medium layer, the nanofibers having diameters less than about 1 μm or 1000 nm. Such filter media can be used in filtration applications for removing particulate material from a fluid stream, in particular, particulate material from a gaseous stream such as air.

[0018] Filtration media suitable for use in air filtration applications, including ASHRAE filtration and vehicle cabin air filtration, can be made by layering one or more nanofiber layer(s) with a scrim layer to form an SN_x structure, or by sandwiching one or more nanofiber layers between two scrim layers to form a SN_xS structure, where x is at least one. Each nanofiber layer has a basis weight of at least about 2.5 g/m^2, and the total basis weight of the nanofiber layers is about 25 g/m^2. Additionally, the filter medium can contain other layers such as one or more meltblown (M) layers.

[0019] In the medium of the invention, the nanofiber layer has a thickness of less than about 100 μm; advantageously the thickness of the nanofiber layer is greater than 5 μm and less than 100 μm. The thickness of the nanofiber layer can vary depending on the density of the nanofiber polymer. The thickness of the nanofiber layer can be reduced without substantial reduction in efficiency or other filter properties if the solids volume fraction of the nanofiber layer is increased, such as by calendering or by collecting the nanofiber layer under high vacuum. Increasing the solidity, at constant layer thickness, reduces pore size and increases particulate storage.

[0020] The nanofiber layer in the present invention may be made in accordance with the barrier webs disclosed in U.S. Published Patent Application No. 2004/0116028 A1, which is incorporated herein by reference.

[0021] The nanofiber layer is made up of substantially continuous polymeric fibers having diameters less than 1000 nm, advantageously between about 100 nm and about 700 nm, or even more advantageously between about 300 nm and about 650 nm. The continuous polymeric fibers of the nanofiber layer can be formed by any process capable of making continuous fibers in this diameter range, including electrostatic spinning or electroblowing. A process for forming nanofibers via electroblowing is disclosed in PCT Patent Publication Number WO 03/080905A (corresponding to U.S. Ser. No. 10/477,882, filed Nov. 20, 2002), which is incorporated herein by reference. WO 03/080905A discloses an apparatus and method for producing a nanofiber web, the apparatus essentially as shown in **FIG. 1**. The method comprises feeding a stream of polymeric solution comprising a polymer and a solvent from a storage tank **100** to a series of spinning nozzles **104** within a spinneret **102** to which a high voltage is applied through which the polymeric solution is discharged. Meanwhile, compressed air that is optionally heated in air heater **108** is issued from air nozzles **106** disposed in the sides or the periphery of spinning nozzle **104**. The air is directed generally downward as a blowing gas stream which envelopes and forwards the newly issued polymeric solution and aids in the formation of the fibrous web, which is collected on a grounded porous collection belt **110** above a vacuum chamber **114**, which has vacuum applied from the inlet of air blower **112**.

[0022] The filter medium of the invention may be made by adhesively laminating the nanofiber layer to the carrier layer (also referred to herein as a "scrim"), or by forming the nanofiber layer directly on the carrier or scrim layer by placing the scrim layer on the collection belt **110** in the above described process to form an SN structure, in which case the nanofiber layer is adhered to the scrim layer by mechanical entanglement. The medium of the invention can be made by forming a nanofiber layer in a single pass or by building up the nanofiber layer to the desired thickness or basis weight using multiple passes, e.g., in an electroblowing process. The electroblowing process allows a nanofiber layer of suitable basis weight for use in an air filter medium to be formed in a single pass because a higher throughput is possible than previously known in the production of nanofibers. The nanofiber layer may be formed with a collection belt speed of at least 5 m/minute, and advantageously at least 10 m/minute. The polymer solution throughput in the electroblowing process for forming nanofibers is at least about 1 cm^3/min/hole of the spinneret, and advantageously at least about 2 cm^3/min/hole. Therefore, by configuring the spinneret to have a series of spinning nozzles or holes along the length of the spinneret, and delivering the polymer solution through each nozzle or hole at such high rates of flow, a higher basis weight nanofiber layer than known to date can be formed on a scrim layer in a single pass. Depending on the polymer solution flow rate and the collection belt speed, single nanofiber layers having basis weights of between about 2.5 g/m^2 and even up to 25 g/m^2 can be formed in a single pass. In conventional processes for forming nanofiber-containing filtration media, forming a nanofiber layer of suitable basis weight on a scrim requires repeated passes of the scrim through the nanofiber formation process to build up to a basis weight of even 1 g/m^2. By forming the nanofiber layer in one pass according to the present invention, less handling is required, reducing the opportunity for defects to be introduced in the final filter medium. The higher polymer solution throughput of the electroblowing process provides a more economical process than previously known in the production of nanofibers. Of course, those skilled in the art will recognize that under certain circumstances it can be advantageous to adjust the spinning conditions to deposit multiple nanofiber layers of at least about 2.5 g/m^2 in multiple passes in order to build-up the total nanofiber layer basis weight to as much as about 25 g/m^2. Variations in the spinning conditions to modify the nanofiber laydown rate, and therefore the basis weight of a single nanofiber layer, can be made in the collection belt speed, polymer solution flow rate and even by varying the concentration of the polymer in the solution.

[0023] The layers of the filter medium are made from organic polymer materials. Advantageously, the scrim layers are spunbond nonwoven layers, but the scrim layers can be carded webs of nonwoven fibers and the like. The scrim layers require sufficient stiffness to hold pleats and dead folds. The stiffness of a single scrim layer is advantageously at least 10 g, as measured by a Handle-o-meter instrument, described below. Particularly high stiffness can be achieved by using an acrylic bonded carded or wet laid scrim comprising coarse staple fibers. Spunbond nonwovens may also be used. The filtration medium of the invention has a total Handle-o-meter stiffness of at least 45 g. Advantageously, the filtration medium has a structure of SNS in which at least two scrim layers contribute to the stiffness.

[0024] The medium of the invention can be fabricated into any desired filter format such as cartridges, flat disks, canisters, panels, bags and pouches. Within such structures, the media can be substantially pleated, rolled or otherwise positioned on support structures. The filtration medium of the invention can be used in virtually any conventional structure including flat panel filters, oval filters, cartridge filters, spiral wound filter structures and can be used in pleated, Z-filter, V-bank, or other geometric configurations involving the formation of the medium to useful shapes or profiles. Advantageous geometries include pleated and cylindrical patterns. Such cylindrical patterns are generally preferred because they are relatively straightforward to manufacture, use conventional filter manufacturing techniques, and are relatively easy to service. Pleating of media increases the media surface area within a given volume. Generally, major parameters with respect to such media positioning are: pleat depth; pleat density (typically measured as a number of pleats per inch along the inner diameter of the pleated media cylinder); and cylindrical length or pleat length. In general, a principal factor with respect to selecting filter medium pleat depth, pleat length, and pleat density, especially for barrier arrangements, is the total surface area required for any given application or situation. Such principles would apply, generally, to the medium of the invention and preferably to similar barrier-type arrangements.

[0025] The filter medium of the invention can be used for the removal of a variety of particulate matter from fluid streams. The particulate matter can include both organic and inorganic contaminants. Organic contaminants can include particulate natural products, organic compounds, polymer particulate, food residue and other materials. Inorganic residue can include dust, metal particulate, ash, smoke, mist and other materials.

[0026] The initial pressure drop (also referred to herein as "pressure drop" or "pressure differential") of the filter medium is advantageously less than about 30 mm H_2O, more advantageously less than about 24 mm H_2O. The pressure drop across a filter increases over time during use, as particulates plug the filter. Assuming other variables to be held constant, the higher the pressure drop across a filter, the shorter the filter life. A filter typically is determined to be in need of replacement when a selected limiting pressure drop across the filter is met. The limiting pressure drop varies depending on the application. Since this buildup of pressure is a result of dust (or particulate) load, for systems of equal efficiency, a longer life is typically directly associated with higher load capacity. Efficiency is the propensity of the medium to trap, rather than to pass, particulates. In general the more efficient filter media are at removing particulates from a gas flow stream, the more rapidly the filter media will approach the "lifetime" pressure differential, assuming other variables to be held constant. The filter medium of the invention has an efficiency of at least about 20%, meaning that the medium is capable of filtering out at least about 20% of particles having a diameter of 0.3 μm in air flowing at a face velocity of 5.33 cm/sec. For use in ASHRAE filters, advantageously, the medium of the invention is capable of filtering out at least about 30% and up to about 99.97% of 0.3 μm particles in air flowing at a face velocity of 5.33 cm/sec.

[0027] The higher the air permeability of the filter medium, the lower the pressure drop, therefore the longer the filter life, assuming other variables are held constant. Advantageously, the Frazier air permeability of the filter medium of the invention is at least about 0.91 $m^3/min/m^2$, and typically up to about 48 $m^3/min/m^2$.

[0028] The filter medium of the present invention is advantageously substantially electrically neutral and therefore is much less affected by air humidity as compared with the filters disclosed in U.S. Pat. Nos. 4,874,659 and 4,178,157, described above, which owe their performances to the electrical charges associated therewith. By "substantially electrically neutral" is meant that the medium does not carry a detectable electrical charge.

Test Methods

[0029] Filtration Efficiency was determined by a Fractional Efficiency Filter Tester Model 3160 commercially available from TSI Incorporated (St. Paul, Minn.). The desired particle sizes of the challenge aerosol particles were entered into the software of the tester, and the desired filter flow rate was set. A volumetric airflow rate of 32.4 liters/min and a face velocity of 5.33 cm/sec were used. The test continued automatically until the filter was challenged with every selected particle size. A report was then printed containing filter efficiency data for each particle size with pressure drop.

[0030] Pressure Drop was reported by the Fractional Efficiency Filter Tester Model 3160 commercially available from TSI Incorporated (St. Paul, Minn.). The testing conditions are described under the Filtration Efficiency test method. Pressure drop is reported in mm of water column, also referred to herein as mm H_2O.

[0031] Basis weight was determined by ASTM D-3776, which is hereby incorporated by reference and reported in g/m^2.

[0032] Thickness was determined by ASTM D177-64, which is hereby incorporated by reference, and is reported in micrometers.

[0033] Fiber Diameter was determined as follows. Ten scanning electron microscope (SEM) images at 5,000× magnification were taken of each nanofiber layer sample. The diameter of eleven (11) clearly distinguishable nanofibers were measured from the photographs and recorded. Defects were not included (i.e., lumps of nanofibers, polymer drops, intersections of nanofibers). The average fiber diameter for each sample was calculated.

[0034] Stiffness was measured using a "Handle-o-meter" instrument manufactured by Thwing Albert Instrument Co. (Philadelphia, Pa.). The Handle-o-meter measures in grams the resistance that a blade encounters when forcing a specimen of material into a slot of parallel edges. This is an indication of the stiffness of the material, which has an inverse relationship with the flexibility of the material. The stiffness is measured in both the longitudinal direction (machine direction) of the material and the transverse direction (cross-machine direction).

[0035] Frazier Permeability is a measure of air permeability of porous materials and is reported in units of $ft^3/min/ft^2$. It measures the volume of air flow through a material at a differential pressure of 0.5 inches (12.7 mm) water. An orifice is mounted in a vacuum system to restrict flow of air through sample to a measurable amount. The size of the orifice depends on the porosity of the material. Frazier permeability is measured in units of $ft^3/min/ft^2$ using a Sherman W. Frazier Co. dual manometer with calibrated orifice, and converted to units of $m^3/min/m^2$.

EXAMPLES

Example 1

[0036] Nanofiber layers were made by electroblowing a solution of nylon 6,6 polymer having a density of 1.14 g/cc (available from E. I. du Pont de Nemours and Company, Wilmington, Del.) at 24 weight percent in formic acid at 99% purity (available from Kemira Oyj, Helsinki, Finland). The polymer and solvent were fed into a solution mix tank, the solution transferred into a reservoir and metered through a gear pump to an electroblowing spin pack having spinning nozzles, as described in PCT Patent Publication No. WO 03/080905. The spin pack was 0.75 meter wide and had 76 spinning nozzles. The pack was at room temperature with the pressure of the solution in the spinning nozzles at 10 bar. The spinneret was electrically insulated and applied with a voltage of 75 kV. Compressed air at a temperature of 44° C. was injected through air nozzles into the spin pack at a rate of 7.5 m^3/minute and a pressure of 660 mm H_2O. The solution exited the spinning nozzles into air at atmospheric pressure, a relative humidity of 65-70% and a temperature of 29° C. The polymer solution throughput of the nanofiber-forming process was about 2 cm^3/min/hole. The fibers formed were laid down 310 mm below the exit of the pack onto a porous scrim on top of a porous belt moving at 5-12 m/minute. A vacuum chamber pulling a vacuum of 100-170 mm H_2O beneath the belt assisted in the laydown of the fibers. A 40 g/m^2 basis weight spunbond nonwoven material obtained from Kolon Industries (S. Korea) was used as the scrim. The scrim had a stiffness of 35 g in the longitudinal direction and 55 g in the transverse direction.

[0037] The SN structure produced was challenged at various particle sizes for filtration efficiency using a TSI tester 3160, and the results are given in Table 1. Efficiencies reported in the data below are for 0.3 micrometer particle challenge only.

Example 2

[0038] An SN structure was made as described in Example 1, but at a higher basis weight of the nanofiber layer. The resulting structure was challenged at various particle sizes for filtration efficiency, and the results are given in Table 1.

TABLE 1

Ex. No.	Nanofiber diameter (nm)*	Nanofiber basis weight (g/m^2)	Efficiency (%)	Pressure Drop (mm H_2O)	Frazier air permeability (m^3/m^2/min)
1	341/387	3	69.9	3.7	37
2	374/362	5	85	6.4	22

*first measurement/second measurement

Example 3

[0039] A filtration medium having an SNS structure was formed by hand consisting a nanofiber layer having a basis weight of about 3 g/m^2 sandwiched between two spunbond layers each having a basis weight of about 21 g/m^2 made from bicomponent sheath-core fibers having a sheath of polyethylene (PE) and a core of poly(ethylene terephthalate) (PET). The average diameter of the nanofibers was about 651 nm. The nanofibers were nylon. The Frazier air permeability, the pressure drop and the efficiency of the filtration medium are listed in Table 2.

Examples 4-10

[0040] Filtration media were formed as in Example 3, with the exception that the media of Examples 4-10 had various numbers of nanofiber (N) layers and meltblown (M) layers sandwiched between the two spunbond (S) layers. The meltblown layers were made from side-by-side PET-PE bicomponent fibers, each meltblown layer having a basis weight of about 17 g/m^2. The structure of each medium, basis weight of the nanofiber layer, basis weight of the filtration medium, Frazier air permeability, pressure drop and efficiency of the filtration medium are listed in Table 2.

Examples 11-15

[0041] Filtration media were formed by electroblowing layers of nylon 6 nanofibers onto a spunbond nonwoven support. The average diameter of the nanofibers was between about 300 and 400 nm. The number of passes to form the nanofiber layer, the nanofiber layer basis weight, the media Frazier air permeability, pressure drop and filtration efficiency are listed in Table 2.

Examples 16-17

[0042] Filtration media were formed by electroblowing layers of nylon 6,6 nanofibers onto a scrim. The media of Examples 16-17 had SN structures including multiple passes of the scrim layer through the electroblowing process. The scrim was a bilayer structure containing a layer of carded nylon and a layer of carded polyester which was subsequently thermally bonded, obtained from HDK Industries, Inc., having a basis weight of about 62 g/m^2. The average diameter of the nanofibers was between about 300 and 400 nm. The number of passes to form the nanofiber layer, the nanofiber layer basis weight, and the filtration media basis weight, Frazier air permeability, pressure drop and filtration efficiency are listed in Table 2.

Example 18

[0043] A filtration medium was formed by electroblowing a single layer of nylon 6,6 nanofibers onto a moving collection belt in an electroblowing process at low vacuum pinning pressure, resulting in a lofty nanofiber layer. The medium had a nanofiber layer with a basis weight of about 20 g/m^2, formed in a single pass through the electroblowing process. The average diameter of the nanofibers was between about 300 and 400 nm. The Frazier air permeability, pressure drop and filtration efficiency of the filtration medium are listed in Table 2.

TABLE 2

Ex. No.	Medium Structure	Nanofiber basis weight (g/m^2)	Medium basis weight (g/m^2)	Frazier air permeability (m^3/m^2/min)	Pressure Drop (mm H_2O)	Efficiency (%)
3	SNS	3.05	45.7	10.8	3.94	62.76
4	SMNNS	6.1	65.7	4.58	8.17	89.07
5	SMNNNS	9.2	68.8	3.41	11.1	94.03
6	SMNNNNS	12.2	71.8	2.87	14.9	97.53

TABLE 2-continued

Ex. No.	Medium Structure	Nanofiber basis weight (g/m^2)	Medium basis weight (g/m^2)	Frazier air perme-ability (m^3/m^2/min)	Pressure Drop (mm H_2O)	Effi-ciency (%)
7	SMMNNS	6.1	82.7	3.57	11.6	92.48
8	SMMNNNS	9.2	85.7	2.86	15.0	97.22
9	SMMNNNNS	12.2	88.8	2.51	17.7	98.14
10	SMMNNNNS-SMMNNNNS	24.4	178	1.21	35.7	99.93
11	SN (1 pass)	5		14.6	3.30	64.50
12	SNN (2 pass)	10		7.31	6.82	87.14
13	SNNN (3 pass)	15		4.57	10.2	91.94
14	SNNNN (4 pass)	20		3.35	14.0	96.00
15	SNNNNN (5 pass)	25		3.35	16.2	96.99
16	SNNNN	17.0	79.4	2.74	16.2	99.13
17	SN	3.63	66.0	4.57	10.6	95.50
18	N (1 pass)	20	n/a	3.57	10.2	96.40

Comparative Examples 19-26

[0044] Filtration media having an SNS structure were formed by hand of nylon nanofiber layers having between about 0.3 and 0.5 g/m^2 basis weight sandwiched between two scrim layers, each scrim layer having a basis weight of about 17 g/m^2. In Comparative Examples 19-20, the scrim layers were spunbond PET on both sides. In Comparative Examples 21-22, the scrim layer was a spunbond PET on one side, and a spunbond nylon (obtained from Cerex Advanced Fabrics) on the other. In Comparative Examples 23-24, the scrim layer was a spunbond PET on one side, and a bilayer structure containing a layer of carded nylon and a layer of carded polyester which was subsequently thermally bonded (obtained from HDK Industries, Inc.) on the other. In Comparative Examples 25-26, the scrim layers were bilayer structures containing a layer of carded nylon and a layer of carded polyester which was subsequently thermally bonded (obtained from HDK Industries, Inc.) on both sides. The nanofiber layer basis weight, average diameter of the nanofibers, the media Frazier air permeability, pressure drop and filtration efficency are listed in Table 3.

TABLE 3

Comp. Ex. No.	Nanofiber basis weight (g/m^2)	Nano-fiber diam-eter (nm)	Medium Basis Weight (g/m^2)	Frazier air permeability (m^3/m^2/min)	Pressure Drop (mm H_2O)	Effi-ciency (%)
19	0.3	917	17.66	199	1.58	15.05
20	0.5		20.16	90.8	2.30	28.35
21	0.3	947	16.5	173	1.58	14.20
22	0.5	956	16.5	77.1	2.70	23.28
23	0.3	852	19.5	178	1.57	8.61
24	0.5	930	19.0	86.2	2.33	18.41
25	0.4	1275	36.0	109	1.38	10.63
26	0.3			206	1.25	8.60

What is claimed is:

1. A filtration medium comprising at least one nanofiber layer of continuous polymeric fibers having diameters less than about 1000 nanometers, each nanofiber layer having a basis weight of at least about 2.5 g/m^2, and at least one scrim layer, wherein the medium has a filtration efficiency of at least about 20% when challenged with particles having an average diameter of 0.3 μm in air flowing at a face velocity of 5.33 cm/sec, and a Handle-o-meter stiffness of at least about 45 g.

2. The filtration medium of claim 1, wherein the total nanofiber layer basis weight is about 25 g/m^2.

3. The filtration medium of claim 1, wherein the nanofiber layer has a thickness of less than 100 μm.

4. The filtration medium of claim 1, wherein the wherein the continuous polymeric fibers of the nanofiber layer have diameters between about 100 nanometers and about 700 nanometers.

5. The filtration medium of claim 1, wherein the wherein the continuous polymeric fibers of the nanofiber layer have diameters between about 300 nanometers and about 650 nanometers.

6. The filtration medium of claim 1, wherein the medium has a filtration efficiency of at least about 30% and up to about 99.97% when challenged with particles having an average diameter of 0.3 μm in air flowing at a face velocity of 5.33 cm/sec.

7. The filtration medium of claim 1, further comprising a second scrim layer wherein the nanofiber layer is sandwiched between the two scrim layers.

8. The filtration medium of claim 1, wherein the medium is substantially electrically neutral.

9. The filtration medium of claim 1, wherein the scrim layer is a spunbond nonwoven web or carded nonwoven web.

10. The filtration medium of claim 1, which has an initial pressure drop less than about 30 mm H_2O.

11. The filtration medium of claim 1, which has an initial pressure drop less than about 24 mm H_2O.

12. The filtration medium of claim 1, which has a Frazier air permeability of at least about 0.91 $m^3/min/m^2$.

13. The filtration medium of claim 1, which has a Frazier air permeability of between about 0.91 $m^3/min/m^2$ and about 48 $m^3/min/m^2$.

14. The filtration medium of claim 1, wherein the filtration medium is pleated.

15. A process for filtering particulate matter from an air stream comprising passing an air stream containing particulate matter through a filtration medium comprising at least one nanofiber layer of continuous polymeric fibers and at least one scrim layer, wherein the continuous polymeric fibers of the nanofiber layer have diameters less than about 1000 nanometers and wherein each nanofiber layer has a basis weight of at least about 2.5 g/m^2 and a thickness of less than about 100 μm, and wherein the filtration medium has a Handle-o-meter stiffness of at least about 45 g, and filtering up to about 99.97% of particles having an average diameter of 0.3 μm in an air stream moving at a face velocity of 5.33 cm/sec.

16. The process of claim 15, wherein at least 20% of particles 0.3 μm and larger are filtered.

17. The process of claim 15, wherein the initial pressure drop of the filtration medium is less than about 30 mm H_2O.

18. The process of claim 15, wherein the total basis weight of the nanofiber layer is about 25 g/m^2.

19. A process of forming a filtration medium comprising

providing at least one scrim layer having a Handle-o-meter stiffness of at least about 10 g on a moving collection belt, and

depositing nanofibers on the scrim layer to form a single nanofiber layer having a basis weight of at least about 2.5 g/m^2 to form a filtration medium having a Handle-o-meter stiffness of at least about 45 g and a pressure drop of less than about 30 mm H_2O.

20. The process of claim 19, wherein the total nanofiber layer basis weight is about 25 g/m^2.

21. The process of claim 20, wherein the nanofiber layer is formed in a single pass of the scrim layer on the moving collection belt.

22. The process of claim 19, wherein the nanofibers are formed by electroblowing a polymer solution from a series of spinneret holes at a rate of at least about 1 cm^3/min/hole and the collection belt moves at a rate of at least 5 m/minute.

23. The process of claim 22, wherein the polymer solution is electroblown from a series of spinneret holes at a rate of at least 2 cm^3/min/hole.

24. The process of claim 19, further comprising pleating the filtration medium.

25. The process of claim 19, further comprising adhering at least a second scrim layer onto said nanofiber layer.

26. The process of claim 19, wherein said scrim layer has a Handle-o-meter stiffness of at least about 45 g.

27. The process of claim 25, wherein said scrim layers have a combined Handle-o-meter stiffness of at least about 45 g.

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