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(54) Title: NONWOVEN PRODUCTS CONTAINING RECLAIMED TEXTILE MATERIALS

(57) Abstract: A nonwoven material is disclosed that contains deconstruct-
ed material obtained from recycled textile waste. The textile waste is decon-
structed in a way that produces freed fibers and freed yarn sections. The com-
bination of the freed fibers and the freed yarn sections can greatly enhance
the properties of the nonwoven material.

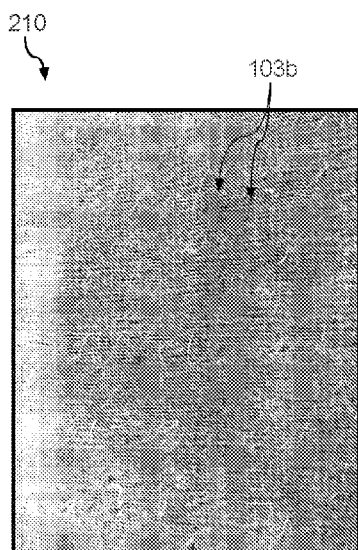


FIG. 10

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NONWOVEN PRODUCTS CONTAINING RECLAIMED TEXTILE MATERIALS

BACKGROUND

Domestic and industrial wipers are often used to pick up and absorb both polar liquids and non-polar liquids. The wipers should be constructed to have a sufficient absorption capacity to hold a liquid within the wiper structure. In addition, the wipers should also possess good physical strength and abrasion resistance to withstand the tearing, stretching and abrading forces often applied during use.

Conventional wiping products have been made from woven and knitted fabrics. Such wipers have been used in all different types of industries, such as for industrial applications, food service applications, health and medical applications, and for general consumer use.

In the past, nonwoven wipers have also been constructed made from pulp fibers alone or in combination with synthetic fibers. For example, in the past, spunbond webs made from continuous filaments have been hydroentangled with pulp fibers in order to produce a resilient wiping product. In many instances, these webs are for single use applications and then disposed. Although these wipers possess good levels of strength and absorbency, the wipers require significant amounts of polymer, particularly fossil-based polymers, for constructing the wipers.

In the past, attempts have also been made to incorporate recycled fibers into a nonwoven material. For example, U.S. Patent No. 6,037,282, which is incorporated herein by reference, describes a nonwoven material containing recycled fibers that have been mechanically shredded or torn from nonwoven waste or textile waste. The nonwoven material is made through a hydroentangling process. The resulting material contains flocks, which remain as non-uniformities in the material. These flocks can, in some applications, cause an undesirable reduction in strength.

In view of the above, a need currently exists for an improved process and product for incorporating recycled textile fibers into a nonwoven web.

SUMMARY

In general, the present disclosure is directed to nonwoven webs having an excellent balance of properties that contain recycled textile fibers. In accordance with the present disclosure, textile fabrics and other materials are reclaimed from the recycle stream and deconstructed in a manner that produces nonwoven webs with excellent properties. In particular, the deconstruction of textile materials is carefully controlled so as to produce a fiber furnish that not only contains freed individual fibers, but also contains freed yarn sections where the individual fibers have not been liberated. The combination of freed fibers and freed yarn sections has been found to produce nonwoven webs with unique and distinctive properties.

In one embodiment, the present disclosure is directed to a nonwoven material comprising freed fibers and freed yarn sections that have been obtained from a recycled textile material. The freed fibers and freed yarn sections are blended together to form the nonwoven material. The freed fibers have an average fiber length of greater than about 5 mm. The freed yarn sections also have an average fiber length of greater than about 5 mm. For example, the freed fibers can have an average fiber length of from about 6 mm to about 18 mm, including all increments of 0.5 mm therebetween. The freed yarn sections can have an average length of from about 6 mm to about 25 mm, including all increments of 0.5 mm therebetween. The freed yarn sections can be present in the nonwoven web generally in an amount greater than about 1% by weight, such as in an amount from about 2% to about 50% by weight, such as in an amount from about 5% to about 30% by weight.

The freed fibers and the freed yarn sections can be made from various different natural and synthetic materials. For instance, the freed fibers and the freed yarn sections can comprise polyester fibers. Alternatively, the freed fibers and freed yarn sections can comprise cellulose fibers, such as cotton fibers or regenerated cellulose fibers, such as rayon fibers. In one aspect, the freed fibers and the freed yarn sections can comprise a blend of polyester fibers and cotton fibers. For instance, the freed fibers and the freed yarn sections can contain polyester fibers in an amount from about 25% to about 75% by weight and can contain cotton fibers in an amount from about 25% to about 75% by weight.

In one aspect, the freed fibers and the freed yarn sections can be combined with pulp fibers. For example, pulp fibers can be present in the nonwoven material in an amount from about 5% to about 90% by weight, such as in an amount from about 55% to about 80% by weight. In one embodiment, the freed fibers and the freed yarn sections can comprise from about 10% to about 50% by weight, such as from about 15% to about 40% by weight of the nonwoven material.

The nonwoven web can be formed using various different processes and techniques. In one embodiment, the nonwoven web is a fluid formed web, such as a foam formed web. In one embodiment, the fluid formed web can also be hydroentangled.

The freed fibers present in the nonwoven material can generally have a relatively small size. For instance, the freed fibers can have a size of from about 0.5 denier to about 5 denier, such as from about 0.5 denier to about 3 denier, such as from about 0.5 denier to about 1.5 denier. The yarn sections can comprise spun yarns and can also have a relatively small size. For instance, the yarn sections can have a yarn size of from about 5 denier to about 15 denier, such as from about 5 denier to about 12 denier. In one embodiment, the nonwoven material can be produced without containing any flocks. The nonwoven material can generally have a basis weight of from about 20 gsm to about 500 gsm, such as from about 30 gsm to about 250 gsm.

The nonwoven material of the present disclosure can be used in numerous and diverse applications. In one embodiment, the nonwoven material can be used to produce a wiping product. For example, the nonwoven material can be used to produce industrial wipes. In one embodiment, the wiping products can be produced from the nonwoven material and then stacked together. In one
5 embodiment, the nonwoven material is formed into individual wiping products that are then pre-saturated with a cleaning fluid.

Other features and aspects of the present disclosure are discussed in greater detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

A full and enabling disclosure of the present disclosure is set forth more particularly in the
10 remainder of the specification, including reference to the accompanying figures, in which:

Figure 1 is a diagram illustrating one embodiment of a process for deconstructing textile materials for forming freed fibers and freed yarns for use in producing nonwoven materials according to the present disclosure;

Figure 2a and Figure 2b illustrate freed fibers and freed yarns obtained from a recycled textile
15 material;

Figure 3 is another view of freed fibers and freed yarns obtained from a recycled textile material;

Figures 4a and 4b are enlarged views from Figure 3 illustrating the freed fibers and the freed
yarns;

20 Figure 5 is a cross-sectional view illustrating yarns contained in a textile material;

Figure 6 is a perspective view of one embodiment of a freed yarn that can be incorporated into nonwoven materials made according to the present disclosure;

Figure 7 is a diagram illustrating one embodiment for forming nonwoven materials in accordance with the present disclosure;

25 Figure 8 is a schematic diagram of one embodiment of a process for forming a nonwoven material in accordance with the present disclosure;

Figure 9 is a schematic diagram of an enlarged partial view of the schematic diagram illustrated in Figure 8;

30 Figure 10 is a plan view of one embodiment of a nonwoven material made in accordance with the present disclosure;

Figure 11 is an enlarged portion of a nonwoven material made in accordance with the present disclosure illustrating freed fibers and freed yarns; and

Figure 12 is a diagram illustrating void volume in a nonwoven material.

Repeat use of reference characters in the present specification and drawings is intended to

represent the same or analogous features or elements of the present invention.

DEFINITIONS

The term "freed fibers" refers to individual fibers that have been obtained or extracted from a recycled textile material.

5 The term "freed yarn sections" are yarn sections having a discontinuous length that have been obtained or extracted from a recycled textile material.

 The term "yarn" is directed to a grouping of fibers intentionally associated with one another. Yarns can be formed from fibers using twisting, spinning, laying, layering, or otherwise grouping together the fibers. Yarns can include multifilament yarns made from continuous filaments, stretch
10 broken yarns made from stretch broken filaments, and spun yarns made from an intimate blend of staple fibers. A thread is a type of yarn. As used herein, a yarn is different and distinguished from a flock. The term "flock" is generally known to represent a random grouping of individual fibers and may include areas with surface imperfections, kinks, frayed ends, and the like and are not produced from an automated or man-made process. Nonwoven materials made according to the present disclosure
15 can be free of flocks.

 The term "machine direction" as used herein refers to the direction of travel of the forming surface onto which fibers are deposited during formation of a nonwoven web.

 The term "cross-machine direction" as used herein refers to the direction which is perpendicular to the machine direction defined above.

20 The term "pulp" as used herein refers to fibers from natural sources such as woody and non-woody plants. Woody plants include, for example, deciduous and coniferous trees. Non-woody plants include, for example, cotton, flax, esparto grass, milkweed, straw, jute, hemp, and bagasse. Pulp fibers can include hardwood fibers, softwood fibers, and mixtures thereof.

 The term "average fiber length" as used herein refers to an average length of fibers, fiber
25 bundles and/or fiber-like materials determined by measurement utilizing microscopic techniques. A sample of at least 20 randomly selected fibers is separated from a liquid suspension of fibers. The fibers are set up on a microscope slide prepared to suspend the fibers in water. A tinting dye is added to the suspended fibers to color cellulose-containing fibers so they may be distinguished or separated from synthetic fibers. The slide is placed under a Fisher Stereomaster II Microscope--S19642/S19643
30 Series. Measurements of 20 fibers in the sample are made at 20X linear magnification utilizing a 0-20 mils scale and an average length, minimum and maximum length, and a deviation or coefficient of variation are calculated. In some cases, the average fiber length will be calculated as a weighted average length of fibers (e.g., fibers, fiber bundles, fiber-like materials) determined by equipment such as, for example, a Kajaani fiber analyzer Model No. FS-200, available from Kajaani Oy Electronics,

Kajaani, Finland. According to a standard test procedure, a sample is treated with a macerating liquid to ensure that no fiber bundles or shives are present. Each sample is disintegrated into hot water and diluted to an approximately 0.001% suspension. Individual test samples are drawn in approximately 50 to 100 ml portions from the dilute suspension when tested using the standard Kajaani fiber analysis test procedure. The weighted average fiber length may be an arithmetic average, a length weighted average or a weight weighted average and may be expressed by the following equation:

$$\sum_{x_i=0}^k (x_i * n_i) / n$$

where

k=maximum fiber length

10 x=fiber length

n_i=number of fibers having length x_i

n=total number of fibers measured.

One characteristic of the average fiber length data measured by the Kajaani fiber analyzer is that it does not discriminate between different types of fibers. Thus, the average length represents an average based on lengths of all different types, if any, of fibers in the sample.

As used herein, the term "staple fibers" means discontinuous fibers made from synthetic polymers such as polypropylene, polyester, post-consumer recycle (PCR) fibers, polyester, nylon, and the like, and those not hydrophilic may be treated to be hydrophilic. Staple fibers may be cut fibers or the like. Staple fibers can have cross-sections that are round, bicomponent, multicomponent, shaped, hollow, or the like.

As used herein, the term "nonwoven web or material" refers to a web having a structure of individual fibers, yarns or mixtures thereof that are interlaid, but not in an identifiable manner as in a knitted or woven fabric. Nonwoven materials include, for example, carded webs, wet-laid webs, airlaid webs, foam-formed webs, and the like.

25 DETAILED DESCRIPTION

It is to be understood by one of ordinary skill in the art that the present discussion is a description of exemplary embodiments only and is not intended as limiting the broader aspects of the present disclosure.

In general, the present disclosure is directed to nonwoven materials that incorporate a substantial amount of recycled textile materials. The recycled textile materials incorporated into the nonwoven material can be in the form of freed fibers, freed yarn sections, and mixtures thereof. In

accordance with the present disclosure, recycled textile materials are deconstructed in a manner that produces freed fibers and freed yarn sections that have been found particularly well suited for producing nonwoven materials with many beneficial properties. The recycled freed fibers and yarn sections incorporated into the nonwoven material also can replace virgin materials used in the past, such as polyester fibers. In this regard, nonwoven webs made according to the present disclosure not only remove and utilize materials from the waste stream but also lower reliance on fossil-based polymers. Thus, products made according to the present disclosure are sustainable and economically friendly.

In the past, various attempts have been made in order to incorporate recycled fibers into nonwoven materials. For example, U.S. Patent No. 6,037,282, which is incorporated herein by reference, discloses a nonwoven material that contains recycled fibers. In the above patent, the recycled fibers form flocks in the material which remain as non-uniformities. The presence of the flocks in the material can have various disadvantages. For instance, when present in a certain amount, the flocks can cause an undesirable reduction in the strength of the material.

In order to possibly remove flocks, one possible approach would be to deconstruct the recycled textile material to an extent that only freed fibers remain. For instance, U.S. Patent No. 6,378,179, which is incorporated herein by reference, discloses a method of freeing fibers from textile materials. Producing fully free fibers from recycled textile materials, however, requires much greater energy requirements and slows throughput during the deconstruction process. In addition, the resulting fibers are not amenable to hydroentangling processes due to their shorter sizes.

In this regard, the present disclosure is directed to incorporating recycled textile materials into nonwoven materials wherein the amount the recycled textile materials are deconstructed is controlled and limited such that the resulting furnish includes not only freed fibers, but also freed yarn sections. The freed yarn sections have been found to provide various advantages and benefits when incorporated into the resulting nonwoven products. For instance, the yarn sections can modify the surface texture of the nonwoven materials making them well suited for use as a wiping product. The yarn sections are also believed to increase void volume and therefore increase absorbency. The yarn sections also do not detrimentally affect the strength characteristics of the nonwoven material and, may in fact increase tensile strength in one or more directions.

Referring to **FIG. 1**, one embodiment of a process for deconstructing a recycled textile material in order to obtain freed fibers and freed yarn sections is shown. Initially, a recycled textile material or waste **101** is collected. In accordance with the present disclosure, the recycled textile material can comprise any textile material that contains yarns and fibers that may be incorporated into a nonwoven web in accordance with the present disclosure. In one aspect, the recycled textile material is a fabric

material, such as a woven fabric, a knitted fabric, a nonwoven fabric, or the like. Examples of recycled textile materials that can be used to produce nonwoven products in accordance with the present disclosure include bedding materials, such as sheets, pillow cases, covers, and the like. The recycled textile material can also comprise used towels and/or hospitality materials. Hospitality materials can include tablecloths or coverings, cloth napkins, decorated coverings, and the like. The recycled textile materials can also include clothing items. For instance, the recycled textile materials can include pants, shirts, jeans, blouses, other garments, and mixtures thereof. In still another aspect, the recycled textile material can comprise upholstery fabrics or any other suitable textile materials contained in the recycling stream that can be deconstructed into fibers and yarn sections.

As shown in **FIG. 1**, once the recycled textile materials **101** are collected, the materials are then fed to a deconstruction treatment **102**. During the deconstruction treatment **102**, the recycled textile materials are deconstructed into freed fibers and yarn sections. For example, the recycled textile materials **101** can be cut, shredded or torn into smaller pieces and fed through deconstruction equipment. The deconstruction treatment **102**, for instance, can include but is not limited to, mechanical tearing, shredding, carding, and any other non-chemical manner of transforming the recycled textile material **101** into a deconstructed material **103**.

Deconstruction equipment designed to deconstruct recycled textile materials can include, in one embodiment, drums that include spiked rollers. The recycled textile material is subjected to mechanical shredding and cut into small pieces and with the help of the spiked rollers is torn up to produce the deconstructed material **103**. One embodiment of deconstruction equipment that can be used in accordance with the present disclosure is disclosed in U.S. Patent No. 5,113,559, which is incorporated herein by reference. The '559 patent discloses a textile machine drum that contains a cylinder. Attached to the cylinder are staves which include points or teeth. In order to deconstruct textile material, the textile scraps are fed to one or more successive drums (or fed through a single drum multiple times) and the points or needles deconstruct the material.

In accordance with the present disclosure, the deconstruction equipment is designed to deconstruct the textile material a limited and controlled amount such that the resulting deconstructed material **103** contains freed fibers **103a** combined with freed yarn sections **103b** as shown in **FIG. 1**. More particularly, the deconstruction treatment **102** is particularly controlled to produce a desired specification of deconstructed material **103**. For instance, the deconstruction treatment **102** settings and parameters are controlled in order to produce a predetermined range of freed fibers **103a** in combination with freed yarns **103b**. The parameters and settings are also controlled in order to produce a deconstructed material **103** where the freed fibers **103a** and the yarn sections **103b** have a desired length or range of lengths. More particularly, the deconstruction treatment **102** can be

controlled in order to produce a deconstructed material **103** that has desired fiber lengths, yarn section lengths, degree of freeness, amount of kink or curl, amount of twists, end quality, and with service quality or smoothness if desired.

Referring to **FIGS. 2A, 2B, 3, 4A, and 4B**, deconstructed material **103** that may be used to
5 produce nonwoven materials in accordance with the present disclosure is shown. Referring to **FIGS. 2A and 2B**, for instance, the deconstructed material **103** is shown that includes freed fibers **103a** combined with freed yarn sections **103b**. Referring to **FIG. 2B**, the freed fibers **103a** and the freed yarn sections **103b** are shown in greater detail.

Referring to **FIG 3**, another embodiment of deconstructed textile material **103** in accordance
10 with the present disclosure is shown. The deconstructed material **103** is shown in greater detail in **FIGS. 4A and 4B**. As shown in **FIGS. 4A and 4B**, the deconstructed material **103** includes freed fibers **103a** combined with freed yarn sections **103b**.

The freed yarn sections **103b** are more pronounced in the above figures. The yarn sections
103b can also have a longer average fiber length than the freed fibers, although not necessary. The
15 freed yarn sections **103b** represent yarns contained in the recycled textile materials that have not been deconstructed into fibers. The yarns can be, for instance, spun yarns, stretch broken yarns, or multifilament yarns. For example, referring to **FIG. 5**, a cross-section of a yarn **103b** is shown prior to being deconstructed. The deconstructed yarn section **103b** is illustrated in **FIG. 6**. As shown, the freed yarn section **103b** includes individual fibers **104** that create a particular configuration of void
20 space **301**.

It was discovered that inclusion of the yarn sections **103b** can provide various advantages and benefits. The yarn sections **103b**, for instance, as shown in **FIG. 6**, create a distinct pattern of void space that can provide capillary action when absorbing fluids, such as liquids. In addition, the yarn sections **103b** can enhance the overall strength of the resulting nonwoven material. The yarn sections
25 **103b** also change the surface characteristics of the nonwoven material. In particular, the yarn sections **103b** can produce a material with greater texture or topography that can enhance the abrasive properties of the nonwoven material when rubbed against a surface and/or can increase the absorbency characteristics of the material, especially when used for grease and oil removal.

The yarn sections can exist in the nonwoven material in various forms. For example, the yarn
30 sections can remain intact in the material and appear as sections of spun yarns. Alternatively, the yarn sections can be in the form of unraveled fibers that remain in a bundle-like form. In still another embodiment, the yarn sections can be in the form of unraveled fibers that are spread out through the web. The yarn sections can exist in all forms in the material.

In general, any suitable textile fiber contained within the recycled textile material can be used

to produce nonwoven materials in accordance with the present disclosure. The types of fibers included in the recycled textile materials can include synthetic polymer fibers, synthetic cellulose fibers, natural fibers including natural cellulose fibers, and the like. Synthetic polymer fibers that can be extracted from the recycled textile materials include, for instance, polyester fibers, nylon fibers, polyolefin fibers including polypropylene fibers and polyethylene fibers, or the like. The synthetic polymer fibers can be monocomponent fibers or can be bicomponent fibers that include a sheath-core configuration or a side-by-side configuration.

Any suitable regenerated cellulose fiber can also be extracted from the recycled textile materials and incorporated into nonwoven products made in accordance with the present disclosure.

Regenerated cellulose fibers include rayon in all of its varieties and other fibers derived from viscose or chemically-modified cellulose. For instance, the regenerated cellulose fibers can include lyocell fibers, modal fibers, and the like.

The recycled textile materials can also contain natural fibers that are incorporated into the nonwoven materials made in accordance with the present disclosure. Natural fibers include cotton fibers and pulp fibers. Pulp fibers can include softwood fibers, hardwood fibers, and mixtures thereof.

In one embodiment, the recycled textile material deconstructed in accordance with the present disclosure contains only polyester fibers. In an alternative embodiment, the deconstructed textile material of the present disclosure contains only cotton fibers. In still other embodiments, the deconstructed textile material can contain a blend of fibers, such as a blend of polyester fibers and cellulose fibers, such as cotton fibers and/or regenerated cellulose fibers, such as rayon. The fiber blend can contain polyester fibers, for instance, in an amount greater than about 10% by weight, such as in an amount greater than about 20% by weight, such as in an amount greater than about 30% by weight, such as in an amount greater than about 40% by weight, such as in an amount greater than about 50% by weight, such as in an amount greater than about 60% by weight, such as in an amount greater than about 70% by weight, and generally in an amount less than about 80% by weight, such as in an amount less than about 70% by weight, such as in an amount less than about 60% by weight, such as in an amount less than about 50% by weight. The cellulose fibers contained with the polyester fibers can be present in the deconstructed textile material generally in the same amounts as described above. For instance, the cellulose fibers, such as cotton fibers, can be present in the deconstructed textile material in an amount greater than about 10% by weight, such as in an amount greater than about 20% by weight, such as in an amount greater than about 30% by weight, such as in an amount greater than about 40% by weight, such as in an amount greater than about 50% by weight, such as in an amount greater than about 60% by weight, such as in an amount greater than about 70% by weight, and generally in an amount less than about 80% by weight, such as in an amount less than

about 70% by weight, such as in an amount less than about 60% by weight, such as in an amount less than about 50% by weight, such as in an amount less than about 40% by weight.

In one aspect, the recycled textile material selected for being deconstructed in accordance with the present disclosure can be selected so as to have a particular fiber type for a particular application. For example, when incorporated into a nonwoven material and used to absorb hydrophobic substances, such as oils and greases, the recycled textile material may contain greater amounts of synthetic polymer fibers, such as polyester fibers. For instance, the deconstructed textile material may contain synthetic polymer fibers in an amount greater than about 70% by weight, such as in an amount greater than about 80% by weight. When the nonwoven material of the present disclosure is used to absorb water or otherwise needs to have hydrophilic properties, on the other hand, the deconstructed textile material can contain greater amounts of cellulose fibers. For instance, the deconstructed textile material can contain cellulose fibers in an amount greater than about 50% by weight, such as in an amount greater than about 60% by weight, such as in an amount greater than about 70% by weight, such as in an amount greater than about 80% by weight.

The length of the freed fibers liberated from the recycled textile materials can vary depending upon the particular application and the starting materials used. In addition, the freed fibers can have a relatively wide fiber length distribution or a relatively narrow fiber length distribution. In general, the average fiber length of the freed fibers is greater than about 5 mm, such as greater than about 6 mm, such as greater than about 7 mm, such as greater than about 8 mm, such as greater than about 9 mm, such as greater than about 10 mm, such as greater than about 12 mm, such as greater than about 14 mm, such as greater than about 16 mm. The average fiber length of the freed fibers is generally less than about 25 mm, such as less than about 23 mm, such as less than about 20 mm, such as less than about 18 mm, such as less than about 15 mm, such as less than about 12 mm, such as less than about 10 mm. The fiber length distribution, on the other hand, can be from about 1 mm to about 60 mm, such as from about 3 mm to about 50 mm.

The size of the fibers can also vary. In one embodiment, relatively fine fibers are used. For instance, the fibers can have a size of less than about 15 denier, such as less than about 12 denier, such as less than about 10 denier, such as less than about 8 denier, such as less than about 7 denier, such as less than about 6 denier, such as less than about 5 denier, such as less than about 4 denier, such as less than about 3 denier, such as even less than about 2 denier. The size of the fibers is generally greater than about 0.5 denier, such as greater than about 1 denier, such as greater than about 1.25 denier, such as greater than about 1.5 denier. In one aspect, larger fibers can be used having a size of greater than about 2 denier, such as greater than about 4 denier, such as greater than about 6 denier, such as greater than about 8 denier, such as greater than about 10 denier.

The yarn sections contained in the deconstructed textile material are generally made from the freed fibers described above. Thus, the individual fibers contained in the yarn sections can have any of the sizes described above with respect to the freed fibers.

The length of the yarn sections can also vary depending upon the particular application. The
 5 yarn sections, for instance, can have an average length of greater than about 5 mm, such as greater than about 6 mm, such as greater than about 7 mm, such as greater than about 8 mm, such as greater than about 9 mm, such as greater than about 10 mm, such as greater than about 12 mm, such as greater than about 14 mm, such as greater than about 16 mm, such as greater than about 18 mm, such as greater than about 20 mm, such as greater than about 22 mm, such as greater than about 24
 10 mm, such as greater than about 26 mm. The average fiber length of the yarn sections is generally less than about 80 mm, such as less than about 70 mm, such as less than about 60 mm, such as less than about 50 mm, such as less than about 40 mm, such as less than about 30 mm, such as less than about 25 mm, such as less than about 20 mm, such as less than about 18 mm, such as less than about 16 mm. In one aspect, the average length of the yarn sections can be greater than the average
 15 length of the freed fibers. Alternatively, the average length of the freed fibers can be longer than the average length of the yarn sections.

The length distribution of the yarn sections can vary widely or be relatively narrow. In one embodiment, longer yarn sections are present in the yarn section length distribution. For instance, at least some of the yarn sections can have a length of greater than about 15 mm, such as greater than
 20 about 20 mm, such as greater than about 25 mm, such as greater than about 30 mm, such as greater than about 35 mm, such as greater than about 40 mm, such as greater than about 50 mm, and generally less than about 80 mm, such as less than about 60 mm.

As described above, the freed yarn sections can be spun yarns, multifilament yarns, stretch broken yarns, and the like. The size of the yarns are generally greater than about 5 denier, such as
 25 greater than about 8 denier, such as greater than about 10 denier, such as greater than about 12 denier, such as greater than about 14 denier, such as greater than about 16 denier, such as greater than about 18 denier, such as greater than about 20 denier. The size of the yarns are generally less than about 30 denier, such as less than about 28 denier, such as less than about 26 denier, such as less than about 24 denier, such as less than about 22 denier, such as less than about 20 denier, such
 30 as less than about 18 denier, such as less than about 16 denier, such as less than about 14 denier, such as less than about 12 denier, such as less than about 10 denier.

The proportion of freed yarn sections in the deconstructed textile material can also be varied and controlled based upon the deconstruction process. In one aspect, the freed yarn sections can be contained in the deconstructed textile material in an amount less than about 80% by weight, such as in

an amount less than about 60% by weight, such as in an amount less than about 40% by weight, such as in an amount less than about 30% by weight, such as in an amount less than about 20% by weight, such as in an amount less than about 10% by weight. The freed yarn sections can be contained in the deconstructed textile material in an amount greater than about 1% by weight, such as in an amount greater than about 5% by weight, such as in an amount greater than about 10% by weight, such as in an amount greater than about 20% by weight, such as in an amount greater than about 30% by weight, such as in an amount greater than about 40% by weight, such as in an amount greater than about 50% by weight, such as in an amount greater than about 60% by weight, such as in an amount greater than about 70% by weight. The rest of the deconstructed textile material can comprise the freed fibers. For instance, freed fibers can be contained in the deconstructed textile material in an amount from about 1% to about 99% by weight, including all increments of 1% by weight therebetween. For instance, the freed fibers can be contained in the deconstructed textile material in an amount greater than about 10% by weight, such as in an amount greater than about 20% by weight, such as in an amount greater than about 30% by weight, such as in an amount greater than about 40% by weight, such as in an amount greater than about 50% by weight, such as in an amount greater than about 60% by weight, such as in an amount greater than about 70% by weight, such as in an amount greater than about 80% by weight, such as in an amount greater than about 90% by weight. The freed fibers can be contained in the deconstructed textile material generally in an amount less than about 95% by weight, such as in an amount less than about 90% by weight, such as in an amount less than about 80% by weight, such as in an amount less than about 70% by weight, such as in an amount less than about 60% by weight, such as in an amount less than about 50% by weight, such as in an amount less than about 40% by weight.

In forming nonwoven materials according to the present disclosure, the nonwoven materials can be formed exclusively from the deconstructed textile materials containing freed fibers combined with freed yarn sections. Alternatively, the freed fibers and freed yarn sections can be combined with virgin fibers in forming nonwoven materials. The virgin fibers can be natural cellulose fibers, synthetic cellulose fibers, synthetic polymer fibers, and the like. The nonwoven materials can also contain binders, such as chemical binders and/or binder fibers. Chemical binders include latex binders. Binder fibers are fibers that include a surface made from a low melt polymer that softens and bonds to adjacent fibers when heated. The binder fibers can be bicomponent fibers in one embodiment. Binder fibers can be present in the nonwoven web in an amount of from about 2% to about 40% by weight including all increments of 1% by weight therebetween.

In one embodiment, for instance, the freed fibers and freed yarn sections can be combined with cellulosic fibers. Cellulosic fibers that may be incorporated into the material include but not limited

to nonwoody fibers, such as cotton, abaca, kenaf, sabai grass, flax, esparto grass, straw, jute hemp, bagasse, milkweed floss fibers, and pineapple leaf fibers; and woody or pulp fibers such as those obtained from deciduous and coniferous trees, including softwood fibers, such as northern and southern softwood kraft fibers; hardwood fibers, such as eucalyptus, maple, birch, and aspen. Pulp
5 fibers can be prepared in high-yield or low-yield forms and can be pulped in any known method, including kraft, sulfite, high-yield pulping methods and other known pulping methods. Fibers prepared from organosolv pulping methods can also be used. The cellulosic fibers described above, for instance, can have an average fiber length of less than about 8 mm, such as less than about 6 mm, such as less than about 4 mm. The average fiber length of the cellulosic fibers is generally greater
10 than about 1 mm, such as greater than about 2 mm, such as greater than about 3 mm.

Other cellulosic fibers that can be incorporated into the material and combined with the freed fibers and the freed yarn sections include cotton fibers and/or any suitable regenerated cellulose fibers including rayon fibers, viscose fibers, model fibers, lyocell fibers, and the like.

15 In still another embodiment, the freed fibers and the freed yarn sections can be combined with virgin synthetic polymer fibers. The synthetic polymer fibers can be polyester fibers, nylon fibers, polyolefin fibers, and the like.

In one embodiment, the deconstructed textile material containing the freed fibers and the freed yarn sections can be made exclusively from polyester fibers, can be made exclusively from
20 cellulosic fibers, or can be made from a blend of cellulosic fibers and polyester fibers. The cellulosic fibers can be cotton fibers or can be regenerated cellulose fibers, such as rayon fibers. When the deconstructed textile material contains a blend of different fibers, the polyester fibers can be present in an amount from about 25% to about 75% by weight including all increments of 1% therebetween and the cellulosic fibers can be present in the deconstructed textile material in an amount from about 25%
25 to about 75% by weight including all increments of 1% by weight therebetween. The above deconstructed textile material can then be used alone or combined with virgin fibers. For instance, the deconstructed textile material can be combined with pulp fibers, can be combined with other cellulose fibers, or can be combined with virgin polyester fibers.

When combined with pulp fibers, such as softwood fibers, hardwood fibers, or mixtures
30 thereof, the pulp fibers can be present in the resulting nonwoven material in an amount greater than about 40% by weight, such as in an amount greater than about 50% by weight, such as in an amount greater than about 60% by weight, such as in an amount greater than about 70% by weight, and generally in an amount less than about 90% by weight, such as in an amount less than about 80% by weight. The remainder of the nonwoven material can be made from the deconstructed textile material

containing freed fibers and freed yarn sections. For instance, the deconstructed textile material can be contained in the resulting nonwoven material in an amount less than about 60% by weight, such as in an amount less than about 50% by weight, such as in an amount less than about 40% by weight, and generally in an amount greater than about 10% by weight, such as in an amount greater than about 20% by weight. In one embodiment, when combined with pulp fibers, the deconstructed textile material can contain polyester fibers in an amount from about 50% to about 80% by weight, such as in an amount from about 55% to about 75% by weight and can contain cellulose fibers, particularly cotton fibers and/or regenerated cellulose fibers, in an amount from about 20% to about 50% by weight, such as in an amount from about 25% to about 45% by weight.

When combined with virgin polyester fibers, virgin cotton fibers, virgin regenerated cellulose fibers, or mixtures thereof, the deconstructed textile material containing the freed fibers and the freed yarn sections can be present in the nonwoven material generally in an amount from about 5% to about 95% by weight, including all increments of 1% therebetween. In one embodiment, the deconstructed textile material is present in the nonwoven material in amounts greater than about 40%, such as in amounts greater than about 60%, and generally in amounts less than about 85%, such as in amounts less than about 70%. Alternatively, the deconstructed textile material can be present in relatively minor amounts, such as in amounts less than about 35% by weight, such as in amounts less than about 25% by weight, such as in amounts less than about 20% by weight, and generally in amounts greater than about 5% by weight, such as in amounts greater than about 10% by weight. The virgin polyester fibers, virgin cotton fibers, or virgin regenerated cellulose fibers can have an average fiber length of from about 15 mm to about 60 mm, such as from about 25 mm to about 45 mm, and can have a size of from about 0.5 denier to about 15 denier, such as from about 1 denier to about 10 denier, such as from about 1 denier to about 5 denier, such as from about 1 denier to about 4 denier.

Once a fiber furnish has been selected in accordance with the present disclosure containing at least a portion of freed fibers and freed yarn sections, the fiber furnish can be formed into a nonwoven material or web using any suitable process. For example, the nonwoven material can be made through a carding process or can be fluid formed. Fluid forming processes include wetlaid processes, foam-formed processes, air-laid processes, and dry-laid processes. The nonwoven material can also be hydroentangled during the process. Hydroentanglement, for instance, can be used with any of the fluid-formed processes or carding processes described above.

Referring to **FIG. 7**, one embodiment of a diagram showing a process for producing nonwoven materials in accordance with the present disclosure is illustrated. As shown, a recycled textile material **101** is deconstructed into a deconstructed material **103** containing freed fibers and freed yarn sections

as described above. The deconstructed textile material **103** is optionally combined with virgin fibers **203** to form a fiber furnish **202**.

Once the fiber furnish **202** is collected, various different consolidation steps can occur. For instance, the fiber furnish can be consolidated through fiber pulping and blending, headbox formation, foam generation, or can be fed to a mixing tank and foam pulping process.

The fiber furnish **202** is then fed to a web forming process **204**. The web forming process **204** can be a carding process or any of the fluid forming processes described above. From the web forming process **204**, the formed nonwoven web can optionally be subjected to a hydroentangling process **205**. The hydroentangling process can be then used to form the nonwoven material **210**. Optionally, after the hydroentangling process **205**, the nonwoven web can be fed to a drying process **206** prior to collecting the nonwoven material **210**. Any suitable drying process **206** can be used to dry the nonwoven material. For instance, the drying process can include through-air dryers, heated drums, or combinations thereof.

In one particular embodiment, for exemplary purposes only, the fiber furnish can be formed into the nonwoven material using a foam forming process in combination with a hydroentangling step. During foam forming, the fiber furnish is combined with a foam created by blending water with a foaming agent.

The foaming agent, for instance, may comprise any suitable surfactant. In one embodiment, for instance, the foaming agent may comprise sodium lauryl sulfate, which is also known as sodium laureth sulfate or sodium lauryl ether sulfate. In one embodiment, the foaming agent is a nonionic surfactant which may comprise an alkyl polyglycoside. The foaming agent, for instance, can be a C8 alkyl polyglycoside, a C10 alkyl polyglycoside, or a mixture of C8 and C10 alkyl polyglycosides.

Other foaming agents include sodium dodecyl sulfate or ammonium lauryl sulfate. In other embodiments, the foaming agent may comprise any suitable cationic and/or amphoteric surfactant. For instance, other foaming agents include fatty acid amines, amides, amine oxides, fatty acid quaternary compounds, and the like.

The foaming agent is combined with water generally in an amount greater than about 0.1% by weight, such as in an amount greater than about 1% by weight, such as in an amount greater than about 2% by weight, such as in an amount greater than about 3% by weight. One or more foaming agents are generally present in an amount less than about 50% by weight, such as in an amount less than about 10% by weight, such as in an amount less than about 8% by weight, such as in an amount less than about 4% by weight.

Once the foaming agent and water are combined, the mixture is blended or otherwise subjected to forces capable of forming a foam. A foam generally refers to a porous matrix, which is an aggregate of hollow cells or bubbles which may be interconnected to form channels or capillaries.

The foam density can vary depending upon the particular application and various factors including the fiber furnish used. In one embodiment, for instance, the foam density of the foam can be greater than about 200 g/L, such as greater than about 250 g/L, such as greater than about 300 g/L. The foam density is generally less than about 600 g/L, such as less than about 500 g/L, such as less than about 400 g/L, such as less than about 350 g/L. In one embodiment, for instance, a lower density foam is used having a foam density of generally less than about 350 g/L, such as less than about 340 g/L, such as less than about 330 g/L. The foam will generally have an air content of greater than about 30%, such as greater than about 40%, such as greater than about 50%, such as greater than about 60%. The air content is generally less than about 80% by volume, such as less than about 70% by volume, such as less than about 65% by volume.

In order to form the nonwoven web, the foam is combined with a selected fiber furnish in conjunction with any auxiliary agents. The foamed suspension of fibers is then pumped to a tank and from the tank is fed to a headbox. **FIGS. 8 and 9**, for instance, show one embodiment of a process in accordance with the present disclosure for forming the web. As shown particularly in **FIG. 9**, the foamed fiber suspension can be fed to a tank **312** and then fed to the headbox **310**. From the headbox **310**, the foamed fiber suspension is issued onto an endless traveling forming fabric **326** supported and driven by rolls **328** in order to form a web **210**. As shown in **FIG. 9**, a forming board **314** may be positioned below the web **210** adjacent to the headbox **310**. Once formed on the forming fabric **326**, the foam formed web can have a consistency of less than about 50%, such as less than about 20%, such as less than about 10%, such as less than about 5%. In fact, the forming consistency can be less than about 2, such as less than about 1.8, such as less than about 1.5. The forming consistency is generally greater than about 0.5, such as greater than about 0.8. The forming consistency indicates the ability to produce webs according to the present disclosure while minimizing the amount of water needed during formation.

Once the wet web is formed on the forming fabric **326**, the web is conveyed downstream and dewatered. For instance, the process can optionally include a plurality of vacuum devices **316**, such as vacuum boxes and vacuum rolls. The vacuum boxes assist in removing moisture from the newly formed web **210**.

As shown in **FIG. 9**, the forming fabric **326** may also be placed in communication with a steambox **318** positioned above a pair of vacuum rolls **320**. The steambox **318**, for instance, can increase dryness and reduce cross-directional moisture variance. The applied steam from the

steambox **318** heats the moisture in the wet web **210** causing the water in the web to drain more readily, especially in conjunction with the vacuum rolls **320**. From the forming fabric **326**, the newly formed web **210**, in the embodiment shown in **FIG. 8**, is conveyed downstream, subjected to hydroentangling, and dried on a through-air dryer.

5 After the foam formed web has been produced, the web is subjected to one or more hydroentangling steps. In the embodiment illustrated in **FIG. 9**, for instance, the web **210** is subjected to two different hydroentangling steps. In particular, in **FIG. 9**, the web **210** is hydroentangled on a first surface during a first hydroentangling step and then hydroentangled on a second and opposite surface during a second hydroentangling step. As shown in **FIG. 9**, for example, the process can include a
10 first hydroentangling device **330** and a second hydroentangling device **332**. The hydroentangling that occurs at each hydroentangling station may be accomplished utilizing conventional hydroentangling equipment. The hydroentangling of the foam formed web may be carried out with any appropriate working fluid such as, for example, water. The working fluid flows through a manifold which evenly distributes the fluid through a series of individual holes or orifices. Exemplary holes or orifices, for
15 example, can have a diameter of from about 0.003 inches to about 0.015 inches. For example, the manifold may include a strip of orifices having a diameter of 0.007 inches. The manifold may contain about 20 to about 40 holes per inch and can include 1 to 3 rows of holes. Many other manifold configurations and combinations may be used. In the embodiment illustrated in **FIG. 9**, for instance, the hydroentangling device **330** includes a plurality of injectors **334**, while the hydroentangling device
20 **332** includes a plurality of injectors **336**. The injectors **334** and **336** can be part of the manifold and can be in communication with a working fluid supply.

 During the hydroentangling process, the working fluid can pass through the orifices at pressures ranging from about 200 psig to about 3,500 psig. At the upper ranges of the described pressures, it is contemplative that the web may be processed at speeds of from about 500 ft/min to
25 about 2000 ft/min. The fluid impacts the material or web which can be supported on a foraminous surface or wire or may be supported on a porous drum surface. In the embodiment illustrated in **FIG. 9**, for instance, hydroentangling occurs on a first drum **338** and a second drum **340**.

 When supported on a foraminous surface or wire during hydroentangling, the wire can have a mesh size of from about 40x40 to about 100x100. The wire or surface may also be a multi-ply mesh
30 having a mesh size of from about 50x50 to about 200x200.

 As described above, alternatively, the web **210** can be placed directly onto the surface of the drum **338** and on the surface of the drum **340** during hydroentangling. Each drum can include a plurality of openings or vacuum passages for withdrawing excess water. These openings or vacuum passages can also create a pattern into the web **210** during the hydroentangling process. For

example, a pattern can be formed into one surface of the web at the first hydroentangling station and a pattern can be formed into the second and opposite surface of the web at the second hydroentangling station. The pattern formed into each surface of the web 210 can be highly distinctive and can increase the aesthetic appeal of nonwoven materials made from the web. In addition, the pattern
5 formed into the web can be three dimensional including hills and valleys. This three dimensional topography can further improve various properties of the material.

In addition to improving the appearance of the web 210, the one or more hydroentangling stations can also significantly improve various physical properties of the web 210, such as the integrity of the web. For example, the columnar jets of working fluid which directly impact the surfaces of the
10 web serve to entangle and intertwine the fibers contained in the web, especially the freed yarn sections and freed fibers. The hydroentangling processes ultimately form a coherent entangled matrix. The hydroentangling steps also further serve to create a substantially homogeneous fiber mixture within the web. The resulting hydroentangled web, for instance, is "non-layered" and contains no distinguishable separate fibrous layers over the thickness of the web.

15 Once the foam formed web 210 is hydroentangled one or more times, the web can be dried using a non-compressive drying operation. For example, as shown in FIG. 8, the foam formed web can be dried using a through-air dryer.

Referring to FIG. 8, the foam formed and hydraulically entangled web 210 is transferred from the drum 340 to a throughdrying fabric 344 with the aid of a vacuum transfer roll 346 or a vacuum
20 transfer shoe. If desired, the throughdrying fabric can be run at a slower speed than the web 210 to further enhance stretch. Transfer can be carried out with vacuum assistance to ensure deformation of the sheet to conform to the throughdrying fabric, thus yielding desired bulk and appearance if desired.

In the embodiment illustrated in FIG. 8, the foam formed web 210 is transferred to a throughdrying fabric 344. Alternatively, the foam formed web can be transferred to a metal, porous
25 sleeve that forms the circumference of the throughdryer 348. The use of a metal sleeve instead of a fabric may provide various advantages. For instance, a porous metal sleeve may further create porosity for increasing the liquid absorbent properties of the web.

Alternatively, the foam formed web 210 can be conveyed on the throughdrying fabric 344 over the circumference of the throughdryer 348. The throughdrying fabric can contain high and long
30 impression knuckles. For example, the throughdrying fabric can have about from about 5 to about 300 impression knuckles per square inch which are raised at least about 0.005 inches above the plane of the fabric. During drying, the web can be further macroscopically arranged to conform to the surface of the throughdrying fabric. Flat surfaces, however, can also be used in the present disclosure.

The side of the web contacting the throughdrying fabric is typically referred to as the "fabric side" of the nonwoven web. The fabric side of the nonwoven web, as described above, may have a shape that conforms to the surface of the throughdrying fabric after the fabric is dried in the throughdryer. The opposite side of the nonwoven web, on the other hand, is typically referred to as the "air side". The air side of the web is typically smoother than the fabric side during normal throughdrying processes.

The level of vacuum used for the web transfers can be from about 3 to about 15 inches of mercury (75 to about 380 millimeters of mercury), preferably about 5 inches (125 millimeters) of mercury. The vacuum shoe or roll (negative pressure) can be supplemented or replaced by the use of positive pressure from the opposite side of the web to blow the web onto the next fabric in addition to or as a replacement for sucking it onto the next fabric with vacuum.

The web is finally dried to a consistency of about 94 percent or greater by the throughdryer **348** and thereafter transferred to a carrier fabric **350**. The dried basesheet **352** is transported to the reel **354** using carrier fabric **350** and an optional carrier fabric **356**. An optional pressurized turning roll **358** can be used to facilitate transfer of the web from carrier fabric **350** to fabric **356**. Suitable carrier fabrics for this purpose are Albany International 84M or 94M and Asten 959 or 937, all of which are relatively smooth fabrics having a fine pattern. Although not shown, reel calendering or subsequent off-line calendering can be used to improve the smoothness and softness of the basesheet.

In one embodiment, the resulting foam formed web **352** is a textured web, which has been dried in a three-dimensional state. The texture in the web can be created due to the hydroentangling stations, due to the manner in which the web is dried using the through-dryer **348** or can be a result of both processes. For example, the web **352** can be dried while still including a pattern formed into the web.

The basis weight of webs made in accordance with the present disclosure can vary depending upon the final product. For example, the process may be used to produce paper towels, industrial wipers, food service wipers, and the like. In general, the basis weight of the products may vary from about 15 gsm to about 500 gsm. The basis weight, for instance, can be greater than about 30 gsm, such as greater than about 40 gsm, such as greater than about 45 gsm, such as greater than about 50 gsm, such as greater than about 55 gsm, such as greater than about 60 gsm, such as greater than about 65 gsm, and generally less than about 400 gsm, such as less than about 200 gsm, such as less than about 150 gsm, such as less than about 120 gsm.

The process of the present disclosure can also produce webs with good bulk characteristics. The bulk, for instance, can generally be greater than about 3 cc/g, such as greater than about 5 cc/g,

such as greater than about 8 cc/g, such as greater than about 10 cc/g, such as greater than about 12 cc/g, and generally less than about 20 cc/g, such as less than about 15 cc/g.

The sheet "bulk" is calculated as the quotient of the caliper of a dry tissue sheet, expressed in microns, divided by the dry basis weight, expressed in grams per square meter. The resulting sheet bulk is expressed in cubic centimeters per gram. More specifically, the caliper is measured as the total thickness of a stack of ten representative sheets and dividing the total thickness of the stack by ten, where each sheet within the stack is placed with the same side up. Caliper is measured in accordance with TAPPI test method T411 om-89 "Thickness (caliper) of Paper, Paperboard, and Combined Board" with Note 3 for stacked sheets. The micrometer used for carrying out T411 om-89 is an Emveco 200-A Tissue Caliper Tester available from Emveco, Inc., Newberg, Oreg. The micrometer has a load of 2.00 kilo-Pascals (132 grams per square inch), a pressure foot area of 2500 square millimeters, a pressure foot diameter of 56.42 millimeters, a dwell time of 3 seconds and a lowering rate of 0.8 millimeters per second. In one embodiment, caliper can be measured while the web is wet. In fact, nonwoven materials made according to the present disclosure have excellent wet resiliency properties.

Referring to **FIGS. 10** and **11**, one embodiment of a nonwoven material **210** made in accordance with the present disclosure is shown. As shown in **FIG. 10**, the freed yarn sections **103b**, in one embodiment, can be visible when viewing the top surface of the web. **FIG. 11** is a diagram showing the interrelationship between the freed fibers **103a** and the freed yarn sections **103b**. As shown, both fiber types become blended together in forming a consolidated structure. As described above, the nonwoven material **210** can also contain virgin fibers, such as cotton fibers, synthetic polymer fibers, regenerated cellulose fibers, and smaller pulp fibers.

As illustrated in **FIG. 10**, the freed yarn sections **103b** are distributed throughout a fiber matrix formed by the freed fibers **103a**. In general, the distribution of the freed yarn sections **103b** throughout the nonwoven sheet **210** can be from about 0.5% to about 99% per square meter based on area, including all increments of 0.5% therebetween. The amount of freed yarn sections **103b** distributed throughout the nonwoven material **210** can have varying effects on the physical properties of the resulting material. In various embodiments, the distribution of the freed yarn sections **103b** and the nonwoven material **210** can generally be greater than about 10%, such as greater than about 15%, such as greater than about 20%, such as greater than about 25%, such as greater than about 30%, and generally less than about 45%, such as less than about 40%, such as less than about 30% per square meter based upon total surface area.

Nonwoven materials made according to the present disclosure can be used in numerous different types of applications. For example, the nonwoven materials can be used to make absorbent

components in absorbent articles, such as diapers, feminine hygiene products, adult incontinence products, pull-ups, or the like. The nonwoven materials can also be used to produce all types of wiping products, such as consumer wipes, industrial wipes, premoistened wipes, mop heads, towels, and the like.

5 In one embodiment, the nonwoven material can be cut into individual sheets that are well suited for use as an industrial wiper. The wipers may have any suitable size and shape. In one embodiment, the wiper can have a width of from about 8 cm to about 100 cm, such as from about 10 cm to about 50 cm, such as from about 20 cm to about 25 cm. The length of the wiper can be from about 10 cm to about 200 cm, such as from about 20 cm to about 100 cm, such as from about 35 cm
10 to about 45 cm.

 If desired, the wiper may also be pre-moistened with a liquid, such as water, a solvent, a waterless hand cleanser, or any other suitable liquid. The liquid may contain antiseptics, fire retardants, industrial cleaners, surfactants, emollients, humectants, and so forth. The liquid may be applied by any suitable method known in the art, such as spraying, dipping, saturating, impregnating,
15 brush coating and so forth. The amount of the liquid added to the wiper may vary depending upon the nature of the composite fabric, the type of container used to store the wipers, the nature of the liquid, and the desired end use of the wipers. Generally, each wiper contains greater than about 150 wt. %, in some embodiments from about 150 to about 1500 wt. %, and in some embodiments, from about 300 to about 1200 wt. % of the liquid based on the dry weight of the wiper.

20 The wipers may be packaged in a variety of forms, materials and/or containers, including, but not limited to, rolls, boxes, tubs, flexible packaging materials, and so forth. Some examples of suitable containers include rigid tubs, film pouches, etc.

 As described above, the freed yarn sections **103b** contained within the nonwoven material **210** can contribute to various performance characteristics and enhanced properties. For instance, the
25 freed yarn sections **103b** may increase absorbency, increase strength, increase wicking rate, increase capillary flow, increase void volume, and change the porosity in a very beneficial way.

 As explained with respect to **FIG. 6**, for instance, the freed yarn sections **103b** contain a group of individual fibers that have a void volume and pore structure that is different from the rest of the material. In general, each freed yarn section **103b** can contain from about 10 individual fibers to about
30 500 individual fibers. For instance, each freed yarn section can contain greater than about 15 fibers, such as greater than about 20 fibers, such as greater than about 30 fibers, such as greater than about 40 fibers, such as greater than about 50 fibers, such as greater than about 60 fibers, such as greater than about 70 fibers, such as greater than about 80 fibers, such as greater than about 90 fibers, such as greater than about 100 fibers, such as greater than about 110 fibers, and less than about 170

fibers, such as less than about 150 fibers, such as less than about 130 fibers, such as less than about 110 fibers, such as less than about 90 fibers, such as less than about 70 fibers. In one aspect, the freed yarn sections can contain from about 32 individual fibers to about 80 individual fibers grouped together.

5 Referring to **FIG. 12**, for purposes of explanation, a portion of a freed yarn section is shown containing three individual fibers **303**. As shown, the three fibers **303** form a unique void space or capillary where the fibers intersect. These capillaries are particularly well suited to absorbing all different types of substances and fluids, such as water, oil, grease, solvents, cleaning solutions, and the like. The small capillaries can be used to absorb contaminants and keep them within the
10 nonwoven material or can be used to absorb and release cleaning solutions or solvents.

The void volume (V_{void}) of each freed yarn section **103b** is a function of both the number of individual fibers **303** and the denier of each individual fiber **303** contained within the fiber group. As shown in **FIG. 12**, the void volume between three tangential individual fibers **303** of equal denier can be determined using the following equations:

15

$$\begin{aligned} V_{\text{void}} &= L[A_1 - A_2] \\ A_1 &= (1/2r) \times (r\sqrt{3}) \\ A_2 &= 1/2 \pi r^2 \end{aligned}$$

20

A_1 = Area of Triangles **310** Formed
by Center of 3 Fibers **303**
 r = Radius of Fiber **303**

25

A_2 = AREA(**307**) of the section of Fiber
303 Intersected by Triangle **310**

L = Length of Freed Yarn **103B**

30 As shown, the void volume of a freed yarn section containing three individual fibers of equal denier is the result of the area of the equilateral triangle **310** formed from the center of the three fibers **303** minus the three sectional areas **307** of the individual fibers **303** intersected by the equilateral triangle **310**, all multiplied by the length of the freed yarn section **103b**. In embodiments where the freed yarn sections **103b** contain more than three individual fibers, the equations above can be used
35 to determine the void volume for every three tangential fibers creating a total void volume between them.

Depending upon the fiber furnish used to create the nonwoven material, the void volume created by the freed yarn sections can have a varied impact. As described above, the nonwoven

material can be combined with virgin fibers including pulp fibers, synthetic polymer fibers, regenerated cellulose fibers, and the like. In one embodiment, the void volume contained within the freed yarn sections can be greater than the void volume created by the freed fibers. Alternatively, the void volume created by the fibers in the nonwoven material can be greater than the void volume created by the freed yarn sections. In one embodiment, the void volume created by the freed yarn sections can have a different pore structure and serve a different function when absorbing fluids. For instance, the void volume created by the freed yarn sections can create capillary forces that cause fluids to remain within the fiber structure once contacted with the freed yarn sections. In this manner, the freed yarn sections can greatly improve the absorbency characteristics of the nonwoven material.

These and other modifications and variations to the present invention may be practiced by those of ordinary skill in the art, without departing from the spirit and scope of the present invention, which is more particularly set forth in the appended claims. In addition, it should be understood that aspects of the various embodiments may be interchanged both in whole or in part. Furthermore, those of ordinary skill in the art will appreciate that the foregoing description is by way of example only and is not intended to limit the invention so further described in such appended claims.

WHAT IS CLAIMED:

1. A nonwoven material comprising:
freed fibers and freed yarn sections that are both obtained from a recycled textile material, the freed fibers and freed yarn sections being blended together to form the nonwoven material, the freed fibers having an average fiber length of greater than about 5 mm, freed yarn sections also having an
5 average fiber length of greater than about 5 mm, the nonwoven material optionally containing pulp fibers.
2. A nonwoven material as defined in claim 1, wherein the freed fibers have an average fiber length of from about 6 mm to about 18 mm.
3. A nonwoven material as defined in any of the preceding claims, wherein the freed yarn sections have an average length of from about 6 mm to about 25 mm.
4. A nonwoven material as defined in any of the preceding claims, wherein the yarn sections are present in the nonwoven material in an amount from about 2% by weight to about 50% by weight, such as in an amount from about 5% by weight to about 30% by weight based upon the total weight of the freed yarn sections and freed fibers.
5. A nonwoven material as defined in any of the preceding claims, wherein the freed fibers and freed yarn sections comprise a polyester polymer.
6. A nonwoven material as defined in any of claims 1-4, wherein the freed fibers and the freed yarn sections comprise cellulose fibers.
7. A nonwoven material as defined in any of the preceding claims, wherein the freed fibers and the freed yarn sections comprise a blend of polyester fibers and cotton fibers.
8. A nonwoven material as defined in claim 7, wherein the freed fibers and the freed yarn sections comprise from about 25% by weight to about 75% by weight polyester fibers and from about 25% by weight to about 75% by weight cotton fibers.
9. A nonwoven material as defined in any of the preceding claims, wherein the nonwoven material comprises a fluid formed web.
10. A nonwoven material as defined in any of the preceding claims, wherein the nonwoven material comprises a foam formed web.
11. A nonwoven material as defined in any of the preceding claims, wherein the nonwoven material contains pulp fibers.
12. A nonwoven material as defined in claim 11, wherein the nonwoven material contains pulp fibers in an amount from about 55% by weight to about 80% by weight.
13. A nonwoven material as defined in any of the preceding claims, wherein the nonwoven material contains the freed fibers and the yarn sections in an amount from about 10% by

weight to about 50% by weight, such as in an amount from about 15% by weight to about 40% by weight.

14. A nonwoven material as defined in any of the preceding claims, wherein the yarn sections comprise spun yarns.

15. A nonwoven material as defined in any of the preceding claims, wherein the nonwoven material has been hydroentangled.

16. A nonwoven material as defined in any of the preceding claims, wherein the nonwoven material has a basis weight of from about 20 gsm to about 400 gsm, such as from about 30 gsm to about 250 gsm.

17. A nonwoven material as defined in any of the preceding claims, wherein the freed fibers and the fibers contained in the freed yarn sections have a size of from about 0.5 denier to about 5 denier, such as from about 0.5 denier to about 3 denier, such as from about 0.5 denier to about 1.5 denier.

18. A nonwoven material as defined in any of the preceding claims, wherein the yarn sections have a yarn size of from about 5 denier to about 15 denier, such as from about 5 denier to about 12 denier.

19. A nonwoven material as defined in any of the preceding claims, wherein the nonwoven material is free of flock.

20. An absorbent product made from the nonwoven material as defined in any of the preceding claims.

21. An absorbent product as defined in claim 20, wherein the absorbent product comprises an industrial wiper.

22. An absorbent product as defined in claim 20 or 21, wherein the absorbent product comprises a plurality of individual wipers stacked together.

23. An absorbent product as defined in claim 20, wherein the absorbent product comprises the nonwoven material pre-saturated with a cleaning solvent.

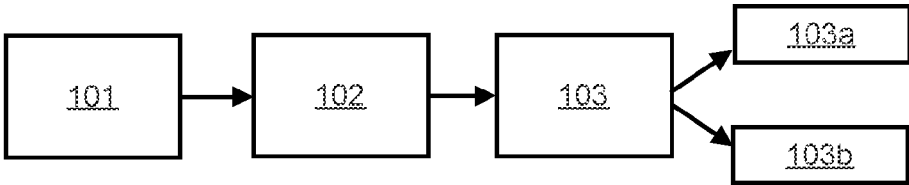


FIG. 1

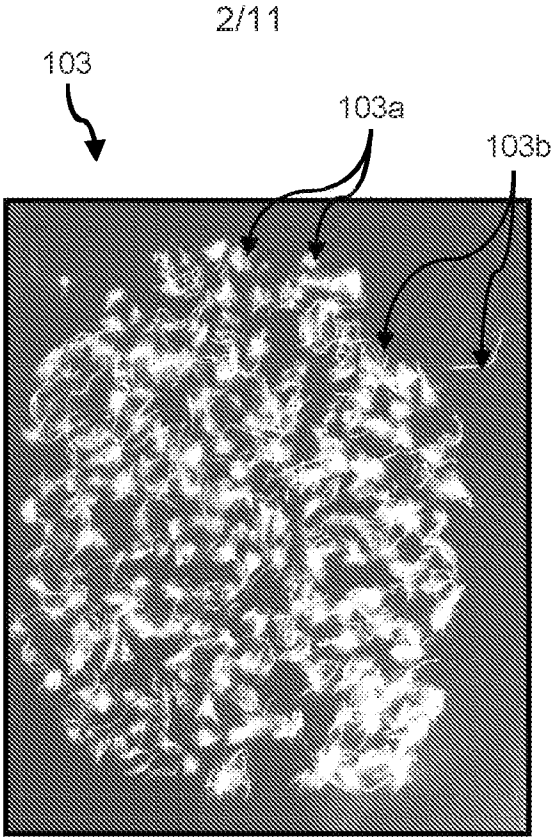


FIG. 2A

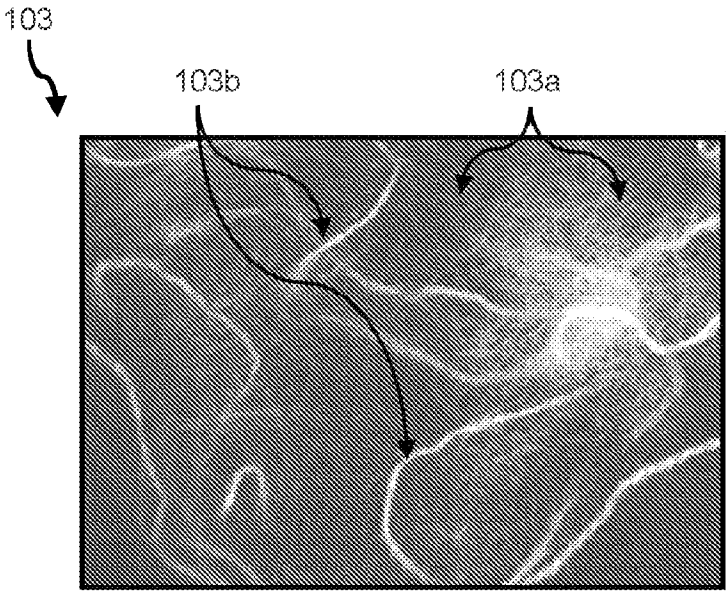


FIG. 2B

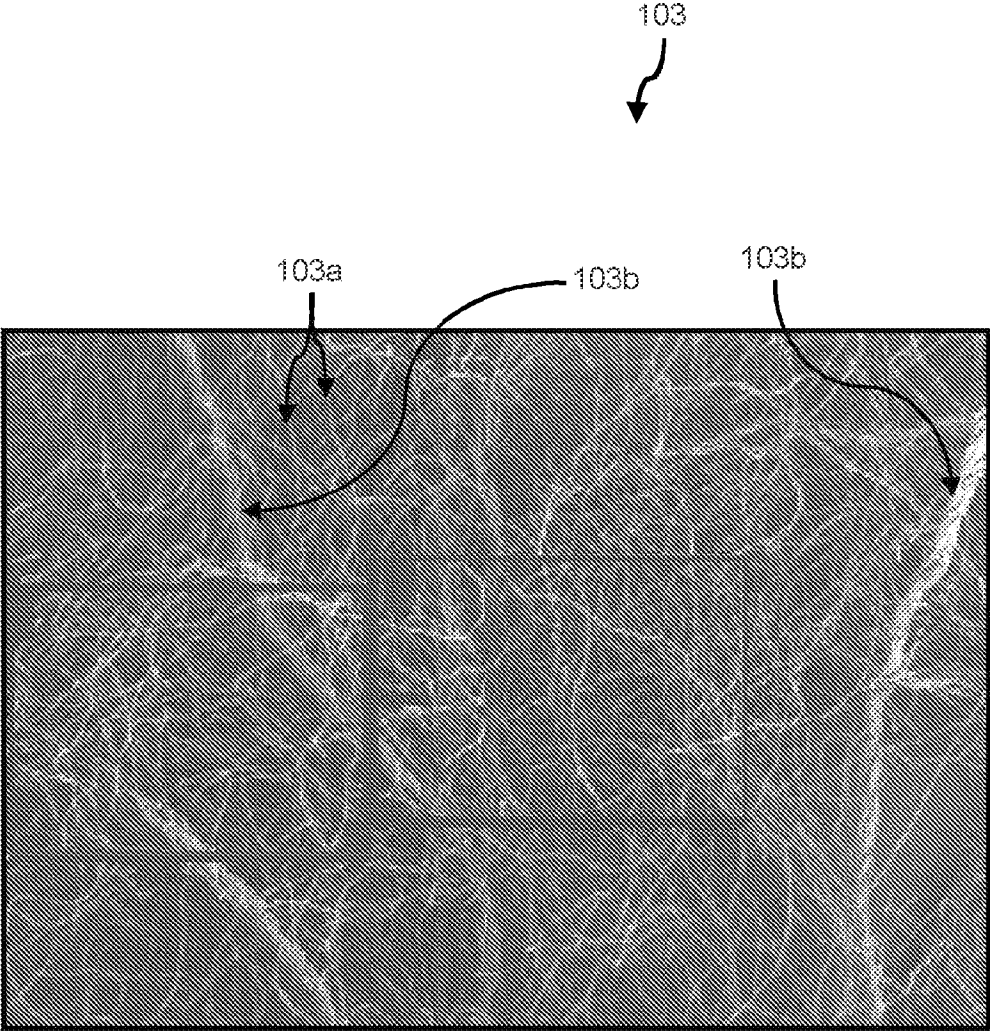


FIG. 3

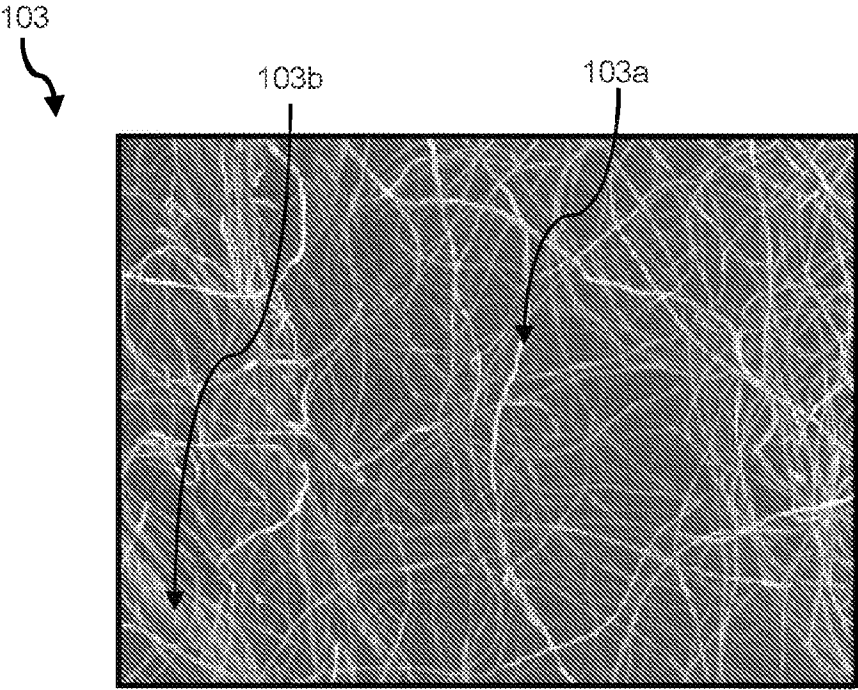


FIG.4A

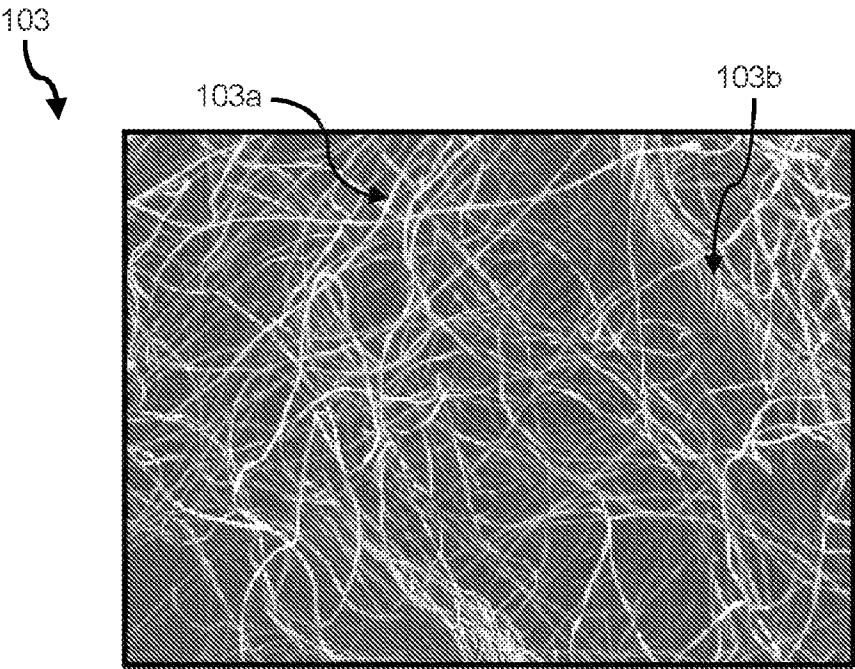


FIG.4B

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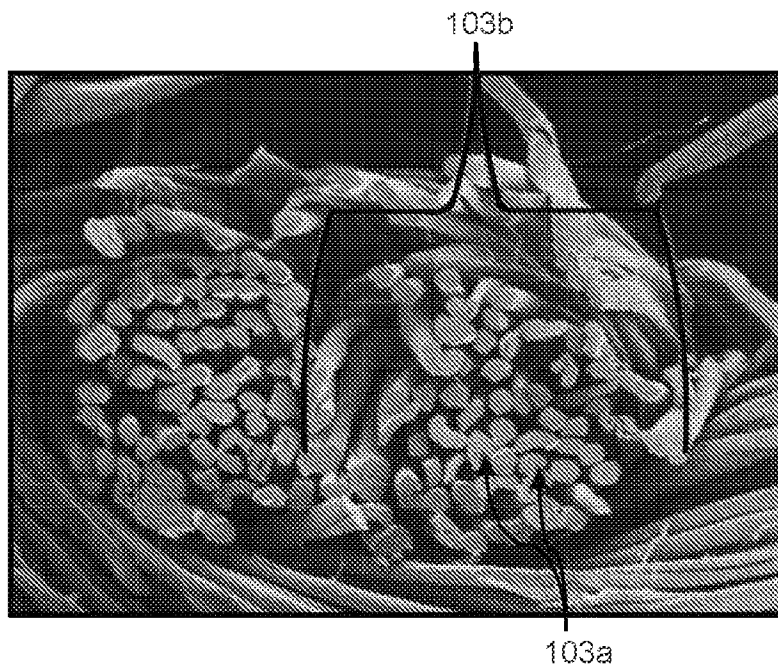


FIG. 5

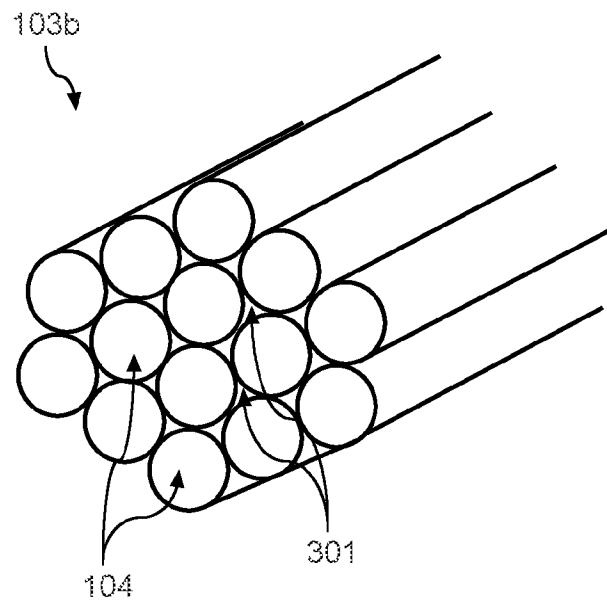


FIG. 6

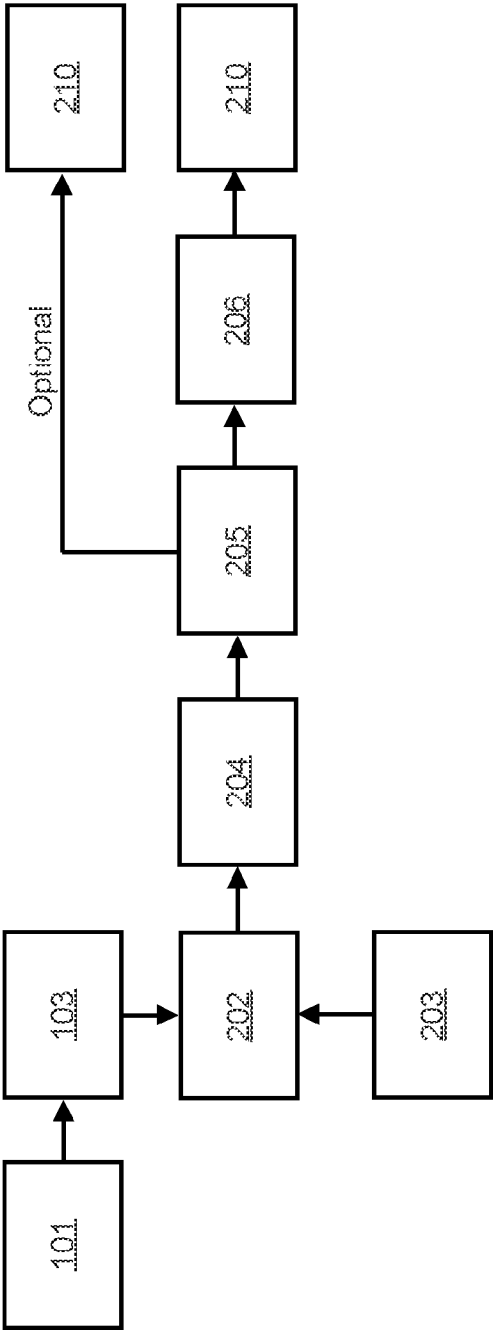


FIG. 7

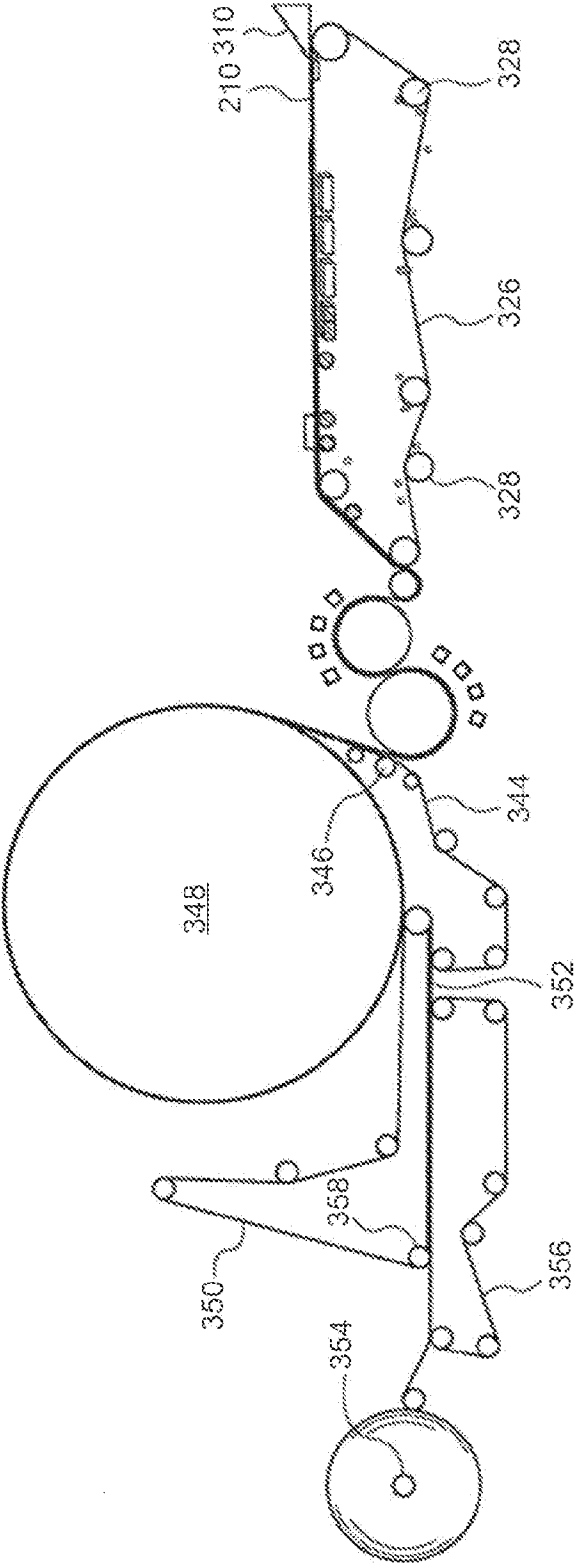
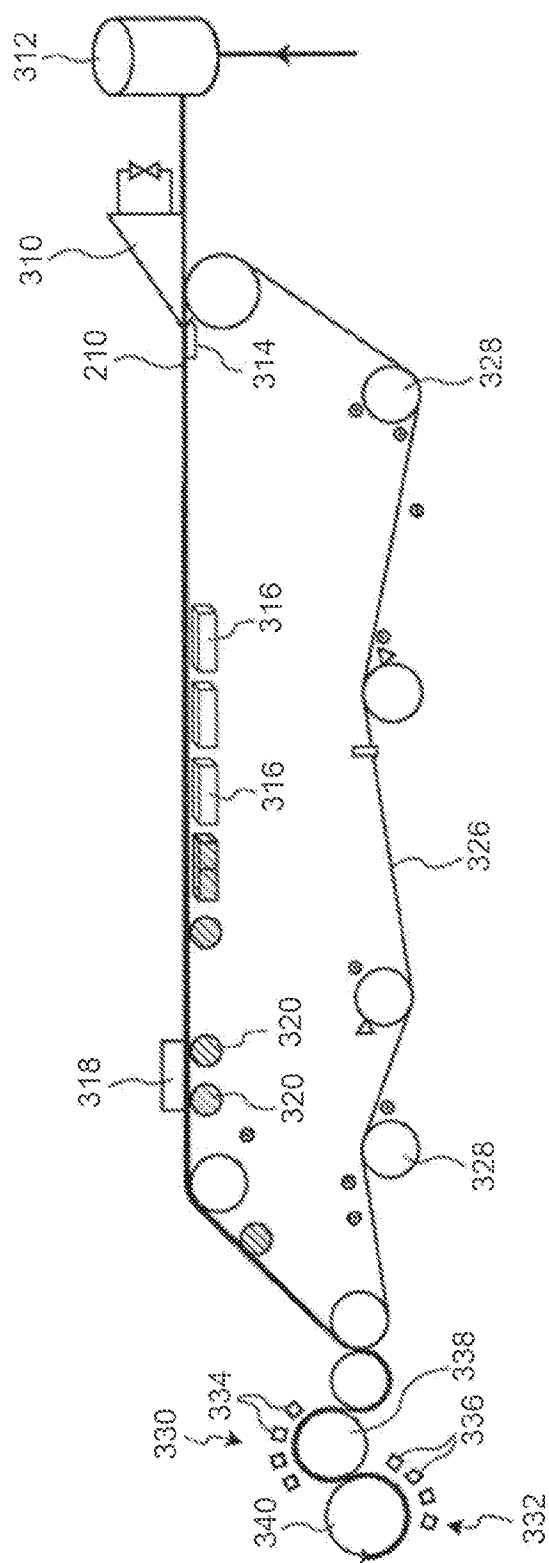


FIG. 8

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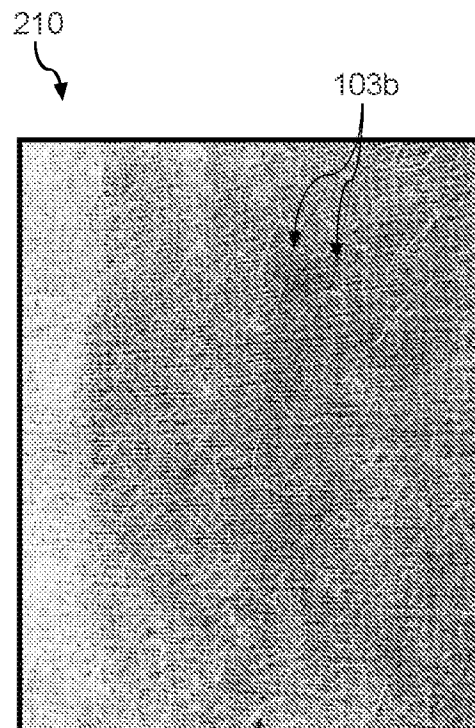


FIG. 10

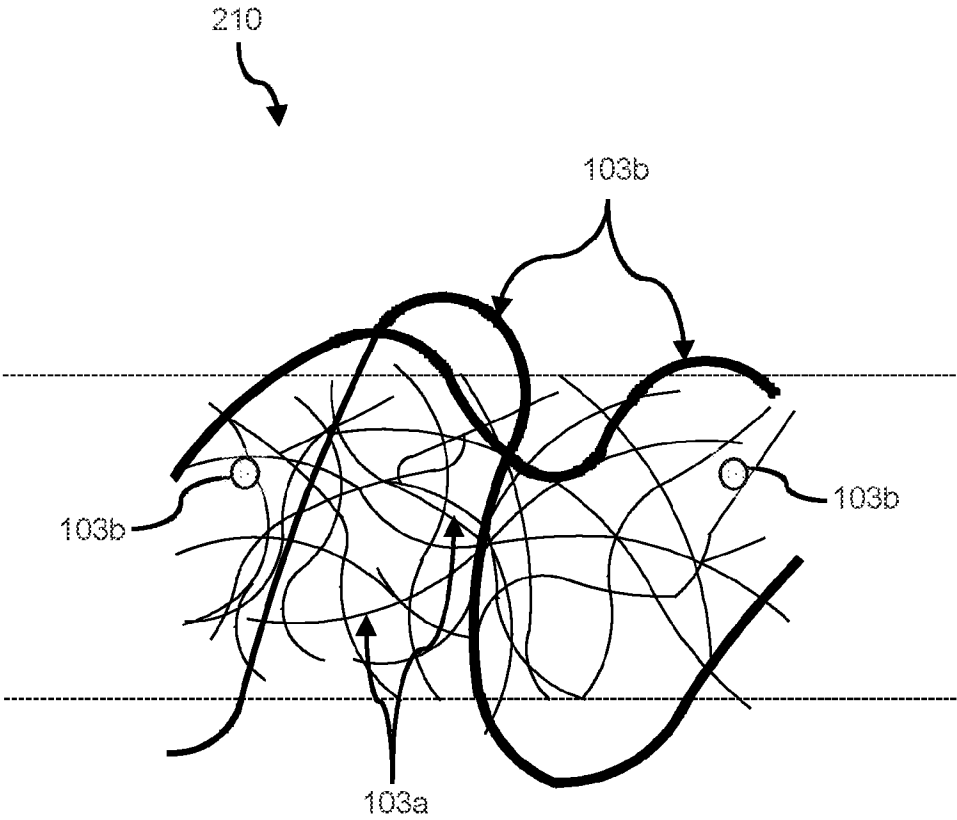


FIG. 11

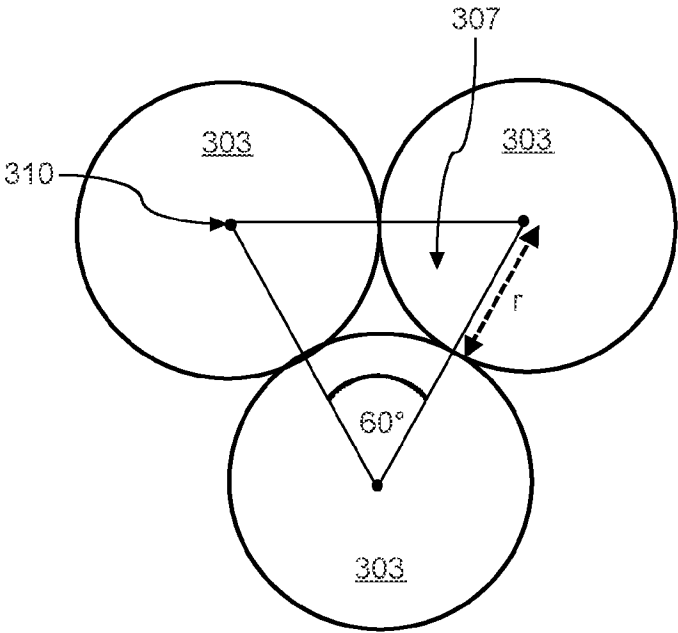


FIG. 12

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2023/027908

A. CLASSIFICATION OF SUBJECT MATTER**D04H 3/011**(2012.01)i; **D04H 3/015**(2012.01)i; **D01F 8/14**(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

D04H 3/011(2012.01); B32B 5/02(2006.01); B60N 3/04(2006.01); B60R 13/08(2006.01); D04H 1/10(2006.01);
D04H 1/42(2006.01); D04H 1/44(2006.01); D04H 5/06(2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: nonwoven, fiber, yarn, recycled textile material, length

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2020-101588 A1 (YUENSA YUENLUE SANAYI VE TICARET ANONIM SIRKETI) 22 May 2020 (2020-05-22) claims 1, 11; pages 2, 5	1-3
Y	JP 2003-201658 A (KASAI KOGYO CO., LTD.) 18 July 2003 (2003-07-18) claims 1, 5	1-3
A	EP 0777782 B2 (SCA HYGIENE PRODUCTS AB) 22 January 2003 the whole document	1-3
A	WO 2010-125545 A2 (KIMBERLY-CLARK WORLDWIDE INC.) 04 November 2010 (2010-11-04) the whole document	1-3
A	US 2011-0293911 A1 (COATES, M. W. et al.) 01 December 2011 (2011-12-01) the whole document	1-3



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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“D” document cited by the applicant in the international application

“E” earlier application or patent but published on or after the international filing date

“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

“O” document referring to an oral disclosure, use, exhibition or other means

“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search

07 November 2023

Date of mailing of the international search report

07 November 2023

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2023/027908**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: **8, 12, 21-23**
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

Claims 8, 12, 21-23 are regarded to be unclear because it refers to a claim which does not comply with PCT Rule 6.4(a).

3. ☒ Claims Nos.: **4-7, 9-11, 13-20**
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/US2023/027908

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)		Publication date (day/month/year)	
WO	2020-101588	A1	22 May 2020	None			
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EP	0777782	B2		JP	10-504613	A	06 May 1998
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				WO	2010-125545	A3	21 April 2011
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				CN	102308039	B	17 August 2016
				EP	2370623	A1	05 October 2011
				EP	2370623	B1	08 May 2019
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				KR	10-1658628	B1	22 September 2016
				KR	10-2011-0110145	A	06 October 2011
				US	2016-0222561	A1	04 August 2016
				US	9315930	B2	19 April 2016
				WO	2010-063079	A1	10 June 2010