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(54) SPLITTABLE CHARGEABLE FIBER, SPLIT MULTICOMPONENT FIBER, A SPLIT MULTICOMPONENT FIBER WITH A DURABLE CHARGE, NONWOVEN FABRIC, FILTER, AND YARN CONTAINING THE SPLIT FIBER, AND MANUFACTURING PROCESSES THEREFOR

(57) A process for forming a splittable fiber having the steps of providing a multicomponent fiber; or a multicomponent staple fiber, providing a finish material, and at least partially coating the multicomponent fiber with the finish material to form a splittable fiber. The multicomponent fiber; or a multicomponent staple fiber, contains a first thermoplastic segment comprising polymer component A and a second thermoplastic segment comprising polymer component B. The finish material has an evaporation point of less than about 160°C. A process for forming a nonwoven fabric, a split multicomponent fiber, a split multicomponent fiber with a durable charge, a nonwoven fabric, and a filter and/or a spun yarn formed by the fibers herein is also described.

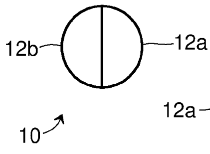

Fig. 1a

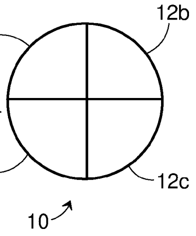

Fig. 1b

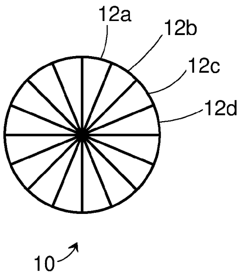

Fig. 1c

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Description

FIELD OF THE INVENTION

[0001] The current invention relates to the field of splittable fibers and manufacturing processes therefor. More particularly the current invention relates to the field of splittable fibers formed of a multicomponent staple fiber and manufacturing processes therefor.

BACKGROUND OF THE INVENTION

[0002] Artificial fibers are typically spun, drawn, and textured prior to being spun into a yarn. Often such artificial fibers are textured by crimping prior to use as crimping provides benefits such as processability (carding in particular), improved skin feel, softness, stretch, fluffiness, etc. to the fibers. The fibers may be selected for various properties, such as chemical resistance, fluffiness, surface area, hydrophobicity/hydrophilicity, etc.

[0003] Carded fibers are known for use in filtration media and other uses, via mechanical filtration principles such as diffusion, interception, inertial impaction and sieving to capture and retain particles of various sizes. Splittable fibers having an increased surface area are also known for use in filtration media, leading to a reduced pore size with the same amount of material which leads to higher filtration efficiency in the Z direction of the filter media.

[0004] Splittable fibers are known in the art to produce sub-fibers which have an increased surface area, and therefore different properties than the original (single-strand) splittable fiber itself. Such splittable fibers are typically produced from a multicomponent fiber which is then split into multiple sub-fibers. The multicomponent fibers are known to contain mixtures of polymers, a charge-enhancing additive, a filler, a finish material, etc. to create the splittable fiber. See, e.g., US Patent No. 5,336,552 by Strack, et al., to Kimberly-Clark Corp., granted on August 9, 1994; US 5,382,400 to Pike, et al., to Kimberly-Clark Corp.,granted on January 17, 1995; US 2003/0203695 A1 by Polanco, et al., to Kimberly Clark Worldwide Inc., published on October 30, 2003, all of which are hereby incorporated by reference in their entireties. Finish materials are known to be added to splittable fibers to reduce the friction and heat generated during further processing, such as during a carding process. Finish materials are also employed to prevent static electricity from building up on the fibers during such further processing.

[0005] Such splittable fibers and corresponding processes are known to produce fibers which have a significantly larger surface are when split into sub-fibers. Either before or after splitting, these fibers may be then formed into, for example, filters, filter materials, nonwoven fabrics/materials, etc. Such splittable fibers are especially useful in filters, filter materials, etc. where the splittability of the fibers can significantly increase filtration efficiency. Similarly, higher water pressure during hydroentanglement may lead to higher splitting, but may conversely also create "large" apertures throughout the nonwoven fabric which then in turn decreases the filtration efficiency. Furthermore, traditional hydroentanglement equipment is large, employing high pressure water with many required safety features; these machines are therefore very expensive to purchase and install, and yet often such high energy/high impact processes are typically required in order to significantly split the current splittable fibers used in nonwoven fabrics into their component sub-fibers.

[0006] Relatively gentle processes such as carding and needle punching will not (significantly) split current splittable fibers, because they lack the physical force necessary to significantly split current splittable fibers.

[0007] Additional methods of increasing filtration efficiency are also known, such as electret charging of fibers. However, it has been found that current splittable fibers are difficult to charge and/or quickly lose whatever charge they acquire. Typically, current splittable fibers are multicomponent fibers that are split during a hydroentanglement process. As a hydroentanglement process is a very energetic process the water jets impart sufficient kinetic energy to break the multicomponent fibers into sub-fibers. However such hydroentangled nonwoven fabrics suffer from specific drawbacks as the hydroentanglement process itself causes large holes/pores in the nonwoven fabric which decreases the potential filtration efficiency. Also, such nonwoven fabrics, and the split fibers therein, are typically not chargeable, and certainly are not capable of holding a durable charge, which also reduces their potential filtration efficiency. Accordingly, the filtration efficiency of current splittable fibers is limited by their lack of charge/chargeability. See, for example, US 2015/0343455 A1 by Schultz, et al., to 3M Innovative Properties Co., published on December 3, 2015, hereby incorporated by reference in its entirety.

[0008] Next Nano (nxtnano.com; Claremore, Oklahoma, USA) nano fiber-based filter media are formed by depositing fine fibers onto the surface of a pleatable support layer making a physical filtration structure that relies upon sieving only. The fibers are very sensitive and it is difficult to get them to adhere to the surface of the support layer. The fibers act as a high surface area membrane would, by basically surface loading contaminant particles. As soon as the surface blinds off or builds a "dirt cake" the resistance increases to maximum and the filter media has difficulty maintaining airflow. Furthermore, such nano fiber-based filters are known to typically cost up twice what other filters cost.

[0009] Conversely, structures that rely only on a high charge potential such as "Tribo electret media" are designed to be of very low air resistance but have a very powerful surface charge. The advantage from this type of media is that they "depth load" particulates and possess a long life with only a small increase of resistance over many weeks or even months. However, if a filter made with this fibers ingests an oily smoke from cigarettes or forest fires, the charge is quickly masked, and the filter rapidly loses efficiency. These filters have been mis-applied and placed in commercial buildings where the filters prematurely fail due to the loss of charge when the building ventilation system becomes contaminated with cigarette smoke. The EU has recognized this mis-application and has initiated the new ISO 16890 standard, hereby incorporated by reference in its entirety, where the filter is given a rating by averaging the beginning efficiency, discharging the media and retesting. The results are quite dramatic for a media like Tribo electret where it may have an initial efficiency of MERV 13 but after discharging may end up with a MERV 6.

[0010] However, it has been found that as the finish materials currently used are intended to reduce static build up in the nonwoven fabric, they also may cause the splittable fiber to quickly lose the charge after, for example, electret charging via corona processing. Thus, current splittable fibers are not known to be charged, or to durably carry an electret charge. This in turn has been now found to limit their filtration efficiency. Accordingly, there exists a need for a finish material for splittable fibers which does not cause the splittable fiber to lose charge.

[0011] Accordingly, there exists a need for a splittable chargeable fiber capable of holding a durable charge, especially for the production of filtration media, a nonwoven fabric made therefrom, and processes for forming such a splittable chargeable fiber and nonwoven fabric. There also exists the need for a process to manufacture a splittable chargeable fiber capable of holding a durable charge. There also exists a need for a filtration product which possesses the advantages of a nano fiber-based filter and a charged filter to provide efficient and lasting filtration.

SUMMARY OF THE INVENTION

[0012] An embodiment herein relates to a process for forming a splittable fiber having the steps of providing a multicomponent fiber; or a multicomponent staple fiber, providing a finish material, and at least partially coating the multicomponent fiber with the finish material to form a splittable fiber. The multicomponent fiber; or a multicomponent staple fiber, contains a first thermoplastic segment comprising polymer component A and a second thermoplastic segment comprising polymer component B. The finish material has an evaporation point of less than about 160 °C.

[0013] An embodiment of the present invention relates to a process for forming a nonwoven fabric having the steps of providing a splittable fiber by providing a multicomponent fiber; or a multicomponent staple fiber as described herein, and forming the splittable fiber into a nonwoven fabric.

[0014] An embodiment of the present invention relates to a split multicomponent fiber comprising a durable charge.

[0015] An embodiment of the present invention relates to a nonwoven fabric, a filter and/or a spun yarn formed by the fibers and processes described herein.

[0016] Without intending to be limited by theory, it is believed that the present invention may provide a splittable fiber which is capable of receiving and maintaining / holding a durable charge. This splittable fiber may then be further formed into, for example, a filtration media possessing significant advantages over existing filtration media.

[0017] Without intending to be limited by theory, it is also believed that the present invention may provide surprising benefits by combining the best advantages of nano fiber-based filters and electret-charged filters by incorporating high surface area physical filtration and electret charge to enhance fine particle retention. The present invention is believed to provide both depth load filtration and to maintain long-lasting performance with little or no resistance spikes. It is believed that the present invention significantly reduces the chances of prematurely failure due to, for example, cigarette smoke, while also providing significant manufacturing and cost advantages. The invention herein may provide one or more benefits such as improved filter loading, improved filter life, improved MERV rating, improved resilience/scuff resistance, etc.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018]

Fig. 1a shows a cross-sectional views of an embodiment of a splittable multicomponent fiber;
Fig. 1b shows a cross-sectional views of an embodiment of a splittable multicomponent fiber;
Fig. 1c shows a cross-sectional views of an embodiment of a splittable multicomponent fiber;
Fig. 2 shows a partial side view of an embodiment of a splittable fiber of the present invention after splitting;
Fig. 3 shows a partial side view of an embodiment of a splittable fiber of the present invention after splitting; and
Fig. 4 shows a cross-sectional view of a hollow multicomponent fiber containing a plurality of alternating thermoplastic segments.

[0019] The figures herein are for illustrative purposes only and are not necessarily drawn to scale.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0020] Unless otherwise specifically provided, all tests herein are conducted at standard conditions which include a room and testing temperature of 25 °C, sea level (1 atm.) pressure, pH 7, and all measurements are made in metric units. Furthermore, all percentages, ratios, etc. herein are by weight, unless specifically indicated otherwise. It is understood that unless otherwise specifically noted, the materials, compounds, chemicals, etc. described herein are typically commodity items and/or industry-standard items available from a variety of suppliers worldwide.

[0021] As used herein, the terms "a", "an", and "the" are interchangeable with "at least one" to mean one or more of the elements as described.

[0022] As used herein, the term "durable charge" indicates an electret charge that retains at least 90% of the original charge after at least about 1 year; or at least about 2 years; or at least about 3 years, in normal conditions of packaging, storage and handling. A simple hand held static measuring device can be used to measure the initial charge after electret charging, and the retained charge after the above period of time, and the percentage retention is easily calculated.

[0023] As used herein, "electret" refers to a material that exhibits a quasi-permanent electric charge.

[0024] As used herein the phrase "multicomponent fiber" indicates a fiber that has been formed from a plurality of component polymers, or the same polymer having different properties and/or additives, and extruded as separate sub-fibers (i.e., strands) from separate extruders. Typically the multicomponent fiber will be made from a plurality of different component copolymers; or each sub-fiber is made from a different polymer from that of the adjacent sub-fiber(s). The sub-fibers are then combined to form a single fiber, for example, by spinning. Typically the sub-fibers are arranged in consistently-positioned positions across the cross-section of the multicomponent fiber. The relative positions of the sub-fibers may be in, for example, pie-wedges such as seen in Figs 1a-1c, stripes, etc. as known in the art. See, for example, US Patent No. 5,108,820 to Kaneko, et al., assigned to Mitsubishi Petrochemical Industries, granted on April 28, 1992, hereby incorporated herein by reference in its entirety.

[0025] As used herein the term "nonsplittable fiber" indicates a fiber having a single, relatively fixed and constant denier along substantially its entire length even after processing, including, for example, carding, hydroentanglement, etc., into a nonwoven web. In an embodiment herein, the nonsplittable fiber is a fiber having a roughly circular cross-sectional shape in which the entire fiber surface comprises a single polymer to a depth of at least 10% of the fiber's maximum radius; or for a non-circular cross sectional fiber, such as a trilobal fiber, wherein a single polymer comprises substantially the entire fiber surface.

[0026] As used herein "splittable fiber" indicates that a multicomponent fiber having a given width and cross-sectional configuration may be changed after fiber extrusion, substantially as part of the nonwoven fabric formation process, typically through physical disruption of the attachment between individual sub-fibers by the application of mechanical energy. Typically, a splittable fiber herein will split into at least 2 sub-fibers for about 20% or more; or for about 30% or more of its length; or for about 40% or more of its length after a typical carding process having a main cylinder : worker roll speed ratio of 20:1; or 15:1; or 10:1 at a given output speed.

[0027] As used herein the term "staple fiber" indicates a fiber; typically an extruded fiber, which may be from about 1.25 cm to about 16 cm in length typically, due to cutting. Staple fibers are typically then formed into a nonwoven fabric via one or more forming processes such as carding, air laying, adhesive bonding, thermal bonding, etc.

[0028] An embodiment of the present invention relates to a process for forming a splittable fiber having the steps of providing a multicomponent fiber; or a multicomponent staple fiber, providing a finish material, and at last partially coating the multicomponent fiber, or the multicomponent staple fiber, with the finish material. The multicomponent staple fiber contains a first thermoplastic segment containing polymer component A, and a second thermoplastic segment containing polymer component B. The finish material has an evaporation point of less than 160 °C.

[0029] The polymer component A and polymer component B are typically useful herein when a carded web made from a pie wedge fiber made from the polymer pair is observed to contain at least 20% of the pie wedge fibers that have split to any degree after carding. This typically means that polymer component A and polymer component B have different empirical chemical formulas. Without intending to be limited by theory, it is believed that, for example, two different grades of polypropylene with different molecular weights would have the same empirical chemical formula and would not be sufficiently different for 20% or more of the pie wedge fibers to split during carding. Similarly, it is believed that a polyethylene terephthalate (PET) and an isophthalic acid/terephthalic acid coPET would have identical empirical chemical formulas (but not identical chemical structures) and would thus it would be unlikely for 20% or more of the pie wedge fibers to split during carding. In contrast, for example, PET and polypropylene have different chemical formulas and are sufficiently different so as to function in the invention. Thus, without intending to be limited by theory, it is believed that the present invention is operable and may provide a splittable fiber so long as the empirical chemical formula of polymer component A is significantly different from; or different from, polymer component B.

[0030] The multicomponent fiber; or multicomponent staple fiber, useful herein is a fiber having a plurality of thermoplastic segments; typically a first thermoplastic segment and a second thermoplastic segment, although additional thermoplastic segments may also be included, such as a third thermoplastic segment, a fourth thermoplastic segment, etc.

The multicomponent fiber typically contains at least 4 distinct thermoplastic segments; or from about 4 to about 128 distinct thermoplastic segments; or from about 8 to about 64 distinct thermoplastic segments, or from about 16 to about 32 distinct thermoplastic segments. Each thermoplastic segment may be formed of polymer component A or polymer component B as desired, as long as at least one thermoplastic segment in the multicomponent fiber is formed of polymer component A, and at least one thermoplastic segment in the multicomponent fiber is formed of polymer component B. Typically, in order to promote the desired splitting of the multicomponent fiber into the desired sub-fibers, each segment will be of a different polymer than the adjacent segment(s).

[0031] It is further understood that in a multicomponent fiber, the thermoplastic segments are typically arranged in the fiber such that they define a specific spatial arrangement within the fiber's cross section. Furthermore, this specific spatial arrangement typically does not vary significantly along the entire length of the multicomponent fiber prior to splitting. See, for example, embodiments of the multicomponent fiber herein containing multiple thermoplastic segments in Figs. 1a-1c., showing cross-sectional views of various multicomponent fiber embodiments, where the multicomponent fiber, 10, contains a plurality of thermoplastic segments, 12, 12a, 12b, 12c, 12d, etc. each of which may correspond to a sub-fiber (see Fig. 2 at 14). The various thermoplastic segments are typically coextruded together to form a single multicomponent fiber, although they may be separately extruded and then combined, typically quickly combined (before the individual thermoplastic segments harden), to form the multicomponent fiber. Each thermoplastic segment has the potential to form its own sub-fiber (see Fig. 2 at 14) upon splitting.

[0032] In an embodiment herein, a process for forming a nonwoven fabric includes the steps of providing a splittable fiber, and forming the splittable fiber into a nonwoven fabric. The splittable fiber is provided by providing a multicomponent fiber; or a multicomponent staple fiber, containing a first thermoplastic segment containing a polymer component A, and a second thermoplastic segment containing a polymer component B, providing a finish material having an evaporation point of less than 160 °C and at least partially coating the multicomponent staple fiber with the finish material.

[0033] In an embodiment herein, the step of forming the splittable fiber into a nonwoven fabric may be, for example, forming step is selected from the group consisting of carding, thermal bonding, needle punching, spunbonding/spinbonding, air laying, hydroentanglement, melt blowing, hydro pulping, refining, wet laying, passing thorough air oven, cross-lapping, and a combination thereof; or thermal bonding, needle punching, hydropulping, wet-laying, chemical bonding (e.g., for acrylic latex), melt blowing, air laying, carding, needling, hydroentanglement, and a combination thereof; or thermal bonding, needlepunching, hydropulping, wet laying, and a combination thereof. Typically carding, spunbinding/spunbonding, air-laying, melt blowing and melt laying are considered processes for initially forming a nonwoven web, while thermal bonding, needle punching, hydroentanglement, chemical bonding, and cross-lapping are processes that consolidate the initially-formed nonwoven web into a nonwoven web which is typically possesses increased strength, rigidity, etc. as compared to the initially-formed nonwoven web. Hydro pulping and refining are used prior to wet-laying to condition the water-borne fibers. Accordingly, as used herein, the term "forming step" includes all different phases of the physical forming process, from the point that fibers are extruded, to the final production of the nonwoven fabric. However, the forming process as used herein does not necessarily include the electret charging step.

[0034] It is understood that when the multicomponent fiber splits apart into sub-fibers, they do so in a distribution of splitting at any specific location along the multicomponent fiber (see, e.g., Fig. 2 and Fig. 3). That is, for example, at a certain location, a multicomponent fiber comprising 16 thermoplastic segments may split entirely into 16 separate sub-fibers, with each sub-fiber containing a single thermoplastic segment. Alternatively a multicomponent fiber (or even the same multicomponent fiber at a different location) may split into 6 sub-fibers each containing one thermoplastic segment each, 2 sub-fibers comprising 2 thermoplastic segments each (not split apart from each other), and one sub-fiber comprising 6 thermoplastic segments that remain adhered to each other in a single sub-fiber. In other fibers, or even along the same multicomponent fiber, the distribution of single-segment and multiple segment sub-fibers may be different.

[0035] Fig. 2 shows a partial side view of an embodiment of a splittable fiber, 20, of the present invention after splitting. The multicomponent fiber, 10, contains 8 different thermoplastic sub-fibers, 12a-12h from top to bottom respectively, to form the splittable fiber, 20. At point A-A, along the multicomponent fiber, 10, thermoplastic segments 12a, 12b, 12c, 12d, and 12e are joined together in a sub-fiber 14a, while thermoplastic segments 12f, 12g and 12h are joined together in a sub-fiber, 14b. The split distribution can be measured using, for example, the BET test, the Micronaire test, SEM analysis, etc. as described herein.

[0036] However, at point B-B along the same multicomponent fiber, thermoplastic segment 12a has split from thermoplastic segments 12b and 12c which are still joined together. Thermoplastic segment 12d and thermoplastic segment 12e are split as well as single sub-fibers, 14, while thermoplastic segments 12f, 12g, and 12h are still joined together in sub-fiber 14b.

[0037] At point C-C, all of the 8 thermoplastic segments 12, have split apart, so thermoplastic segments 12a, 12b, 12c, 12d, 12e, 12f, 12g and 12h can all be seen and identified separately as individual sub-fibers.

[0038] At point D-D, all of the 8 thermoplastic segments are joined together as a single multicomponent fiber. One skilled in the art understands that additional combinations and arrangements of the thermoplastic segments to form various sub-fibers are also possible as well, either in different multicomponent fibers, or at different places in the same multicomponent fiber.

[0039] Without intending to be limited by theory it is believed that such a splittable fiber having a variable split distribution is useful as it allows the production of various nonwoven fabrics having different physical features and properties such as fluffiness, thickness, insulation levels, air/water resistance, filtration levels, etc. from the same multicomponent fiber. Furthermore, it is believed that the split distribution can be increased by changing the process, for example, more vigorous carding leads to a higher splitting of the splittable fibers, both along the same fiber as well as in different fibers.

[0040] Fig. 3 shows a partial side view of an embodiment of a splittable fiber of the present invention after splitting. Specifically, the splittable fiber, 20, can be shown split into thermoplastic segments, 12a, 12b, 12c, 12d, 12e, 12f, 12g, and 12h, for a majority of its length. As can be seen on the right side of the figure, the splittable fiber, 20, is split into thermoplastic segments, 12a, 12b, 12c, 12d, 12e, 12f, 12g, and 12h, each of which corresponds to a sub-fiber, 14a, 14b, 14c, 14d, 14e, 14f, 14g, and 14h.

[0041] Fig. 4 shows a cross-sectional view of a hollow multicomponent fiber, 10, containing a plurality of alternating thermoplastic segments, 12a and 12b. Specifically, the multicomponent fiber, 10, contains a hollow center, 16. Each segment 12a is formed of polypropylene and in the embodiment of Fig. 4 each segment 12b is formed of polymethylpentene, which would normally bind together too strongly to be split when formed into a shape such as Fig. 1a. However, due to the lower adjoining surface area, 18, between the different segments, 12a and 12b, due to the hollow center, 16, in the multicomponent fiber, 10, these segments, 12a and 12b, may still be split from each other during a carding process. Thus, in an embodiment herein, the multicomponent fiber is a hollow fiber. In an embodiment herein, the polymer component A is polypropylene and polymer component B is polymethylpentene.

[0042] As mentioned above, polymer component A and polymer component B have different empirical chemical formulas. In an embodiment herein, the polymer component A includes a polymer; or a polymer selected from the group consisting of a polyamide, a sulfur-containing polymer, an aromatic polyester, an aliphatic polyester, a polyolefin, and a combination thereof; or a polyamide, a polyphenylene sulfide, a polyarylene terephthalate, a polyarylene isopthalate, a polylactic acid, a polyhydroxyalkanoate an aliphatic polyester, a polypropylene, a polyethylene, a polymethylpentene, and a combination thereof; or nylon, polyphenylene sulfide, polyethylene terephthalate, polylactic acid, poly propylene, and a combination thereof; or PET, polylactic acid polymer, polypropylene, and a combination thereof. As used herein with respect to the polymers, the term "a combination thereof' specifically includes copolymers, homopolymers, and blends thereof.

[0043] In an embodiment herein, the polymer component B includes a polymer; or a polymer selected from the group consisting of a polyamide, a sulfur-containing polymer, an aromatic polyester, an aliphatic polyester, a polyolefin, and a combination thereof; or a polyamide, a polyphenylene sulfide, a polylactic acid, a polyarylene terephthalate, a polyarylene isopthalate, a polyhydroxyalkanoate an aliphatic polyester, a polypropylene, a polyethylene, a polymethylpentene, and a combination thereof; or a nylon, a polyphenylene sulfide, a polylactic acid, a polyethylene terephthalate, a poly propylene, and a combination thereof; or a PET, a polylactic acid polymer, a polypropylene, and a combination thereof.

[0044] In an embodiment herein, the polymer component A and/or the polymer component B contains a polyolefin; or a polyolefin selected from the group consisting of a polypropylene, a polyethylene, and a combination thereof. Without intending to be limited by theory, it is believed that polyolefins; or polypropylene, polyethylene, and the combination thereof are especially useful for acquiring and holding an electret charge.

[0045] In an embodiment herein, the polymer component A contains a polyolefin polymer, and polymer component B contains a non-polyolefin polymer. In an embodiment herein, the polymer component A contains a polylactic acid polymer, and polymer component B contains a non-polylactic acid polymer.

[0046] The finish material herein is applied to the surface of the splittable fiber to aid in lubricating the splittable fiber to reduce heat generation and to reduce static during further processing, such as carding, etc. Generally in the art, traditional finish materials contain mineral oils or synthetic oils with anti-static additives. Sometimes these traditional finish materials may contain animal fats, or fatty acids. However, it has now been found that these traditional finish materials reduce or eliminate the charge induced or added on to the splittable fiber, during, for example, electret charging; or electret charging via corona charging. Accordingly, an embodiment of the invention herein includes the step of removing the finish material from the splittable fiber prior to electret charging; or removing the finish material from the splittable fiber during the electret charging process. In an embodiment herein, the finish material is removed during, for example, the dwell time in an oven, etc.

[0047] A finish material may be required for increasing lubrication during further processing, to reduce static charge build up, etc. Thus, in an embodiment herein, the finish material has an evaporation point of less than about 160 °C; or from about 30 °C to about 160 °C; or from about 40 °C to about 150 °C; or from about 50°C to about 100 °C.

[0048] The finish material herein may be a substantially water-soluble; or water-soluble finish material, which is especially intended to wash away during, for example, washing, a hydroentanglement process, etc. In an embodiment herein, the finish material is a water-soluble finish material, and the forming process includes the step of hydroentangling the splittable fiber while coated with the finish material.

[0049] Without intending to be limited by theory, it has been found that when the evaporation temperature is in the range above, then most; or substantially all, of the finish material is removed; or evaporated, during the thermal bonding process to form the nonwoven web. In an embodiment herein, the process herein includes the step of removing, by weight, at least a portion; or from about 50% to about 100% of the finish material; or from about 75% to about 100% of the finish material; or form about 80% to about 100% of the finish material, from the nonwoven fabric, the multicomponent fiber, and/or the splittable fiber; or from the splittable fiber, during or after the forming step when the splittable fiber is formed into a nonwoven fabric and prior to the electret charging process. In an embodiment herein, the nonwoven fabric forming process removes at least a portion of the finish material; or from about 50% to about 100% of the finish material; or from about 75% to about 100% of the finish material; or form about 80% to about 100% of the finish material; or substantially all of the finish material, by weight from the nonwoven fabric.

[0050] In an embodiment herein, the finish material comprises water, a lubricant, and an emulsifier. In an embodiment herein, the lubricant is a selected from a plant-based oil, a natural oil, a synthetic oil, a water-soluble lubricant, and a combination thereof; or a vegetable oil, a mineral oil and a combination thereof; or a light vegetable oil, a light mineral oil, and a combination thereof; or a coconut oil, a corn oil, and a combination thereof. It is preferred that the lubricant herein possess a low molecular weight, a high viscosity, and few, or no molecular byproducts when exposed to heat, and no residue after evaporation. In an embodiment herein the finishing material and/or the lubricant are compliant with the United States Federal Drug Administration guidelines regarding GRAS (Generally Regarded As Safe) list (See, for example, https://www.fda.gov/food/food-ingredients-packaging/generally-recognized-safe-gras; and US Code of Federal Regulations: 21 CFR 177.2800; 21 CFR 176.210; 21 CFR 178.3400), all hereby incorporated by reference in its entirety.

[0051] In an embodiment herein, the finish material is a water-soluble finish material; typically containing a water-soluble lubricant; or containing sufficient emulsifier to fully emulsify any and all oil in the finish material, or is a fully water-soluble finish material, so that during, for example, a hydroentanglement process, the finish material washes away; or substantially washes away, from the splittable fiber.

[0052] In an embodiment herein, the emulsifier acts as an antistatic compound; or an antistatic compound having an evaporation point of less than about 160 °C; or from about 30 °C to about 160 °C; or from about 40 °C to about 150 °C; or from about 50°C to about 100 °C. In addition, the finish material may contain a specific antistatic material other than the emulsifier.

[0053] In an embodiment herein, the finish material may also contain a stabilizer, a thickener, a thinner, an anticoagulant, an antimicrobial compound and a combination thereof. These compounds are well-known in the art and available from multiple well-known suppliers worldwide.

[0054] The multicomponent fiber is at least partially coated; or coated, in a coating step with the finish material to form a splittable fiber. The coating step may include, for example, spraying the finish material onto the multicomponent fiber, immersing the multicomponent staple fiber in the finish material, contacting the fiber and a film of liquid finish material on the surface of a transfer roll (for example, a kiss-roll application process), contacting the fiber with a bead of the finish material as the fiber passes through a grooved applicator (e.g., using a metered-finish application process), and a combination thereof.

[0055] In an embodiment herein, where the invention employs a multicomponent staple fiber, the process herein may further include the step of cutting a multicomponent fiber to form a multicomponent staple fiber, crimping a multicomponent staple fiber to a length of from about 1.25 cm to about 16 cm, and a combination thereof.

[0056] Once the multicomponent fiber is formed into the splittable fiber, then the splittable fiber is typically formed into a nonwoven fabric by, for example, by the forming processes described herein. Such forming processes are known in the art.

[0057] In an embodiment herein, the splittable fiber is fully split into a plurality of sub-fibers. In an embodiment herein, the smallest sub-fibers have a linear density of less than about 5 denier; or less than about 2 denier; or less than about 1 denier; or less than about 0.8 denier; or less than about 0.4 denier.

[0058] In an embodiment herein, the nonwoven web includes a nonsplittable fiber having a linear density of greater than about 1 denier; or from about 1.5 denier to about 4 denier; or from about 1.5 denier to about 3 denier. In an embodiment herein, the nonwoven fabric herein further contains an additional nonsplittable fiber having a linear density of from about 1 denier to about 20 denier to provide additional properties such as stiffness, the ability to hold a shape or a crease/fold, etc.

[0059] An embodiment of the present invention further includes a split multicomponent fiber having a durable charge as described herein.

[0060] In an embodiment herein, the nonwoven fabric also contains a nonsplittable fiber in addition to the splittable fiber. Thus, in an embodiment of the nonwoven fabric formation process herein, the process includes the step of providing a nonsplittable fiber. The nonwoven web is then formed from the splittable fiber and the nonsplittable fiber. In an embodiment herein the nonwoven fabric contains from about 1% to about 100%; or from about 3% to about 97%; or from about 5% to about 95%; or from about 10% to about 90% splittable fibers by weight of the nonwoven fabric. It is believed that a blend of both splittable fibers and nonsplittable fibers may provide benefits such as strength, shape retention, filtering, etc. In an embodiment herein, the nonwoven fabric contains at least 20% nonsplittable fibers, especially if it is thermal bonded during the forming step.

[0061] In an embodiment herein the finish material is removed after the forming step; or after the splittable fiber is split. Without intending to be limited by theory, it is believed that by removing the finish material from the splittable fiber, the nonwoven fabric, the split multicomponent fiber, etc. the resulting individual split multicomponent fiber's ability to acquire and hold a durable charge will not be significantly abated or reduced by the antistatic properties of the finish material.

[0062] In an embodiment herein, the process for forming a nonwoven web includes the step of splitting the multicomponent fiber; or the multicomponent staple fiber; or the splittable fiber, into a split fiber. In an embodiment herein, the splitting step includes a needle punching process, a hydroentanglement process, a carding process, a flexing process, a twisting process, a stretching process, a drawing process, a scraping process, a crushing process, a rolling process, a hydropulping process, a stitchbonding/stitchbinding process, and a combination thereof; or a carding process, a needle punching process, a hydropulping process, and a combination thereof. In an embodiment herein the splitting step is the same as the forming step.

[0063] In an embodiment herein, the electret charging process charges a thermoplastic component in the splittable fiber, the split fiber, the multicomponent fiber, the multicomponent staple fiber, the nonwoven fabric, and/or etc. selected from the group of the first thermoplastic component, the second thermoplastic component, and a combination thereof; or the split fiber, the multicomponent fiber, the split multicomponent fiber, and/or the nonwoven fabric. In an embodiment herein, the electret charging process useful herein is selected from the group of corona charging, ion bombardment, atmospheric plasma deposition (APD), other charging methods, and a combination thereof; or corona charging, ion bombardment, APD and a combination thereof; or corona charging, APD, and a combination thereof. Corona charging is known in the art and has its roots in the foil and film lamination process. Early research in nonwoven media started in the 1990's when Dr. Peter Tsai from University of Tennessee developed and patented a system to enhance melt blown polypropylene with a similar technology designed to give films a normalized surface energy for secondary processing. Dr. Tsai found that by applying a strong polarity of charge to a polypropylene melt blown structure that the surface energy attracted, removed and held fine particles (> 1.0 micron) enhancing an otherwise low efficiency filtration media.

[0064] In an embodiment herein, the electret charging process includes the process of APD. In an embodiment herein, the electret charging process first employs an atmospheric plasma deposition process and subsequently a corona charging process. Without intending to be limited by theory, it has been found that in addition to including an electret charge in the fibers, APD may can also remove oligomers and other low molecular weight by-products, such as the finish material, from thermoplastic polymeric fibers as well as providing a nano-etched finish giving the fibers a more suitable surface. It is further believed that the APD process may actually clean and functionalize the fiber surface such that when the APD process is followed by a corona charging process, the corona charge may be stronger, and/or may last an even longer time; i.e., is even more durable.

[0065] In an embodiment herein, the electret charging; or the corona charging process, ion bombardment, the APD process, other charging methods, and a combination thereof; or the heat from the corona charging process, the APD process, and a combination thereof, helps to remove finish material from the splittable fiber, the nonwoven fabric, the multicomponent fiber, the multicomponent staple fiber, the split fiber, and/or sub-fiber. In an embodiment herein, the electret charging; or the corona charging, imparts a negative charge to the outer surface of the splittable fiber, the nonwoven fabric, the split fiber, the multicomponent fiber, the multicomponent staple fiber, and/or sub-fiber. Without intending to be limited by theory, it is believed that this negative surface energy on the outer surface of the splittable fiber, the nonwoven fabric, the split fiber therefore attracts positively-charged particles from the air or other media passing through the filter, thereby significantly increasing filtration efficacy. The electret charging may impart either a net negative charge or a net positive charge on the nonwoven fabric, the multicomponent fiber, multicomponent staple fiber, and/or the split fiber. An electric charge allows the nonwoven fabric, the multicomponent fiber, the multicomponent staple fiber, and/or the split fiber to attract oppositely-charged particles when being used as, for example, a filtration matrix.

[0066] In an embodiment herein, a charge-enhancing additive added is included into the multicomponent fiber; or the polymer component A; or the polymer component B. The charge-enhancing additive enhances the development and/or retention of an electret charge; or a static electrical charge. In an embodiment herein, the charge-enhancing additive is selected from the group of stearate salts; phosphate metal salts, benzoic acid salts, zinc, and a combination thereof; or the charge-enhancing additive is selected from the group of calcium stearate, magnesium stearate, sodium phosphate, sodium benzoate, zinc salts, and a combination thereof; or the charge-enhancing additive is selected from the group of calcium stearate; magnesium stearate, sodium phosphate, and a combination thereof. Without intending to be limited by theory, it is believed that stearate salts; or calcium stearate and magnesium stearate particles; or calcium stearate particles having a diameter of 5 microns (μ) or less and magnesium stearate particles having a diameter of 5μ or less are especially desirable if the multicomponent fiber and/or a sub-fiber contains polypropylene. Without intending to be limited by theory it is believed that once the multicomponent fiber and/or the sub-fiber contains and/or is coated with the charge-enhancing additive(s), the charge-enhancing additive(s) may form a capacitor-like structure which may enhance the electret charge density and/or durability as compared to when no charge-enhancing additive is present.

[0067] In an embodiment herein, the charge-enhancing additive is an organic acid metal salt composed of at least a C_{10} carbon-chain organic acid and a metal ion work function of 4eV or more. Examples of the organic acid useful herein include C_{10} or higher carbon chain length carboxylic acids, organic phosphoric acids, organic sulfonic acids, and the like, especially lauric acid, linolenic acid, t-butylbenzoic acid, di-(t-butylphenyl) phosphoric acid, and/or stearic acid. The metal salt ions useful herein include, for example, aluminum ions, iron ions, nickel ions, cobalt ions, tin ions, copper ions, lead ions, cadmium ions, etc., especially aluminum ions. See JP H06-254319A by Tokuda, et al., to TOYOBO Co., Ltd., published on September 13, 1994 hereby incorporated by reference in its entirety.

[0068] In an embodiment herein, the charge-enhancing additive is selected from the group of triphenylmethanes; ammonium compounds and immonium compounds; intensely fluorinated ammonium and immonium compounds; biscationic acid amide and acid imide derivatives; polymeric ammonium compounds; diallylammonium compounds; arylsulfide compounds; phenolic compounds (respectively compounds of the CAS-No. 41481-66-7 and 13288-70-5); phosphonium compounds; highly fluorine-substituted phosphonium compounds; calix(n)arene compounds; metal complex compounds like chromium-, cobalt-, iron-, zinc- or aluminum azocomplexes or chromium-, cobalt-, iron-, zinc- or aluminum salicyclic acid complexes (such as described by CAS-Numbers 31714-55-3, 104815-18-1, 84179-68-8, 110941-75-8, 32517-36-5, 38833-00-00, 95692-86-7, 85414-43-3, 136709-14-3, 135534-82-6, 135534-81-5, 127800-82-2, 114803-10-0, 114803-08-6 and the like); benzimidazolon compounds; and/or azines of the following Color Index numbers, C. I Solvent Black 5, 5:1, 5:2, 7, 31, 50; C.I. Pigment Black 1, C. I. Basic Red 2 and C. I. Basic Black 1 and 2. See, EP 623941A2 to Groh, et al., published on March 5, 1994, assigned to Hoechst Celanese Corp., hereby incorporated by reference in its entirety.

[0069] In an embodiment herein, the charge-enhancing additive contains an arylamino-substituted benzoic acid and/or an arylamino-substituted benzoic acid salt. The salts useful herein may be metal-containing salts and may be salts of monovalent, divalent or trivalent metals. Alternatively, the charge-enhancing additive useful herein may contain phenolate salts; or triazine phenol salts; or a triazine phenolate anion and a metal cation. See US 2016/0067717 A1 by Schultz, et al., to 3M Innovative Properties Co., published on March 10, 2016; and US 2019/0336896 A1 by Schultz, et al., to 3M Innovative Properties Co., published on November 7, 2019, all of which are hereby incorporated by reference in their entireties.

[0070] The charge-enhancing additive may be present in any suitable level as known in the art; or in an amount up to about 10%; or from about 0.02% to about 5%, by weight of the polymer component.

[0071] Fillers useful herein are typically particulate materials added into the polymer component to provide bulk and to reduce the overall material cost and are extruded together. The particles are typically from about 0.5μ to 5μ in diameter, although they may not have a regular shape. Non-limiting examples of fillers useful herein include inorganic fillers such as calcium carbonate, titanium dioxide, talc, barium carbonate, magnesium carbonate, magnesium sulfate, mica, clays, kaolin, diatomaceous earth, and the like. Organic fillers include chitin, carbon black, wood and cellulose powders, etc.

[0072] In an embodiment herein, a pigment, whether liquid, solid, etc., may be added to any of the fibers herein to provide a color to the fiber.

[0073] Without intending to be limited by theory it is believed that once the splittable fibers herein are split into split fibers, and further provided with an electret charge, the filter material's MERV (Minimum Efficiency Reporting Values) rating will very likely increase, indicating that the filter is better at removing particulates, especially charged particulates. See, for example, https://www.epa.gov/indoor-air-quality-iaq/what-merv-rating-1, hereby incorporated by reference in its entirety, which explains MERV ratings and that it is derived from the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) [see www.ashrae.org].

[0074] In an embodiment herein the splittable fiber, the split fiber, the multicomponent fiber, the multicomponent staple fiber, and/or the nonwoven fabric is formed into a filter, such as an air filter for removing particulates from the air; or a face mask; or a HEPA filter; or a filter having a MERV rating of at least 8; or a filter having a MERV rating of at least 10; or a filter having a MERV rating of at least 14; or a filter having a MERV rating to at least 16.

[0075] In an embodiment herein, the splittable fiber, the split fiber, the multicomponent fiber, the multicomponent staple fiber, and/or the nonwoven fabric is formed into a filter; or an air filter; or a vehicle air filter; or an automotive engine air filter, an automotive cabin air filter, an HVAC air filter, a face mask/respirator filter; and a combination thereof; or a cigarette filter. In an embodiment herein, the splittable fiber, the split fiber, the multicomponent fiber, the multicomponent staple fiber, and/or the nonwoven fabric is formed into an insulator; or a heat insulator; or a sound insulator; or a thermal insulator. In an embodiment herein, the splittable fiber, the split fiber, the multicomponent staple fiber, and/or the multicomponent fiber is included or formed into a spun yarn. In an embodiment herein, the splittable fiber, the split fiber, the multicomponent fiber, the multicomponent staple fiber, and/or the nonwoven fabric is included in a wipe.

TESTING PROCEDURES AND EQUIPMENT:

[0076] The TSI 8130A automated filter tester (see: https://www.tsi.com/products/filter-testers/automated-filter-tester-8130a/ by TSI Incorporated, Shoreview, Minnesota, USA) can be used to test the filtration efficiency herein. The TSI 8130A creates 0.3μ particles which are injected into an airstream and passed through a filter sample. See: https://youtu.be/HSngoNqKXvI, which shows how the filter tester works. The 0.3 μ particles are measured both upstream and downstream of the filter sample. As charge (or lack thereof) greatly impacts such small particles, it this device and the associated test can easily show whether the filter sample has an electret charge and/or show its efficiency as measured in % penetration. The % penetration is calculated as: (downstream particle concentration) / (upstream particle concentration) × 100.

[0077] A high % penetration indicates low filtration efficiency - i.e., many particles are passing through the filter. Conversely, a low % penetration indicates a high filtration efficiency where many particles are caught and held by the filter. As the particles build up on the filter sample, the filter tester continuously monitors the flow rate and the resulting pressure drop across the filter.

[0078] All MERV tests herein are conducted according to ASHRAE MERV Standard 52.2-2017 from the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), hereby incorporated by reference in its entirety, available from the ASHRAE website at: https://ashrae.iwrapper.com/ASHRAE_PREVIEW_ONLY_STANDARDS/STD_52.2_2017.

[0079] The TOPAS Flat Sheet Filter Media Test System (Model # AFC132; "TOPAS") quickly tests small discs of filter media according to the ASHRAE Standard 52.2-2017, hereby incorporated by reference in its entirety. TOPAS has proprietary software that creates potassium chloride particles from 0.3 microns to 10.0 microns in diameter. The horizontal duct holds the sample and challenges the media per the ASHRAE Standard 52.2-2017 at the filter design velocity (Residential furnace filters are 110 fpm). Upstream and downstream particle counters determine the size and number of particles which are trapped and pass through the media giving each particle range (E1 0.3 - 1 micron, E2 1.0 - 3 micron, E3 3.0 - 10 micron) and correlating the efficiency in each group with the ASHRAE Standard 52.2 MERV rating chart.

[0080] Although flat sheet accuracy is reasonably close to that of a pleated filter, the dynamics of air flow, size of actual filter, pleat geometry etc. can have small effects on the filter performance vs. a flat sheet. See below comparison of flat sheet data to outside test lab of full filter. Resistance is nearly doubled due to this filter being a wire back design where the wire holds the pleat form but also adds resistance because of the blind area of the metal mesh. The filter frame also reduces the available media exposed to flow causing the TOPAS design to result in a slightly higher velocity than the flat sheet test per ASHRAE Standard 52.2:

Sample Description	IR (in w.g.)	E1	E2	E3	MERV	Velocity fpm
Flat sheet	0.20	32.2	65.5	91.3	11	110
Filter	0.40	21.8	71	93	11	113
IR = Initial resistance in w.g. = inches water gauge fpm = feet per minute (1 fpm = 1828.8 cm/min)						

[0081] Calculating the Area of a Pleated Filter:

Width in inches	Pleat height (in inches)	Please count	Pleat Length (in feet)	Pleated area (in sq. inches)	Pleated area (in square feet)	Volumetric air flow (in CFM)	Volumetric Air Flow Rate (in cubic meters/hour)	Media Velocity (in feet/min)	Media Velocity (in cm/sec)
23.75	0.9	35	5.51	1571.06	10.91	1968	3343.65	180.38	91.63
23.75	1.75	29	8.88	2531.16	17.58	1968	3343.65	111.96	56.88

[0082] The SIMCO-ION Electrostatic Fieldmeter (specifically model # FMX-003) is a commercially-available (see: https://www.simco-ion.com/) fieldmeter which measures the static charge of a material such as a fiber, a nonwoven fabric, etc.

[0083] In an embodiment herein, the split distribution of the splittable fiber (and/or the multicompoenent splittable fiber, the multicomponent splittable staple fiber, the nonwoven fabric, etc.) is determined with a Braunauer-Emmett-Teller (BET) test (see, for example, https://en.wikipedia.org/wiki/BET_theory) according to ISO 9277:2010 "Determination of the specific surface area of solids by gas absorption - BET method" (see, https://www.iso.org/standard/44941.html), hereby incorporated by reference in its entirety. The BET test measures the physical absorption of gas molecules onto the fiber (or sub-fiber) surface and therefore an increase in the BET test indicates an increase in surface area which corresponds to a higher split distribution/more splitting of the splittable fiber into sub-fibers as compared to a sample which does not contain split fibers.

[0084] That being said, it is recognized that the BET test only measures the total surface area (increase) and does not specifically distinguish between, for example, a single fiber which is split entirely into sub-fibers, and a plurality of fibers that are split only once to give the same total surface area.

[0085] In an embodiment herein, the splittable fiber; or the multicompoenent splittable fiber; or the multicomponent splittable staple fiber; or the nonwoven fabric, herein possess a surface area after splitting; or after carding, of from about 115% to about 800%; or from about 125% to about 700%; or from about 135% to about 650%; or from about 150% to about 600% of the surface area of a comparable sample; or of substantially the same sample, before splitting; or carding. In an embodiment wherein the splittable fiber constitutes about 50% of the total fiber mass, then the splittable fiber; or the multicompoenent splittable fiber; or the multicomponent splittable staple fiber; or the nonwoven fabric, herein possess a surface area after splitting; or after carding, of from about 115% to about 400%; or from about 125% to about 350%; or from about 135% to about 325%; or from about 150% to about 300% of the surface area of a comparable sample; or of substantially the same sample, before splitting; or carding.

[0086] In an embodiment herein, the split distribution of the splittable fiber (and/or the multicompoenent splittable fiber, the multicomponent splittable staple fiber, the nonwoven fabric, etc.) is determined with a Micronaire test (MIC) which is a Cotton industry standard measurement of a sample's air permeability and is used as an indication of fiber fineness and maturity (see, https://barnhardtcotton.net/blog/what-is-a-micronaire-in-cotton-and-why-does-it-matter/ and also https://www.cotton.org/journal/2005-09/2/upload/jcs09-081.pdf), all hereby incorporated by reference in their entireties. The MIC may be measured via, for example, the Uster® HVI 1000 (https://www.uster.com/en/instruments/cotton-classing/uster-hvi-2/), available from Uster Technologies AG, Sonnenbergstrasse 10, CH-8610 Uster, Switzerland. When comparing a sample containing unsplit fibers with a sample containing split fibers, the sample containing split fibers should have a higher air resistance. Thus, for a single (or otherwise substantially identical) sample, measuring the MIC before and after splitting (for example, before and after carding) would indicate whether or not the splittable fiber(s) have actually split, and provide an indication of the split distribution.

[0087] The scaling of a Micronaire instrument is by gauging known fiber sizes over a range of 0.2 denier (100% opened fibers) to 3 denier (100% un-opened fibers). The scale is accentually aligned with known fiber sizes across the expected range of opening to determine a 0% - 100% scale. Once the scale is established, then a nonwoven fabric sample containing splittable fibers having an original known denier can be tested both before and after splitting to determine the split distribution.

[0088] In an embodiment herein, the split distribution of the splittable fiber (and/or the multicompoenent splittable fiber, the multicomponent splittable staple fiber, the nonwoven fabric, etc.) is determined via visual and/or computer analysis of, for example, one or more scanning electron micrographs (SEMs). In such a method, identical; or substantially identical, samples may be compared before and after the splitting step (for example, by carding), to determine the split distribution.

[0089] In an embodiment herein, the split distribution is characterized by analyzing scanning electron micrographs (SEMs) to estimate and/or calculate the split distribution. SEMs may also be used herein to estimate/calculate the increase in surface area after splitting; or carding. It is recognized herein that counting microfibers and sub-fibers in a SEM image has one advantage over counting them in a cross section image, in that there is no ambiguity introduced by splitting that might occur in cutting the fiber for the cross section image. However, the cross section image also has an advantage over the SEM, which is that in the cross section image there is no uncertainty whether a microfiber comprises one, two, or three segments, or 7, 8, or 9 segments, etc. In an SEM image, even discerning between fibers that might comprise 3, 4, or 5 segments from those that might contain 6, 7, or 8 segments, for instance, is also a difficult judgment call. For this reason, counting the split and unsplit fibers in a cross section image is more reliable than counting fibers in an SEM image.

EXAMPLE 1

[0090] Control media is formed from 100% 3 dpf (denier per fiber) fibers. Splittable fibers according to the invention of the same (initial) size are formed into a nonwoven web and then split into a nonwoven fabric containing split fibers.

This nonwoven fabric is formed into a comparable filter, and then charged and left uncharged. All three structures are the same. The MERV test is conducted according to ASHRAE MERV Standard 52.2-2017 and the data recorded below.

Sample Description	BW (gsy)	Thickness (mils)	Air Perm (CFM)	IR (PA)	IR (in w.g.)	E1	E2	E3	MERV	Velocity fpm
Control	98.1	48.6	280.4	40	0.16	-0.6	26.6	79.9	8	110
Uncharged Split fibers	99.2	43.6	167.6	82	0.33	16.9	56.3	85.4	10	110
Charged Split fibers	99.2	43.6	167.6	73	0.29	59.8	82.1	95.6	12	110
BW = basis weight gsy = grams per square yard [1 gsy X 1.196 = GSM (grams per square meter)] Air perm = air permeability] CFM = cubic feet per minute as measured by Frazier Precision Instrument per ASTM D737 (1 CFM = 28.32 liters per minute) IR = Initial resistance PA = Pascals in w.g. = inches water gauge fpm = feet per minute (1 fpm = 30.48cm/min)										

[0091] From the above it can be seen that the uncharged split fiber sample increases in efficiency for E1, E2 and E3 as compared to the control sample. The charged split fiber sample increases in efficiency E1, E2, and E3 with respect to both the control sample and the uncharged split fiber sample. The control sample achieves a rating of MERV 8, while the uncharged split fiber sample achieves a rating of MERV 10, and the charged split fiber sample achieves a rating of MERV 12. In addition, the lower CFM of the split fiber samples also indicates an increased surface area compared to the control due to fibers due to the splitting.

EXAMPLE 2

[0092] A commercially available nano fiber-based media from Next Nano (Product Number NP048. Web Address: https://nxtnano.com/products/hvac/) is purchased. Nano fiber-based filtration media are typically fibers less than 200 nano meters (nm) in diameter and are not typically charged. The pure physical filtration (through sieving) does not allow for depth filtration and larger particles can build up on the surface of the media causing premature high resistance. Nano fiber-based filtration media are also to be used for a typical residential furnace filter. Below is an internal flat sheet test of such media compared to the invention which uses depth filtration, physical filtration and electro statics to balance the filtration media allowing adequate filtration.

Sample	IR (in w.g)	E1	E2	E3	MERV	Velocity fpm	Velocity m^3/hr
Next Nano	0.26	45.0	78.8	97.1	12	110	35.4
Invention	0.29	59.8	82.1	95.6	12	110	35.4
IR = Initial resistance in w.g. = inches water gauge fpm = feet per minute (1 fpm = 30.48 cm/min)							

[0093] As can be seen the present invention provides similar measurements as the Next Nano sheet; however, in a different technical manner.

EXAMPLE 3

[0094] In an embodiment herein, nonwoven fabric samples with various split distributions are compared.

[0095] Control Sample is a nonwoven fabric containing 100% nonsplittable fibers (3 dpf) is measured by the BET test, and compared to Samples 1-3. The Control Sample is not carded.

[0096] Sample 1 contains, by weight, 50% nonsplittable fibers and 50% splittable fibers. Both the splittable fibers and the nonsplittable fibers are initially of the same denier (3 dpf) as the control sample and thus the fabric sample (prior to splitting) is essentially identical to the Control Sample. Sample 1 is then "slightly" carded in order to split the splittable fibers into sub-fibers.

[0097] Sample 2 is essentially identical to Sample 1, except that Sample 2 is "normally" carded to split the splittable fibers into sub-fibers.

[0098] Sample 3 is essentially identical to Sample 2, except that Sample 3 contains a charge-enhancing additive is added to the splittable fiber and Sample 3 is charged via Corona Charging. Without intending to be limited by theory it is believed that the significant increase in surface area between Sample 3 and Sample 2 is due to the charged fibers repelling each other and thereby increasing the overall surface area.

[0099] The BET test results for these samples are show in the table below.

Sample	BET test surface area measurement (square meters surface area / gram of sample)	Surface area after carding (as % of Control)
Control Sample	0.145	100
Sample 1	0.209	144
Sample 2	0.267	184
Sample 3	0.303	209

[0100] Accordingly, it can be seen that carding significantly increases the surface area of the samples according to the present invention with a surface are ranging from 144% to 209% of the Control Sample which is substantially the same as the Samples before splitting.

EXAMPLE 4

[0101] In an embodiment of the present invention a conventional charge is applied to the formed nonwoven fabric after a thermal bonding process. The charge polarity is negative 30Kv @ 2.5 mA but can range from 0.5 KV @ 1 mA to 50Kv @ 3.0 mA. A SIMCO-ION FMX-003 Electrostatic Fieldmeter is used to measure the charge after the formation to the nonwoven fabric and before electret charging. The same electrostatic fieldmeter is used to measure the charge after electret charging and the results are shown below.

Sample	Charge (in kV)
Nonwoven fabric before charging	0.0
Nonwoven web after charging	-7.7 kV

[0102] Charge retention is a function of applied voltage, dwell time under the applicator bar (i.e., line speed in a continuous process), fiber density (surface area and basis weight), base fiber polymer, charge-enhancing additives and atmospheric conditions.

[0103] It should be understood that the above only illustrates and describes examples whereby the present invention may be carried out, and that modifications and/or alterations may be made thereto without departing from the spirit of the invention.

[0104] It should also be understood that certain features of the invention, which are, for clarity, described in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the invention which are, for brevity, described in the context of a single embodiment, may also be provided separately, or in any suitable subcombination.

[0105] All references specifically cited herein are hereby specifically incorporated by reference in their entireties. However, the citation or incorporation of such a reference is not necessarily an admission as to its appropriateness, citability, and/or availability as prior art to/against the present invention.

Claims

1. A process for forming a splittable or optionally a split fiber comprising the steps of:

A) providing a multicomponent fiber; or a multicomponent staple fiber, comprising:

  i) a first thermoplastic segment comprising polymer component A; and
  ii) a second thermoplastic segment comprising polymer component B;

B) providing a finish material, wherein the finish material has an evaporation point of less than about 160 °C; and
C) at least partially coating the multicomponent fiber; or a multicomponent staple fiber with the finish material to form a splittable fiber

  i) optionally wherein the coating step is selected from the group consisting of spraying the finish material onto the multicomponent fiber, immersing the multicomponent staple fiber in the finish material, contacting the fiber and a film of liquid finish material on the surface of a transfer roll, contacting the fiber with a bead of the finish material as the fiber passes through a grooved applicator, and a combination thereof; or a kiss-roll application process, a metered-finish application process, and a combination thereof, and
  ii) optionally wherein the finish material comprises a lubricant; or wherein the lubricant is selected from the group consisting of a plant-based oil, a natural oil, a synthetic oil, a water-soluble lubricant, and a combination thereof; or a vegetable oil, a mineral oil and a combination thereof; or a light vegetable oil, a light mineral oil, and a combination thereof; or a coconut oil, a corn oil, and a combination thereof

D) optionally comprising a splitting step of splitting the splittable fiber into a split fiber; or wherein the splitting step comprises a needle punching process, a hydroentanglement process, a carding process, a flexing process, a twisting process, a stretching process, a drawing process, a scraping process, a crushing process, a rolling process, a stitchbonding/stitchbinding process, and a combination thereof, wherein the splitting step is the same as the forming step; or wherein the splitting step comprises a hydropulping process and wherein the splitting step is before the forming step; or optionally comprising the step of splitting the multicomponent staple into a split fiber.

2. The process for forming a splittable or optionally a split fiber according to Claim 1, further comprising the step of removing the finish material from the splittable fiber, after the fiber is split, optionally wherein when the splittable fiber is fully split into a plurality of sub-fibers, the sub fiber has a linear density of less than about 5 denier; or less than about 2 denier; or less than about 1 denier; or less than about 0.8 denier; or less than about 0.4 denier.

3. The process for forming a splittable or optionally a split fiber according to any of the previous claims, further comprising the step of electret charging the split fiber; or wherein the electret charging comprises a process selected from the group of corona charging, atmospheric plasma deposition, and a combination thereof; or wherein the electret charging comprises corona charging and atmospheric plasma deposition.

4. The process for forming a splittable or optionally a split fiber according to any of the previous claims, further comprising the step of removing the finish material from the splittable fiber, after the fiber is split.

5. The process for forming a splittable or optionally a split fiber according to any of the previous claims, wherein the process does not employ a hydroentangling process.

6. A process for forming a nonwoven fabric comprising the steps of:

A) providing a splittable or optionally a split fiber according to any of the previous claims:
wherein the finish material has an evaporation point of less than 160 °C; and further comprising the step of
B) forming the splittable or optionally split fiber into a nonwoven fabric, optionally wherein the forming step is selected from the group consisting of carding, thermal bonding, needle punching, spunbonding/spinbonding, air laying, hydroentanglement, melt blowing, hydro pulping, refining, wet laying, thorough air oven, cross-lapping, and a combination thereof; or thermal bonding, needle punching, hydropulping, wet-laying, chemical bonding, melt blowing, air laying, carding, needling, hydroentanglement, and a combination thereof; or thermal bonding, needle punching, hydropulping, wet laying, and a combination thereof.

7. The process for forming a nonwoven fabric according to Claim 6, further comprising the steps of:
providing a nonsplittable fiber,
wherein the forming step comprises forming the nonwoven web from the splittable fiber and the nonsplittable fiber.

8. The process for forming a nonwoven fabric according to any of Claims 6 to 7, further comprising the step of removing at least a portion; or from about 50% to about 100%; or from about 75% to about 100%; or form about 80% to about 100% by weight of the finish material.

9. The process for forming a nonwoven fabric according to Claim 8, wherein the removing step occurs during or after the forming step.

10. A nonwoven fabric produced according to the process of any of Claims 6 to 9:

A) optionally wherein the nonwoven fabric comprises a nonsplittable fiber having a linear density of greater than about 1 denier; or from about 1.5 denier to about 4 denier; or from about 1.5 denier to about 3 denier;
B) optionally comprising an additional nonsplittable fiber; or an additional nonsplittable fiber having a linear density of from about 1 denier to about 20 denier; and
C) optionally comprising a charge-enhancing additive.

11. The nonwoven fabric according to Claim 4, wherein at a point in the splittable fiber, the splittable fiber is fully split into a plurality of sub-fibers, wherein the sub-fiber has a linear density of less than about 5 denier; or less than about 2 denier; or less than about 1 denier; or less than about 0.8 denier; or less than about 0.4 denier.

12. A split multicomponent fiber, or a nonwoven fabric comprising the split multicomponent fiber comprising a durable charge:

A) optionally wherein the durable charge lasts for at least about 1 year; or at least about 2 years; or at least about 3 years;
B) optionally having a linear density of less than about 5 denier; or less than about 2 denier; or less than about 1 denier; or less than about 0.8 denier; or less than about 0.4 denier;
C) optionally comprising a charge-enhancing additive; and
D) optionally wherein the nonwoven fabric comprises a nonsplittable fiber.

13. A filter comprising the nonwoven fabric of any of claims 6 to 11.

14. A spun yarn comprising the split fiber according to any claims 1 to 5.

15. The splittable fiber, or split fiber produced by the process according to any of claims 1 to 5.

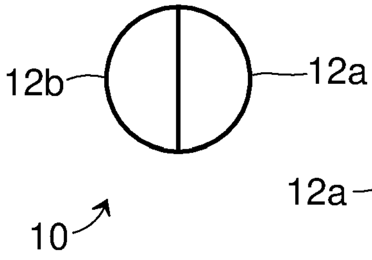


Fig. 1a

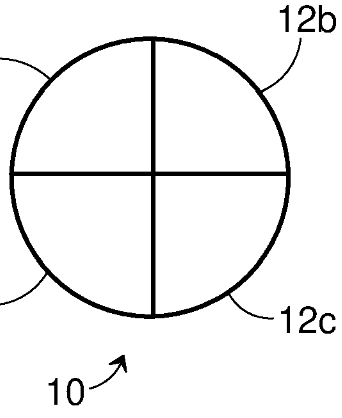


Fig. 1b

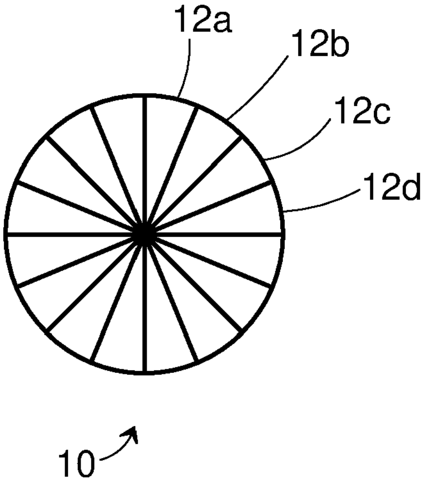


Fig. 1c

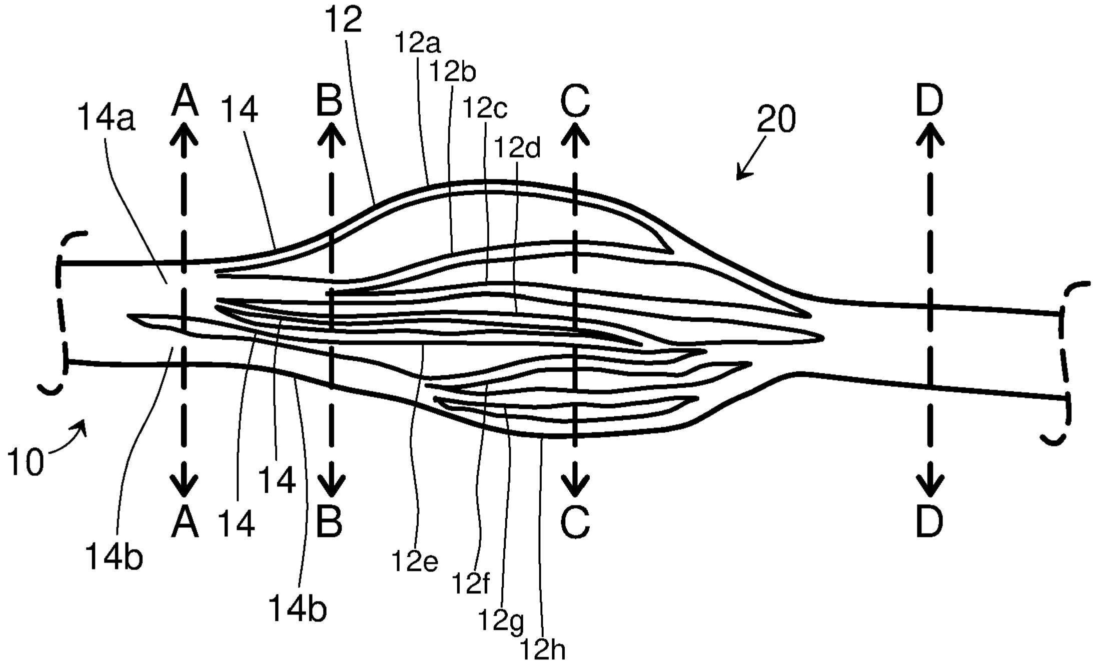
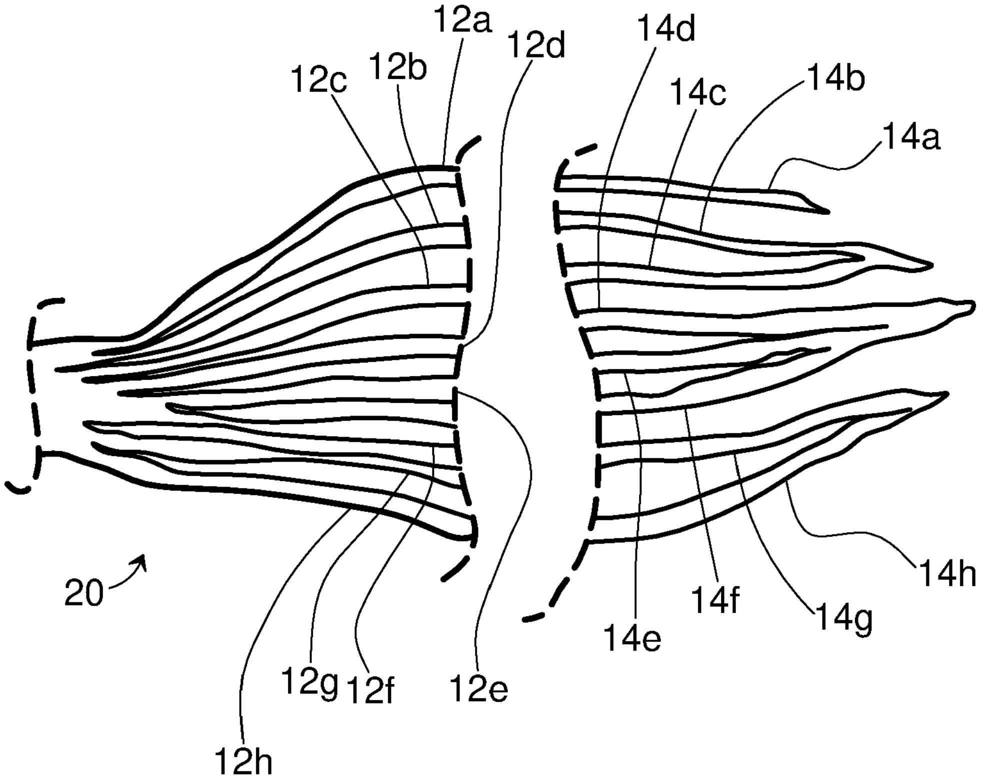


Fig. 2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12d
12c
12b
14d
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14b
14a
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14h
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Fig. 3

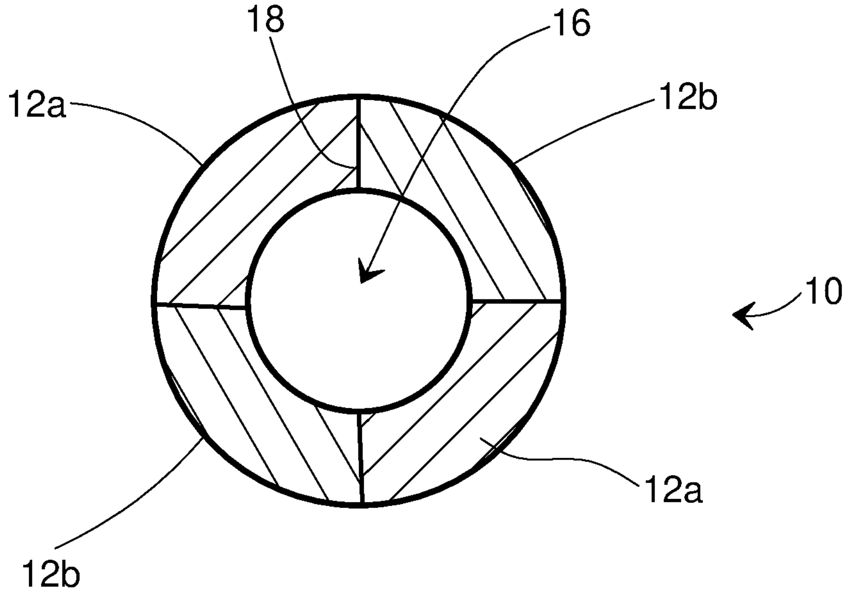
18
16
12a
12b
10
12a
12b

Fig. 4

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