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(71) Applicant: **THE PROCTER & GAMBLE COMPANY**
[US/US]; One Procter & Gamble Plaza, Cincinnati, OH
45202 (US).

(72) Inventors: **CABELL, David, William**; 742 Stonehill Run,
Cincinnati, OH 45245 (US). **CABELL, David, William**;
742 Stonehill Run, Cincinnati, Ohio 45245 (US). **MICHAEL, John, Gerhard**; 2536 Briarcliff Avenue, Cincinnati,
Ohio 45212 (US). **EROGLU, Hasan**; 7255 Airy
View Drive, Liberty Township, Ohio 45044 (US).

(74) Agent: **GUFFEY, Timothy, B.**; c/o The Procter & Gamble
Company, Global Patent Services, 299 East 6th Street, Sy-
camore Building, 4th Floor, Cincinnati, OH 45202 (US).

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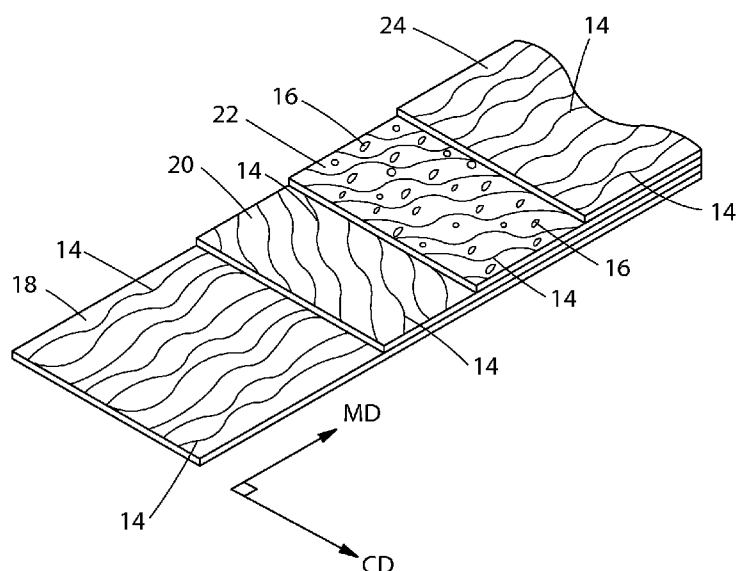


Fig. 2

(57) Abstract: Fibrous structures containing a plurality of solid additives and a plurality of filaments are provided.

FIBROUS STRUCTURES AND METHODS FOR MAKING SAME

FIELD OF THE INVENTION

The present invention relates to fibrous structures, more particularly to fibrous structures comprising a plurality of solid additives and a plurality of filaments, and even more particularly to fibrous structures comprising a plurality of solid additives and a plurality of starch filaments, and methods for making such fibrous structures.

BACKGROUND OF THE INVENTION

Fibrous structures comprising solid additives, such as pulp fibers, and filaments, such as starch filaments, are known in the art. Such fibrous structures have been made using filament sources, such as meltblow dies. Conventionally, the meltblow dies have been oriented the same as one another with respect to the machine direction of the fibrous structure being made by filaments provided by such meltblow dies. For example, the meltblow dies have been oriented at 90° angles to the machine direction. The problem with making fibrous structures with the filament sources, such as meltblow dies, oriented the same, for example at 90° angles to the machine direction, is that each layer of filaments within the fibrous structure provided by each filament source exhibit the same orientation as each other layer of filaments each other filament source as shown in Fig. 1. Fig. 1 shows a fibrous structure 10 comprising three layers 12 of filaments 14 where each layer 12 is produced by a filament source that is oriented at a 90° angle to the machine direction, which results in each layer 12 of filaments 14 exhibiting a machine direction orientation. As a result, the fibrous structure 10, which contains solid additives 16 (for example pulp fibers) and three layers 12 of filaments 14 that exhibit the same orientation, exhibits an average Tensile Ratio of greater than 2 as measured according to the Dry Tensile Strength Test Method described herein. The impact of the layers of filaments exhibiting the same orientation can be exasperated by the fibrous structure being made at speeds of greater than 200 ft/min and/or by the fibrous structure being greater than 20 inches wide.

In addition to the above, it is known in the art to make fibrous structures, void of solid additives, for example void of pulp fibers, from thermoplastic polymer filaments provided by spunbond dies and/or meltblow dies that are oriented at different angles with respect to the machine direction of the fibrous structure.

Accordingly, there is a need for a fibrous structure that comprises a plurality of solid additives, for example pulp fibers, and a plurality of filaments, for example starch filaments,

wherein the filaments are present in the fibrous structure in two or more different layers based on their orientation in each layer and methods for making such fibrous structures.

SUMMARY OF THE INVENTION

5 The present invention fulfills the needs described above by providing novel fibrous structures comprising a plurality of solid additives, for example pulp fibers, and a plurality of filaments, for example starch filaments.

In one example of the present invention, a fibrous structure comprising a plurality of solid additives and a plurality of filaments wherein the filaments are present in the fibrous structure in two or more different layers of filaments based on their orientation in each layer, is provided.

In another example of the present invention, a fibrous structure comprising a plurality of filaments comprising one or more polysaccharides, wherein the fibrous structure exhibits a Tensile Ratio of 2 or less as measured according to the Dry Tensile Strength Test Method described herein, is provided.

In another example of the present invention, a single- or multi-ply sanitary tissue product comprising a fibrous structure according to the present invention, is provided.

In still another example of the present invention, a method for making a fibrous structure, the method comprising the steps of:

- a. providing a plurality of filaments from a filament source; and
- b. collecting the filaments on a collection device to form a fibrous structure such that the fibrous structure exhibits a Tensile Ratio of 2 or less as measured according to the Tensile Ratio Test Method described herein, is provided.

In even another example of the present invention, a method for making a fibrous structure, the method comprising the steps of:

- a. providing first filaments from a first source of filaments;
- b. providing second filaments from a second source of filaments;
- c. optionally, providing additional filaments from additional sources of filaments;
- d. providing solid additives from a source of solid additives; and
- e. collecting the first and second filaments (and any additional filaments) and the solid additives to form a fibrous structure, wherein the first source of filaments is oriented at a first angle to the machine direction of the fibrous structure and the second source of filaments is oriented at a second angle to the machine direction different from the first angle, is provided.

Accordingly, the present invention provides fibrous structures and methods for making fibrous structures that fulfill the needs described above.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic representation of a prior art fibrous structure;

Fig. 2 is a schematic representation of an example of a fibrous structure in accordance
5 with the present invention;

Fig. 3 is a photograph of a layer of filaments of a fibrous structure produced by a source of filaments oriented at a 90° angle to the machine direction of the fibrous structure;

Fig. 4 is a photograph of a layer of filaments of a fibrous structure produced by a source of filaments oriented at about a 40° angle to the machine direction of the fibrous structure;

10 Fig. 5 is a schematic representation of one example of a fibrous structure in accordance with the present invention;

Fig. 6 is a cross-sectional view of the fibrous structure of Fig. 5 taken along line 6-6;

Fig. 7 is a schematic representation of one example of a method for making a fibrous structure according to the present invention;

15 Fig. 8 is a schematic representation of one example of a portion of fibrous structure making process according to the present invention;

Fig. 9 is a schematic representation of an example of a meltblow die in accordance with the present invention;

Fig. 10A is a schematic representation of an example of a barrel of a twin screw extruder
20 in accordance with the present invention; and

Fig. 10B is a schematic representation of a screw and mixing element configuration for the twin screw extruder of Fig. 10A.

DETAILED DESCRIPTION OF THE INVENTION

25 Definitions

“Fibrous structure” as used herein means a structure that comprises one or more filaments, for example a plurality of filaments, and one or more solid additives, such as a plurality of pulp fibers. In one example, a fibrous structure according to the present invention is an association of filaments and solid additives that together form a structure capable of
30 performing a function.

Non-limiting examples of processes for making fibrous structures according to the present invention include known wet, solution, and dry filament spinning processes that are typically referred to as nonwoven processes. In one example, the filament spinning process is a meltblowing process where filaments are provided from a meltblow die (a filament source).

5 Further processing of the fibrous structure may be carried out such that a finished fibrous structure is formed. For example, the finished fibrous structure is a fibrous structure that is wound on a reel at the end of a fibrous structure making process. The finished fibrous structure may subsequently be converted into a finished product, e.g. a sanitary tissue product.

10 “Filament” as used herein means an elongate particulate having a length greatly exceeding its average diameter, i.e. a length to average diameter ratio of at least about 10. In one example, the filament is a single filament rather than a yarn, which is a strand of filaments twisted together along their lengths. In one example, a filament exhibits a length of greater than or equal to 5.08 cm and/or greater than or equal to 7.62 cm and/or greater than or equal to 10.16 cm and/or greater than or equal to 15.24 cm.

15 Filaments are typically considered continuous or substantially continuous in nature especially with respect to the fibrous structure in which they are present. Filaments are relatively longer than fibers. Non-limiting examples of filaments include meltblown and/or spunbond filaments. Non-limiting examples of polymers that can be spun into filaments include natural polymers, such as starch, starch derivatives, cellulose, such as rayon and/or lyocell, and cellulose derivatives, hemicellulose, hemicellulose derivatives, and synthetic polymers including, but not limited to thermoplastic polymer filaments, such as polyesters, nylons, polyolefins such as polypropylene filaments, polyethylene filaments, and biodegradable thermoplastic fibers such as polylactic acid filaments, polyhydroxyalkanoate filaments, polyesteramide filaments and polycaprolactone filaments.

25 The filaments of the present invention may be monocomponent and/or multicomponent. For example, the filaments may comprise bicomponent filaments. The bicomponent filaments may be in any form, such as side-by-side, core and sheath, islands-in-the-sea and the like.

“Solid additive” as used herein means a solid particulate such as a powder, granule, and/or fiber.

30 “Fiber” as used herein means an elongate particulate as described above that exhibits a length of less than 5.08 cm and/or less than 3.81 cm and/or less than 2.54 cm.

Fibers are typically considered discontinuous in nature especially with respect to the fibrous structure. Non-limiting examples of fibers include pulp fibers, such as wood pulp fibers,

and synthetic staple fibers such as polypropylene, polyethylene, polyester, copolymers thereof, rayon, glass fibers and polyvinyl alcohol fibers.

Staple fibers may be produced by spinning a filament tow and then cutting the tow into segments of less than 5.08 cm thus producing staple fibers.

5 In one example of the present invention, a fiber may be a naturally occurring fiber, which means it is obtained from a naturally occurring source, such as a vegetative source, for example a tree and/or plant. Such fibers are typically used in papermaking and are oftentimes referred to as papermaking fibers. Papermaking fibers useful in the present invention include cellulosic fibers commonly known as wood pulp fibers. Applicable wood pulps include chemical pulps, such as
10 Kraft, sulfite, and sulfate pulps, as well as mechanical pulps including, for example, groundwood, thermomechanical pulp and chemically modified thermomechanical pulp. Chemical pulps, however, may be preferred since they impart a superior tactile sense of softness to tissue sheets made therefrom. Pulps derived from both deciduous trees (hereinafter, also referred to as "hardwood") and coniferous trees (hereinafter, also referred to as "softwood") may
15 be utilized. The hardwood and softwood fibers can be blended, or alternatively, can be deposited in layers to provide a stratified web. Also applicable to the present invention are fibers derived from recycled paper, which may contain any or all of the above categories of fibers as well as other non-fibrous polymers such as fillers, softening agents, wet and dry strength agents, and adhesives used to facilitate the original papermaking.

20 In addition to the various wood pulp fibers, other cellulosic fibers such as cotton linters, rayon, lyocell and bagasse fibers can be used in the fibrous structures of the present invention.

 In another example, the fibrous structure may comprise solid additives that comprise trichomes and/or seed hairs.

 "Layer of filaments" as used herein means a plurality of filaments that form at least a part
25 of a fibrous structure wherein the filaments of the layer extend along a common primary direction. In other words, the filaments of the layer exhibit the common primary direction orientation. For example, the filaments of a layer may exhibit a machine direction orientation. In another example, the filaments of a layer may exhibit an orientation that is different from the machine direction, for example an orientation along an angle between the machine direction and
30 the cross machine direction. In one example, one or more layers of filaments may be combined, such as deposited on one another, to form a fibrous structure according to the present invention. In addition, the fibrous structure may comprise two or more different layers of filaments. For example, as shown in Fig. 2, a fibrous structure 10 may comprise a first layer 18 of filaments 14

that exhibits a machine direction orientation and a second layer 20 of filaments 14 that exhibits an orientation different from the machine direction orientation exhibited by the first layer 18.

“Orientation” as used herein with respect to orientation of filaments within a layer of filaments means that the filaments within a layer extend along a common primary direction.

5 Obviously, there may be some filaments that extend in a secondary direction within a layer, but the vast majority of the filaments in a layer extend in a common primary direction and that common primary direction establishes the orientation of the filaments within a layer. As shown in Fig. 3, a layer of filaments exhibits a machine direction orientation. In Fig. 4, a layer of filaments exhibits an angled orientation with respect to the machine direction of the layer. In
10 another example, the angle of a source of filaments (with respect to the machine direction of a fibrous structure being made), such as a meltblow die, provides the filaments of the layer of filaments produced from the source of filaments with an defined orientation. Therefore, if two or more layers of filaments are produced by two or more sources of filaments (for example meltblow dies) that are oriented at different angles (for example within the range of 0° to 90°
15 positive or negative from the MD) with respect to the machine direction, then the filaments within the two or more layers will exhibit different orientations by default.

For purposes of measuring the angle of orientation of a source of filaments, such as a meltblow die, the smaller angle with respect to the machine direction is measured and considered as the angle of orientation of the source of filaments. If the angles of orientation of a source of
20 filaments are the same with respect to the machine direction, then the angle of orientation is 90°.

“Nonwoven substrate” as used herein means a web comprising one or more layers of filaments of the present invention.

“Sanitary tissue product” as used herein means a fibrous structure useful as a wiping implement for post-urinary and post-bowel movement cleaning (toilet tissue), for
25 otorhinolaryngological discharges (facial tissue), and multi-functional absorbent and cleaning uses (absorbent towels). The sanitary tissue product may be convolutedly wound upon itself about a core or without a core to form a sanitary tissue product roll.

In one example, the sanitary tissue product of the present invention comprises one or more fibrous structures according to the present invention.

30 The sanitary tissue products of the present invention may exhibit a basis weight between about 10 g/m² to about 120 g/m² and/or from about 15 g/m² to about 110 g/m² and/or from about 20 g/m² to about 100 g/m² and/or from about 30 to 90 g/m². In addition, the sanitary tissue product of the present invention may exhibit a basis weight between about 40 g/m² to about 120

g/m² and/or from about 50 g/m² to about 110 g/m² and/or from about 55 g/m² to about 105 g/m² and/or from about 60 to 100 g/m².

The sanitary tissue products of the present invention may exhibit a density of less than about 0.60 g/cm³ and/or less than about 0.30 g/cm³ and/or less than about 0.20 g/cm³ and/or less than about 0.10 g/cm³ and/or less than about 0.07 g/cm³ and/or less than about 0.05 g/cm³ and/or from about 0.01 g/cm³ to about 0.20 g/cm³ and/or from about 0.02 g/cm³ to about 0.10 g/cm³.

The sanitary tissue products of the present invention may be in the form of sanitary tissue product rolls. Such sanitary tissue product rolls may comprise a plurality of connected, but perforated sheets of fibrous structure, that are separably dispensable from adjacent sheets.

The sanitary tissue products of the present invention may comprise additives such as softening agents, temporary wet strength agents, permanent wet strength agents, bulk softening agents, lotions, silicones, wetting agents, latexes, patterned latexes and other types of additives suitable for inclusion in and/or on sanitary tissue products.

“Scrim” as used herein means a web material, such as a web comprising filaments, that is used to overlay solid additives within the fibrous structures of the present invention such that the solid additives are positioned between the web material and another layer of filaments within the fibrous structures. In one example, the scrim comprises a web material that exhibits a basis weight of less than 10 g/m² and/or less than 7 g/m² and/or less than 5 g/m² and/or less than 3 g/m² and the remaining layer(s) of filaments of the fibrous structure of the present invention exhibit a basis weight of greater than 10 g/m² and/or greater than 15 g/m² and/or greater than 20 g/m² and/or to about 120 g/m².

“Hydroxyl polymer” as used herein includes any hydroxyl-containing polymer from which filaments of the present invention may be made. In one example, the hydroxyl polymer of the present invention includes greater than 10% and/or greater than 20% and/or greater than 25% by weight hydroxyl moieties. In another example, the hydroxyl within the hydroxyl-containing polymer is not part of a larger functional group such as a carboxylic acid group.

“Non-thermoplastic” as used herein means, with respect to a filament as a whole and/or a polymer within a filament, that the filament and/or polymer exhibits no melting point and/or softening point, which allows it to flow under pressure, in the absence of a plasticizer, such as water, glycerin, sorbitol, urea and the like.

“Thermoplastic” as used herein means, with respect to a filament as a whole and/or a polymer within a filament, that the filament and/or polymer exhibits a melting point and/or softening point at a certain temperature, which allows it to flow under pressure.

“Non-cellulose-containing” as used herein means that less than 5% and/or less than 3% and/or less than 1% and/or less than 0.1% and/or 0% by weight of cellulose polymer, cellulose derivative polymer and/or cellulose copolymer is present in fibrous element. In one example, “non-cellulose-containing” means that less than 5% and/or less than 3% and/or less than 1% and/or less than 0.1% and/or 0% by weight of cellulose polymer is present in fibrous element.

“Associate,” “Associated,” “Association,” and/or “Associating” as used herein with respect to filaments means combining, either in direct contact or in indirect contact, filaments such that a fibrous structure is formed. In one example, the associated filaments may be bonded together for example by adhesives and/or thermal bonds. In another example, the filaments may be associated with one another by being deposited onto the same fibrous structure making belt.

“Weight average molecular weight” as used herein means the weight average molecular weight as determined using gel permeation chromatography according to the protocol found in Colloids and Surfaces A. Physico Chemical & Engineering Aspects, Vol. 162, 2000, pg. 107-121.

“Basis Weight” as used herein is the weight per unit area of a sample reported in g/m².

“Machine Direction” or “MD” as used herein means the direction parallel to the flow of the fibrous structure through a fibrous structure making machine, such as a papermaking machine and/or product manufacturing equipment.

“Cross Machine Direction” or “CD” as used herein means the direction perpendicular to the machine direction in the same plane of the fibrous structure and/or sanitary tissue product comprising the fibrous structure.

“Ply” or “Plies” as used herein means an individual fibrous structure optionally to be disposed in a substantially contiguous, face-to-face relationship with other plies, forming a multiple ply fibrous structure. It is also contemplated that a single fibrous structure can effectively form two “plies” or multiple “plies”, for example, by being folded on itself.

“Spinnerette” as used herein means a plate that comprises one or more filament forming nozzles from which filaments of a melt composition can flow. In one example, the spinnerette comprises a plurality of filament forming nozzles arranged in one or more rows and/or columns. Such a spinnerette is referred to as a multi-row spinnerette.

“Abut one another” as used herein with reference to two or more spinnerettes that abut one another means that a surface of one spinnerette is in contact with a surface of another spinnerette.

“Seam” as used herein means the line of contact between two abutting spinnerettes.

“Seam filament forming nozzle opening” as used herein means one or more filament forming nozzle openings that are closest in distance to the seam formed by two abutting spinnerettes.

As used herein, the articles “a” and “an” when used herein, for example, "an anionic
5 surfactant" or "a fiber" is understood to mean one or more of the material that is claimed or described.

All percentages and ratios are calculated by weight unless otherwise indicated. All percentages and ratios are calculated based on the total composition unless otherwise indicated.

Unless otherwise noted, all component or composition levels are in reference to the active
10 level of that component or composition, and are exclusive of impurities, for example, residual solvents or by-products, which may be present in commercially available sources.

Filaments

In one example, the fibrous structure of the present invention comprises filaments comprising a hydroxyl polymer. In another example, the fibrous structure may comprise starch
15 and/or starch derivative filaments. The starch filaments may further comprise polyvinyl alcohol and/or other polymers.

The filaments of the present invention may be produced from a polymer melt composition comprising a hydroxyl polymer, such as an uncrosslinked starch, a crosslinking system comprising a crosslinking agent, such as an imidazolidinone, and water. The polymer melt
20 composition may also comprise a surfactant, such as a sulfosuccinate surfactant. A non-limiting example of a suitable sulfosuccinate surfactant comprises Aerosol[®] AOT (a sodium dioctyl sulfosuccinate) and/or Aerosol[®] MA-80 (a sodium dihexyl sulfosuccinate), which is commercially available from Cytec Industries, Woodland Park, NJ.

In one example, the filaments of the present invention comprise greater than 25% and/or
25 greater than 40% and/or greater than 50% and/or greater than 60% and/or greater than 70% to about 95% and/or to about 90% and/or to about 80% by weight of the filament of a hydroxyl polymer, such as starch, which may be in a crosslinked state. In one example, the filament comprises an ethoxylated starch and an acid thinned starch, which may be in their crosslinked states.

30 In addition to the hydroxyl polymer, the filament may comprise polyvinyl alcohol at a level of from 0% and/or from 0.5% and/or from 1% and/or from 3% to about 15% and/or to about 12% and/or to about 10% and/or to about 7% by weight of the filament.

The filaments may comprise a surfactant, such as a sulfosuccinate surfactant, at a level of from 0% and/or from about 0.1% and/or from about 0.3% to about 2% and/or to about 1.5% and/or to about 1.1% and/or to about 0.7% by weight of the filament.

The filaments may also comprise a polymer selected from the group consisting of:
5 polyacrylamide and its derivatives; polyacrylic acid, polymethacrylic acid, and their esters; polyethyleneimine; copolymers made from mixtures of monomers of the aforementioned polymers; and mixtures thereof at a level of from 0% and/or from about 0.01% and/or from about 0.05% and/or to about 0.5% and/or to about 0.3% and/or to about 0.2% by weight of the filament. Such polymers may exhibit a weight average molecular weight of greater than
10 500,000 g/mol. In one example, the filament comprises polyacrylamide.

The filaments may also comprise a crosslinking agent, such as an imidazolidinone, which may be in its crosslinked state (crosslinking the hydroxyl polymers present in the filaments) at a level of from about 0.5% and/or from about 1% and/or from about 2% and/or from about 3% and/or to about 10% and/or to about 7% and/or to about 5.5% and/or to about 4.5% by weight of
15 the filament. In addition to the crosslinking agent, the filament may comprise a crosslinking facilitator that aids the crosslinking agent at a level of from 0% and/or from about 0.3% and/or from about 0.5% and/or to about 2% and/or to about 1.7% and/or to about 1.5% by weight of the filament.

The filament may also comprise various other ingredients such as propylene glycol,
20 sorbitol, glycerine, and mixtures thereof.

Polymers

The filaments of the present invention that associate to form the fibrous structures of the present invention may contain various types of polymers such as hydroxyl polymers, non-thermoplastic polymers, thermoplastic polymers and mixtures thereof.

25 Non-limiting examples of hydroxyl polymers in accordance with the present invention include polyols, such as polyvinyl alcohol, polyvinyl alcohol derivatives, polyvinyl alcohol copolymers, starch, starch derivatives, starch copolymers, chitosan, chitosan derivatives, chitosan copolymers, cellulose, cellulose derivatives such as cellulose ether and ester derivatives, cellulose copolymers, hemicellulose, hemicellulose derivatives, hemicellulose copolymers, gums,
30 arabinans, galactans, proteins and various other polysaccharides and mixtures thereof.

In one example, a hydroxyl polymer of the present invention is a polysaccharide.

In another example, a hydroxyl polymer of the present invention is a non-thermoplastic polymer.

The hydroxyl polymer may have a weight average molecular weight of from about 10,000 g/mol to about 40,000,000 g/mol and/or greater than about 100,000 g/mol and/or greater than about 1,000,000 g/mol and/or greater than about 3,000,000 g/mol and/or greater than about 3,000,000 g/mol to about 40,000,000 g/mol. Higher and lower molecular weight hydroxyl
5 polymers may be used in combination with hydroxyl polymers having a certain desired weight average molecular weight.

Well known modifications of hydroxyl polymers, such as natural starches, include chemical modifications and/or enzymatic modifications. For example, natural starch can be acid-thinned, hydroxy-ethylated, hydroxy-propylated, and/or oxidized. In addition, the hydroxyl
10 polymer may comprise dent corn starch hydroxyl polymer.

Polyvinyl alcohols herein can be grafted with other monomers to modify its properties. A wide range of monomers has been successfully grafted to polyvinyl alcohol. Non-limiting examples of such monomers include vinyl acetate, styrene, acrylamide, acrylic acid, 2-hydroxyethyl methacrylate, acrylonitrile, 1,3-butadiene, methyl methacrylate, methacrylic acid,
15 vinylidene chloride, vinyl chloride, vinyl amine and a variety of acrylate esters. Polyvinyl alcohols comprise the various hydrolysis products formed from polyvinyl acetate. In one example the level of hydrolysis of the polyvinyl alcohols is greater than 70% and/or greater than 88% and/or greater than 95% and/or about 99%.

“Polysaccharides” as used herein means natural polysaccharides and polysaccharide
20 derivatives and/or modified polysaccharides. Suitable polysaccharides include, but are not limited to, starches, starch derivatives, chitosan, chitosan derivatives, cellulose, cellulose derivatives, hemicellulose, hemicellulose derivatives, gums, arabinans, galactans and mixtures thereof. The polysaccharide may exhibit a weight average molecular weight of from about 10,000 to about 40,000,000 g/mol and/or greater than about 100,000 and/or greater than about
25 1,000,000 and/or greater than about 3,000,000 and/or greater than about 3,000,000 to about 40,000,000.

Non-cellulose and/or non-cellulose derivative and/or non-cellulose copolymer hydroxyl polymers, such as non-cellulose polysaccharides may be selected from the group consisting of: starches, starch derivatives, chitosan, chitosan derivatives, hemicellulose, hemicellulose
30 derivatives, gums, arabinans, galactans and mixtures thereof.

In one example, the filaments of the present invention are void of thermoplastic, water-insoluble polymers.

Solid Additives

Solid additives of the present invention can be applied to a surface of a layer of filaments in a solid form. In other words, the solid additives of the present invention can be delivered directly to a surface of a layer of filaments without a liquid phase being present, i.e. without melting the solid additive and without suspending the solid additive in a liquid vehicle or carrier.

5 As such, the solid additive of the present invention does not require a liquid state or a liquid vehicle or carrier in order to be delivered to a surface of a layer of filaments. The solid additive of the present invention may be delivered via a gas or combinations of gases. In one example, in simplistic terms, a solid additive is an additive that when placed within a container, does not take the shape of the container.

10 In one example, one or more solid additives may be present on a surface of a fibrous structure of the present invention.

The solid additives of the present invention may have different geometries and/or cross-sectional areas that include round, elliptical, star-shaped, rectangular, trilobal and other various eccentricities.

15 In one example, the solid additive may exhibit a particle size of less than 6 mm and/or less than 5.5 mm and/or less than 5 mm and/or less than 4.5 mm and/or less than 4 mm and/or less than 2 mm in its maximum dimension.

The solid additive of the present invention may exhibit an aspect ratio of less than about 25/1 and/or less than about 15/1 and/or less than about 10/1 and/or less than 5/1 to about 1/1. A
20 particle is not a fiber as defined herein.

The solid additives may be present in the fibrous structures of the present invention at a level of greater than about 1 and/or greater than about 2 and/or greater than about 4 and/or to about 20 and/or to about 15 and/or to about 10 g/m². In one example, a fibrous structure of the present invention comprises from about 2 to about 10 and/or from about 5 to about 10 g/m² of
25 solid additives.

In one example, the solid additives are present in the fibrous structures of the present invention at a level of greater than 5% and/or greater than 10% and/or greater than 20% to about 50% and/or to about 40% and/or to about 30% by weight.

In one example, the solid additives 14 comprise fibers, for example wood pulp fibers.
30 The wood pulp fibers may be softwood pulp fibers and/or hardwood pulp fibers. In one example, the wood pulp fibers comprise eucalyptus pulp fibers. In another example, the wood pulp fibers comprise Southern Softwood Kraft (SSK) pulp fibers

The solid additives may be chemically treated, for example chemically treated pulp fiber. In one example, the solid additives comprise softening agents and/or are surface treated with softening agents. Non-limiting examples of suitable softening agents include silicones and/or quaternary ammonium compounds, such as PROSOFT[®] available from Hercules Incorporated.

- 5 In one example, the solid additives comprise a wood pulp treated with a quaternary ammonium compound softening agent, an example of which is available from Georgia-Pacific Corporation. One advantage of applying a softening agent only to the solid additives versus applying it to the entire fibrous structure and/or nonwoven substrate and/or bonding material, ensures that the softening agent softens those components of the entire fibrous structure that need softening
10 compared to the other components of the entire fibrous structure.

Nonwoven Substrate

- The nonwoven substrate of the present invention comprises one or more layers of filaments. Two or more layers of filaments making up the nonwoven substrate may have the same or different orientations. In one example, the nonwoven substrate comprises two or more
15 layers of filaments that exhibit different orientations.

- In one example, the nonwoven substrate comprises a plurality of filaments comprising a hydroxyl polymer. The hydroxyl polymer may be selected from the group consisting of polysaccharides, derivatives thereof, polyvinyl alcohol, derivatives thereof and mixtures thereof. In one example, the hydroxyl polymer comprises a starch and/or starch derivative. The
20 nonwoven substrate 12 may exhibit a basis weight of greater than about 10 g/m² and/or greater than about 14 g/m² and/or greater than about 20 g/m² and/or greater than about 25 g/m² and/or greater than about 30 g/m² and/or greater than about 35 g/m² and/or greater than about 40 g/m² and/or less than about 100 g/m² and/or less than about 90 g/m² and/or less than about 80 g/m².

Fibrous Structures

- 25 In one example, as shown in Figs. 5 and 6, the fibrous structure 10 of the present invention comprises a nonwoven substrate 26 comprising one or more layers of filaments, a plurality of solid additives 16, such as pulp fibers that are positioned between the nonwoven substrate 26 and a scrim 28 which is bonded to the nonwoven substrate 26 at one or more bond sites 30. The bond site 30 is where at least a portion of the scrim 28 and a portion of the
30 nonwoven substrate 26 are connected to one another, such as via a thermal bond, or a bond created by applying high pressure to both the scrim 28 and the nonwoven substrate 26 such that a glassining effect occurs ("a pressure bond").

In one example, the solid additives 16 may be uniformly distributed on a surface 32 of the nonwoven substrate 26.

In one example, the scrim 28 comprises one or more layers of filaments of the present invention. In one example, the scrim 28 consists of a single layer of filaments of the present invention. The scrim 28 and nonwoven substrate 26 may comprise filaments having the same composition, for example hydroxyl polymer-containing filaments, such as starch filaments. The scrim 28 may be present in the fibrous structure of the present invention at a basis weight of greater than 0.1 and/or greater than 0.3 and/or greater than 0.5 and/or greater than 1 and/or greater than 2 g/m² and/or less than 10 and/or less than 7 and/or less than 5 and/or less than 4 g/m². In one example, the scrim 28 may be present in the fibrous structure of the present invention at a basis weight of from about 0.1 to about 4 g/m².

One purpose of the scrim 28 is to reduce the lint produced by the fibrous structure 10 by inhibiting the solid additives 16 from becoming disassociated from the fibrous structure 10. The scrim 28 may also provide additional strength properties to the fibrous structure 10.

As shown in Figs. 5 and 6 the bond sites 30 may comprise a plurality of discrete bond sites. The discrete bond sites may be present in the form of a non-random repeating pattern. One or more bond sites 30 may comprise a thermal bond and/or a pressure bond.

In one example, the fibrous structures of the present invention comprise a plurality of filaments, such as hydroxyl polymer-containing filaments, wherein the filaments are present in the fibrous structure in two or more different layers of filaments based on their orientation in each layer.

The fibrous structures of the present invention unexpectedly exhibit an average Tensile Ratio (MD Tensile/CD Tensile) of 2 or less and/or less than 1.7 and/or less than 1.5 and/or less than 1.3 and/or less than 1.1 and/or greater than 0.7 and/or greater than 0.9 as measured according to the Dry Tensile Strength Test Method described herein. In one example, the fibrous structures of the present invention exhibit an average Tensile Ratio of from about 0.9 to about 1.1 as measured according to the Dry Tensile Strength Test Method described herein.

Table 1 below shows examples of Tensile Ratios for fibrous structures of the present invention and comparative fibrous structures.

Sample	Filaments (Y/N)	Solid Additives (Y/N)	Layers of Filaments of Different Orientation	Tensile Ratio (Average)

Invention Sample 1	Y – starch	Y	Y	1.66
Invention Sample 2	Y – starch	Y	Y	1.51
Invention Sample 3	Y- starch	Y	Y	1.45
Invention Sample 4	Y- starch	Y	Y	2
Invention Sample 5	Y- starch	Y	Y	1.69
Invention Sample 6	Y – starch	Y	Y	1.34
Invention Sample 7	Y - starch	Y	Y	1.21
Invention Sample 8	Y-starch	Y	Y	1.61
Invention Sample 9	Y-starch	Y	Y	1.77
Prior Art 1	Y – starch	Y	N	3
Prior Art 2	Y – starch	Y	N	3.01
Prior Art 3	Y - starch	Y	N	2.4
Prior Art 4	Y – starch	Y	N	2.6
Prior Art 5	Y – starch	Y	N	2.52
Prior Art 6	Y – starch	Y	N	3.09
Prior Art 7	Y – starch	Y	N	2.73
Charmin® Ultra Soft	N	Y	N	1.08
Charmin® Ultra Soft	N	Y	N	0.96

Table 1

The fibrous structure of the present invention may comprise a surface softening agent. The surface softening agent may be applied to a surface of the fibrous structure. The softening agent may comprise a silicone and/or a quaternary ammonium compound.

The fibrous structure of the present invention may comprise embossments such that the fibrous structure is embossed.

In one example, the fibrous structure comprises a nonwoven substrate, which has a plurality of solid additives present on both of the nonwoven substrate's opposite surfaces that are positioned between the nonwoven substrate surfaces and one or more scrims that are bonded to each of the nonwoven substrate surfaces. The solid additives may be different or the same and may be present at different levels or at same levels and may be uniformly distributed on the opposite surfaces of the nonwoven substrate. The scrim may be different or the same and may be present at different levels or at same levels and be bonded to opposite surfaces of the nonwoven substrate at one or more bond sites.

In another example, the fibrous structure of the present invention may comprise one ply within a multi-ply sanitary tissue product.

In another example, a multi-ply sanitary tissue product comprising two or more plies of the fibrous structure according to the present invention is provided. In one example, two or more plies of the fibrous structure according to the present invention are combined to form a multi-ply sanitary tissue product. The two or more plies may be combined such that the solid additives are adjacent to at least one outer surface and/or each of the outer surfaces of the multi-ply sanitary tissue product.

Methods for Making Fibrous Structure

Figs. 7 and 8 illustrate one example of a method for making a fibrous structure of the present invention. As shown in Figs. 7 and 8, the method 34 comprises the steps of:

- a. providing first filaments 36 from a first source 38 of filaments, which form a first layer 40 of filaments;
- b. providing second filaments 42 from a second source 44 of filaments, which form a second layer 46 of filaments;
- c. providing third filaments 48 from a third source 50 of filaments, which form a third layer 52 of filaments;
- d. providing solid additives 16 from a source 54 of solid additives;
- e. providing fourth filaments 56 from a fourth source 58 of filaments, which form a fourth layer 60 of filaments; and
- f. collecting the first, second, third, and fourth filaments 36, 42, 48, 56 and the solid additives 16 to form a fibrous structure 10, wherein the first source 38 of filaments is oriented at a first angle α to the machine direction of the fibrous structure 10, the second source 44 of

filaments is oriented at a second angle β to the machine direction different from the first angle α , the third source 50 is oriented at a third angle δ to the machine direction different from the first angle α and the second angle β , and wherein the fourth source 58 is oriented at a fourth angle ϵ to the machine direction different from the second angle β and third angle δ .

The first, second, and third layers 40, 46, 52 of filaments are collected on a collection device 62, which may be a belt or fabric. The collection device 62 may be a patterned belt that imparts a pattern, such as a non-random, repeating pattern to the fibrous structure 10 during the fibrous structure making process. The first, second, and third layers 40, 46, 52 of filaments are collected (for example one on top of the other) on the collection device 62 to form a multi-layer nonwoven substrate 26 upon which the solid additives 16 are deposited. The fourth layer 60 of filaments may then be deposited onto the solid additives 16 to form a scrim 28.

The first angle α and the fourth angle ϵ may be the same angle, for example 90° to the machine direction.

The second angle β and the third angle δ may be the same angle, just positive and negative of one another. For example the second angle β may be -40° to the machine direction and the third angle δ may be $+40^\circ$ to the machine direction.

In one example, at least one of the first, second, and third angles α , β , δ is less than 90° to the machine direction. In another example, the first angle α and/or fourth angle ϵ is about 90° to the machine direction. In still another example, the second angle β and/or third angle δ is from about $\pm 10^\circ$ to about $\pm 80^\circ$ and/or from about $\pm 30^\circ$ to about $\pm 60^\circ$ to the machine direction and/or about $\pm 40^\circ$ to the machine direction.

In one example, the first, second, and third layers 40, 46, 52 of filaments may be formed into a nonwoven substrate 28 prior to being utilized in the process for making a fibrous structure described above. In this case, the nonwoven substrate 28 would likely be in a parent roll that could be unwound into the fibrous structure making process and the solid additives 16 could be deposited directly onto a surface 32 of the nonwoven substrate 28.

In one example, the step of providing a plurality of solid additives 16 onto the nonwoven substrate 26 may comprise airlaying the solid additives 16 using an airlaying former. A non-limiting example of a suitable airlaying former is available from Dan-Web of Aarhus, Denmark.

In one example, the step of providing fourth filaments 56 such that the filaments contact the solid additives 16 comprises the step of depositing the fourth filaments 56 such that at least a portion (in one example all or substantially all) of the solid additives 16 are contacted by the fourth filaments 56 thus positioning the solid additives 16 between the fourth layer 60 of

filaments and the nonwoven substrate 26. Once the fourth layer 60 of filaments is in place, the fibrous structure 10 may be subjected to a bonding step that bonds the fourth layer 60 of filaments (in this case, the scrim 28) to the nonwoven substrate 26. This step of bonding may comprise a thermal bonding operation. The thermal bonding operation may comprise passing the
5 fibrous structure 10 through a nip formed by thermal bonding rolls 64, 66. At least one of the thermal bonding rolls 64, 66 may comprise a pattern that is translated into the bond sites 30 formed in the fibrous structure 10.

In addition to being subjected to a bonding operation, the fibrous structure may also be subjected to other post-processing operations such as embossing, tuft-generating, gear rolling,
10 which includes passing the fibrous structure through a nip formed between two engaged gear rolls, moisture-imparting operations, free-fiber end generating, and surface treating to form a finished fibrous structure. In one example, the fibrous structure is subjected to gear rolling by passing the fibrous structure through a nip formed by at least a pair of gear rolls. In one example, the fibrous structure is subjected to gear rolling such that free-fiber ends are created in the fibrous
15 structure. The gear rolling may occur before or after two or more fibrous structures are combined to form a multi-ply sanitary tissue product. If it occurs after, then the multi-ply sanitary tissue product is passed through the nip formed by at least a pair of gear rolls.

The method for making a fibrous structure of the present invention may be close coupled (where the fibrous structure is convolutedly wound into a roll prior to proceeding to a converting
20 operation) or directly coupled (where the fibrous structure is not convolutedly wound into a roll prior to proceeding to a converting operation) with a converting operation to emboss, print, deform, surface treat, or other post-forming operation known to those in the art. For purposes of the present invention, direct coupling means that the fibrous structure can proceed directly into a converting operation rather than, for example, being convolutedly wound into a roll and then
25 unwound to proceed through a converting operation.

In one example, one or more plies of the fibrous structure according to the present invention may be combined with another ply of fibrous structure, which may also be a fibrous structure according to the present invention, to form a multi-ply sanitary tissue product that exhibits a Tensile Ratio of 2 or less and/or less than 1.7 and/or less than 1.5 and/or less than 1.3
30 and/or less than 1.1 and/or greater than 0.7 and/or greater than 0.9 as measured according to the Dry Tensile Strength Test Method described herein. In one example, the multi-ply sanitary tissue product may be formed by combining two or more plies of fibrous structure according to the present invention. In another example, two or more plies of fibrous structure according to the

present invention may be combined to form a multi-ply sanitary tissue product such that the solid additives present in the fibrous structure plies are adjacent to each of the outer surfaces of the multi-ply sanitary tissue product.

5 The process of the present invention may include preparing individual rolls of fibrous structure and/or sanitary tissue product comprising such fibrous structure(s) that are suitable for consumer use.

10 In one example, the sources of filaments comprise meltblow dies that produce filaments from a polymer melt composition according to the present invention. In one example, as shown in Fig. 9 the meltblow die 68 may comprise at least one filament-forming hole 70, and/or 2 or more and/or 3 or more rows of filament-forming holes 70 from which filaments are spun. At least one row of the filament-forming holes 70 contains 2 or more and/or 3 or more and/or 10 or more filament-forming holes 70. In addition to the filament-forming holes 70, the meltblow die 68 comprises fluid-releasing holes 72, such as gas-releasing holes, in one example air-releasing holes, that provide attenuation to the filaments formed from the filament-forming holes 70. One 15 or more fluid-releasing holes 72 may be associated with a filament-forming hole 70 such that the fluid exiting the fluid-releasing hole 72 is parallel or substantially parallel (rather than angled like a knife-edge die) to an exterior surface of a filament exiting the filament-forming hole 70. In one example, the fluid exiting the fluid-releasing hole 72 contacts the exterior surface of a filament formed from a filament-forming hole 70 at an angle of less than 30° and/or less than 20° and/or 20 less than 10° and/or less than 5° and/or about 0°. One or more fluid releasing holes 72 may be arranged around a filament-forming hole 70. In one example, one or more fluid-releasing holes 72 are associated with a single filament-forming hole 70 such that the fluid exiting the one or more fluid releasing holes 72 contacts the exterior surface of a single filament formed from the single filament-forming hole 70. In one example, the fluid-releasing hole 72 permits a fluid, such as a gas, for example air, to contact the exterior surface of a filament formed from a filament-forming hole 70 rather than contacting an inner surface of a filament, such as what happens when 25 a hollow filament is formed.

Synthesis of Polymer Melt Composition

30 A polymer melt composition of the present invention may be prepared using a screw extruder, such as a vented twin screw extruder.

A barrel 74 of an APV Baker (Peterborough, England) 40:1, 48 mm twin screw extruder is schematically illustrated in Fig. 10A. The barrel 74 is separated into eight zones, identified as zones 1-8. The barrel 74 encloses the extrusion screw and mixing elements, schematically shown

in Fig. 10B, and serves as a containment vessel during the extrusion process. A solid feed port 76 is disposed in zone 1 and a liquid feed port 78 is disposed in zone 1. A vent 80 is included in zone 7 for cooling and decreasing the liquid, such as water, content of the mixture prior to exiting the extruder. An optional vent stuffer, commercially available from APV Baker, can be employed to prevent the polymer melt composition from exiting through the vent 80. The flow of the polymer melt composition through the barrel 74 is from zone 1 exiting the barrel 74 at zone 8.

A screw and mixing element configuration for the twin screw extruder is schematically illustrated in Fig 10B. The twin screw extruder comprises a plurality of twin lead screws (TLS) (designated A and B) and paddles (designated C) and reverse twin lead screws (RTLS) (designated D) installed in series as illustrated in Table 2 below.

Zone	Total Length Ratio	Element	Pitch	Length Ratio	Element Type
1	1.5	TLS	1	1.5	A
1	3.0	TLS	1	1.5	A
1	4.5	TLS	1	1.5	A
2	6.0	TLS	1	1.5	A
2	7.5	TLS	1	1.5	A
2	9.0	TLS	1	1.5	A
3	10.5	TLS	1	1.5	A
3	12.0	TLS	1	1.5	A
3	13.0	TLS	1	1	A
3	14.0	TLS	1	1	A
4	15.0	TLS	1	1	A
4	16.0	TLS	1	1	A
4	16.3	PADDLE	0	0.25	C
4	16.5	PADDLE	0	0.25	C
4	18.0	TLS	1	1.5	A
4	19.5	TLS	1	1.5	A
5	21.0	TLS	1	1.5	A
5	22.5	TLS	1	1.5	A
5	24.0	TLS	1	1.5	A
5	25.0	TLS	1	1	A
6	25.3	TLS	1	0.25	A
6	26.3	TLS	1	1	A
6	27.3	TLS	1	1	A
6	28.3	TLS	0.5	1	B
6	29.3	TLS	0.5	1	B
6	29.8	RTLS	0.5	0.5	D
7	30.3	RTLS	0.5	0.5	D

7	30.8	RTLS	0.5	0.5	D
7	32.3	TLS	1	1.5	A
7	33.8	TLS	1	1.5	A
7	34.8	TLS	1	1	A
8	35.8	TLS	1	1	A
8	36.8	TLS	0.5	1	B
8	37.8	TLS	0.5	1	B
8	38.8	TLS	0.5	1	B
8	40.3	TLS	0.5	1.5	B

Table 2

Screw elements (A – B) are characterized by the number of continuous leads and the pitch of these leads. A lead is a flight (at a given helix angle) that wraps the core of the screw element. The number of leads indicates the number of flights wrapping the core at any given location along the length of the screw. Increasing the number of leads reduces the volumetric capacity of the screw and increases the pressure generating capability of the screw.

The pitch of the screw is the distance needed for a flight to complete one revolution of the core. It is expressed as the number of screw element diameters per one complete revolution of a flight. Decreasing the pitch of the screw increases the pressure generated by the screw and decreases the volumetric capacity of the screw.

The length of a screw element is reported as the ratio of length of the element divided by the diameter of the element.

This example uses TLS and RTLS. Screw element type A is a TLS with a 1.0 pitch and varying length ratios. Screw element type B is a TLS with a 0.5 pitch and varying length ratios.

Bilobal paddles, C, serving as mixing elements, are also included in series with the TLS and RTLS screw elements in order to enhance mixing. Paddle C has a length ratio of 1/4. Various configurations of bilobal paddles and reversing screw elements D, single and twin lead screws threaded in the opposite directions, are used in order to control flow and corresponding mixing time. Screw element D is a RTLS with a 0.5 pitch and a 0.5 length ratio.

In zone 1, the hydroxyl polymer is fed into the solid feed port at a rate of 230 grams/minute using a K-Tron (Pitman,NJ) loss-in-weight feeder. This hydroxyl polymer is combined inside the extruder (zone 1) with water, an external plasticizer, added at the liquid feed at a rate of 146 grams/minute using a Milton Roy (Ivyland, PA) diaphragm pump (1.9 gallon per hour pump head) to form a hydroxyl polymer/water slurry. This slurry is then conveyed down

the barrel of the extruder and cooked. Table 3 below describes the temperature, pressure, and corresponding function of each zone of the extruder.

Zone	Temp.(°F)	Pressure	Description of Screw	Purpose
1	70	Low	Feeding/Conveying	Feeding and Mixing
2	70	Low	Conveying	Mixing and Conveying
3	70	Low	Conveying	Mixing and Conveying
4	130	Low	Pressure/ Decreased Conveying	Conveying and Heating
5	300	Medium	Pressure Generating	Cooking at Pressure and Temperature
6	250	High	Reversing	Cooking at Pressure and Temperature
7	210	Low	Conveying	Cooling and Conveying (with venting)
8	210	Low	Pressure Generating	Conveying

Table 3

5 After the slurry exits the extruder, part of the melt processed hydroxyl polymer is dumped and another part (100g) is fed into a Zenith®, type PEP II (Sanford NC) and pumped into a SMX style static mixer (Koch-Glitsch, Woodridge, Illinois). The static mixer is used to combine additives such as crosslinking agent, crosslinking facilitator, external plasticizer, such as water, with the melt processed hydroxyl polymer. The additives are pumped into the static mixer via PREP 100 HPLC pumps (Chrom
10 Tech, Apple Valley MN). These pumps provide high pressure, low volume addition capability. The polymer melt composition of the present invention is ready to be processed by a polymer processing operation.

Synthesis of Filaments

15 A non-limiting example of a process for producing filaments by polymer processing a polymer melt composition of the present invention. “Polymer processing” as used herein means any operation and/or process by which a filament comprising a processed hydroxyl polymer is formed from a polymer melt composition. Nonlimiting examples of polymer processing operations include extrusion, molding and/or fiber spinning. Extrusion and molding (either casting or blown), typically produce films, sheets and various profile extrusions. Molding may
20 include injection molding, blown molding and/or compression molding. Fiber spinning may include spun bonding, melt blowing, rotary spinning, continuous filament producing and/or tow

fiber producing. A “processed hydroxyl polymer” as used herein means any hydroxyl polymer that has undergone a melt processing operation and a subsequent polymer processing operation.

One example of a process for making a filament of the present invention from a polymer melt composition of the present invention follows.

5 A polymer melt composition is prepared according to the Synthesis of a Polymer Melt Composition described above. The polymer melt composition present in the twin screw extruder is pumped to a meltblow die using a suitable pump, such as a Zenith®, type PEP II, having a capacity of 10 cubic centimeters per revolution (cc/rev), manufactured by Parker Hannifin Corporation, Zenith Pumps division, of Sanford, NC, USA. The hydroxyl polymer's, such as
10 starch, flow to the meltblow die is controlled by adjusting the number of revolutions per minute (rpm) of the pump. Pipes connecting the extruder, the pump, the meltblow die, and optionally a mixer are electrically heated and thermostatically controlled to 65 °C.

The meltblow die has several rows of circular extrusion nozzles spaced from one another at a pitch P of about 2.489 mm. The nozzles are arranged in a staggered grid with a spacing
15 of about 2.489 mm within rows and a spacing of 2.159 mm between rows. The nozzles 200 have individual inner diameters of about 0.254 mm and individual outside diameters of about 0.813 mm. Each individual nozzle is encircled by an annular orifice formed in an orifice plate having a thickness of about 1.9 mm. A pattern of a plurality of the orifices in the orifice plate correspond to a pattern of extrusion nozzles in the meltblow die. Once the orifice plate is
20 combined with the meltblow dies, the resulting area for airflow is about 36 percent. The plate is fixed so that the filaments being extruded through the extrusion nozzles are surrounded and attenuated by generally cylindrical, humidified air streams supplied through the orifices of the orifice plate. The extrusion nozzles can extend to a distance from about 1.5 mm to about 4 mm, and more specifically from about 2 mm to about 3 mm, beyond the exterior surface of the
25 orifice plate. A plurality of boundary-layer air orifices is formed by plugging extrusion nozzles of two outside rows on each side of the plurality of extrusion nozzles, as viewed in plane, so that each of the boundary-layer air orifices comprise an annular orifice described herein above. Additionally, every other row and every other column of the remaining extrusion nozzles are blocked, increasing the spacing between active extrusion nozzles

30 Attenuation air for attenuating the filaments being produced through the extrusion nozzles can be provided by heating compressed air by an electrical-resistance heater, for example, a heater manufactured by Chromalox, Division of Emerson Electric, of Pittsburgh, PA, USA. An appropriate quantity of steam at an absolute pressure of from about 240 to about 420 kiloPascals

(kPa), controlled by a globe valve, is added to saturate or nearly saturate the heated air at the conditions in the electrically heated, thermostatically controlled delivery pipe. Condensate is removed in an electrically heated, thermostatically controlled, separator. The attenuating air has an absolute pressure from about 130 kPa to about 310 kPa, measured in the controlled delivery

5 pipe. The filaments being extruded from the extrusion nozzles have a moisture content of from about 20% and/or from about 25% to about 50% and/or to about 55% by weight. The filaments are dried by a drying air stream having a temperature from about 149° C to about 315° C by an electrical resistance heater supplied through drying nozzles and discharged at an angle generally perpendicular relative to the general orientation of the filaments being extruded. The filaments

10 are dried from about 45% moisture content to about 15% moisture content (i.e., from a consistency of about 55% to a consistency of about 85%) and are collected on a collection device, for example a moving foraminous belt.

The process parameters for making the filaments of the present invention are set forth below in Table 4.

15

<u>Sample</u>	<u>Units</u>	<u>Value</u>
Attenuation Air Flow Rate	G/min	9000
Attenuation Air Temperature	°C	65
Attenuation Steam Flow Rate	G/min	1800
Attenuation Steam Gage Pressure	kPa	213
Attenuation Gage Pressure in Delivery Pipe	kPa	14
Attenuation Exit Temperature	°C	65
Solution Pump Speed	Revs/min	12
Solution Flow	G/min/hole	0.18
Drying Air Flow Rate	g/min	17000
Air Duct Type		Slots
Air Duct Dimensions	mm	356 x 127
Velocity via Pitot-Static Tube	M/s	65
Drying Air Temperature at Heater	°C	260
Dry Duct Position from Die	mm	80
Drying Duct Angle Relative to Fibers	degrees	0

<u>Sample</u>	<u>Units</u>	<u>Value</u>
Drying Duct to Drying Duct Spacing	mm	205
Die to Forming Box distance	Mm	610
Forming Box Machine direction Length	Mm	635
Forming Box Cross Direction Width	Mm	380
Forming Box Flowrate	g/min	41000

Table 4

A crosslinking system via a crosslinking agent, such as an imidazolidinone, may crosslink the hydroxyl polymers together to provide the filament with wet strength, with or without being subjected to a curing step. The crosslinking occurs such that the polymer melt composition is capable of being delivered through the extrusion nozzles and producing filaments. In other words, the crosslinking system does not prematurely crosslink the hydroxyl polymers in the polymer melt composition so that the extrusion nozzles are clogged and thus no filaments can be produced.

The filaments of the present invention do not include coatings and/or other surface treatments that are applied to a pre-existing form, such as a coating on a fiber, film or foam. However, in one embodiment of the present invention, a filament in accordance with the present invention may be coated and/or surface treated with the crosslinking system of the present invention.

In one example, the filaments produced via a polymer processing operation may be cured at a curing temperature of from about 110°C to about 215°C and/or from about 110°C to about 200°C and/or from about 120°C to about 195°C and/or from about 130°C to about 185°C for a time period of from about 0.01 and/or 1 and/or 5 and/or 15 seconds to about 60 minutes and/or from about 20 seconds to about 45 minutes and/or from about 30 seconds to about 30 minutes. Alternative curing methods may include radiation methods such as UV, e-beam, IR and other temperature-raising methods.

Further, the filaments may also be cured at room temperature for days, either after curing at above room temperature or instead of curing at above room temperature.

The filaments of the present invention may include melt spun filaments and/or spunbond filaments, hollow filaments, shaped filaments, such as multi-lobal filaments and multicomponent filaments, especially bicomponent filaments. The multicomponent filaments, especially bicomponent filaments, may be in a side-by-side, sheath-core, segmented pie, ribbon, islands-in-the-sea configuration, or any combination thereof. The sheath may be continuous or non-

continuous around the core. The ratio of the weight of the sheath to the core can be from about 5:95 to about 95:5. The filaments of the present invention may have different geometries that include round, elliptical, star shaped, rectangular, and other various eccentricities.

Non-limiting Example of a Fibrous Structure

5 Example 1 - Fibrous Structure comprising Starch Filaments/Wood Pulp Fibers

A polymer melt composition comprising 7.5% Mowiol 10-98 commercially available from Kuraray Co. (polyvinyl alcohol), 19% Ethylex 2035 commercially available from Tate & Lyle (ethoxylated starch), 19% CPI 050820-156 commercially available from Corn Products International (acid-thinned starch), 0.5% sulfosuccinate surfactant, such as Aerosol AOT,
10 commercially available from Cytec Industries, 0.25% Hyperfloc NF221 commercially available from Hychem, Inc. (polyacrylamide), 3.25% imidazolidinone crosslinking agent (DHEU), and 0.5% ammonium chloride available from Aldrich (crosslinking facilitator) is prepared. The melt composition is cooked and extruded from a co-rotating twin screw extruder at approx 50% solids (50% H₂O) as described hereinabove.

15 The polymer melt composition is then pumped to a series of meltblow spinnerettes that are oriented at different angles to the machine direction to provide a plurality of filaments from each spinneret. The filaments from each spinnerette are attenuated with saturated air stream to form a layer of filaments that are collected one on top of the other to form a nonwoven substrate. The filaments of two or more of the layers of filaments exhibit different orientations with respect
20 to the machine direction. The nonwoven substrate formed exhibits a basis weight of from about 10 g/m² to about 120 g/m² as described hereinabove. The filaments are dried by convection drying before being deposited on a belt to form the nonwoven substrate. These meltblown filaments are essentially continuous filaments.

If two or more spinnerettes are used to make a source of filaments, such as by abutting
25 two or more spinnerettes together, then the spinnerette assembly may be made by abutting a first spinnerette with a second spinnerette such that the maximum distance between a seam filament forming nozzle opening in the first spinnerette and a seam filament forming nozzle opening in the second spinnerette is less than 9 mm and/or less than 7 mm and/or less than 5 mm. In addition to the abutting spinnerettes, an air plate is used in the spinnerette assembly to cover the
30 seam formed by the abutting spinnerettes. The air plates' purpose to result in air flow that avoids causing the filaments produced by the spinnerette assemblies to collide with neighboring filaments which can result in roping of filaments and/or spitters from the spinnerette assemblies.

Wood pulp fibers, Southern Softwood Kraft (SSK) commercially available from Georgia Pacific available as roll comminution pulp, is disintegrated by a hammermill and conveyed to an airlaid former commercially available from Dan-Web via a blower. The wood pulp fibers are deposited onto a surface of the nonwoven substrate as solid additives.

5 Additional polymer melt composition is pumped to an additional meltblow spinnerette that is oriented at an angle to the machine direction of about 90° to produce an additional layer of filaments (which is a scrim), which is deposited on top of the wood pulp fibers to position the wood pulp fibers between the nonwoven substrate and the scrim to form a fibrous structure. The scrim typically exhibits a basis weight of from about 0.1 g/m² to about 10 g/m².

10 The fibrous structure is then subjected to a bonding process wherein bond sites are formed between the nonwoven substrate and the scrim such that the wood pulp fibers are positioned between the nonwoven substrate and the scrim to form a finished fibrous structure. The bonding process can be used to impart a pattern to the finished fibrous structure and/or the finished fibrous structure may be embossed. The fibrous structure can be subjected to
15 humidification during the fibrous structure making process, for example prior to being bonded and/or embossed.

The finished fibrous structure is then convolutely wound about a core to produce a sanitary tissue product.

The fibrous structure, finished fibrous structure, and/or sanitary tissue product
20 incorporating the finished fibrous structure exhibits a Tensile Ratio of 2 or less.

Test Methods

Unless otherwise specified, all tests described herein including those described under the Definitions section and the following test methods are conducted on samples that have been conditioned in a conditioned room at a temperature of 23°C ± 1.0°C and a relative humidity of
25 50% ± 2% for a minimum of 2 hours prior to the test. The samples tested are “usable units.” “Usable units” as used herein means sheets, flats from roll stock, pre-converted flats, and/or single or multi-ply products. All tests are conducted under the same environmental conditions and in such conditioned room. Do not test samples that have defects such as wrinkles, tears, holes, and like. Samples conditioned as described herein are considered dry samples (such as
30 “dry filaments”) for testing purposes. All instruments are calibrated according to manufacturer’s specifications.

Basis Weight Test Method

Basis weight of a fibrous structure is measured on stacks of twelve usable units using a top loading analytical balance with a resolution of ± 0.001 g. The balance is protected from air drafts and other disturbances using a draft shield. A precision cutting die, measuring 3.500 in ± 0.0035 in by 3.500 in ± 0.0035 in is used to prepare all samples.

- 5 With a precision cutting die, cut the samples into squares. Combine the cut squares to form a stack twelve samples thick. Measure the mass of the sample stack and record the result to the nearest 0.001 g.

The Basis Weight is calculated in lbs/3000 ft² or g/m² as follows:

Basis Weight = (Mass of stack) / [(Area of 1 square in stack) x (No. of squares in stack)]

- 10 For example,

Basis Weight (lbs/3000 ft²) = [(Mass of stack (g) / 453.6 (g/lbs)) / [12.25 (in²) / 144 (in²/ft²) x 12]] x 3000

or,

Basis Weight (g/m²) = Mass of stack (g) / [79.032 (cm²) / 10,000 (cm²/m²) x 12]

- 15 Report result to the nearest 0.1 lbs/3000 ft² or 0.1 g/m². Sample dimensions can be changed or varied using a similar precision cutter as mentioned above, so as at least 100 square inches of sample area in stack.

Dry Tensile Strength Test Method

- 20 Tensile Strength is measured on a constant rate of extension tensile tester with computer interface (a suitable instrument is the EJA Vantage from the Thwing-Albert Instrument Co. Wet Berlin, NJ) using a load cell for which the forces measured are within 10% to 90% of the limit of the load cell. Both the movable (upper) and stationary (lower) pneumatic jaws are fitted with smooth stainless steel faced grips, with a design suitable for testing 1 inch wide sheet material (Thwing-Albert item #733GC). An air pressure of about 60 psi is supplied to the jaws.

- 25 Eight usable units of fibrous structures are divided into two stacks of four usable units each. The usable units in each stack are consistently oriented with respect to machine direction (MD) and cross direction (CD). One of the stacks is designated for testing in the MD and the other for CD. Using a one inch precision cutter (Thwing-Albert JDC-1-10, or similar) take a CD stack and cut one, 1.00 in ± 0.01 in wide by 3 - 4 in long stack of strips (long dimension in CD).
- 30 In like fashion cut the remaining stack in the MD (strip's long dimension in MD), to give a total of 8 specimens, four CD and four MD strips. Each strip to be tested is one usable unit thick, and will be treated as a unitary specimen for testing.

Program the tensile tester to perform an extension test, collecting force and extension data at an acquisition rate of 20 Hz as the crosshead raises at a rate of 2.00 in/min (5.08 cm/min) until the specimen breaks. The break sensitivity is set to 80%, i.e., the test is terminated when the measured force drops to 20% of the maximum peak force, after which the crosshead is returned to its original position.

Set the gage length to 1.00 inch. Zero the crosshead and load cell. Insert the specimen into the upper and lower open grips such that at least 0.5 inches of specimen length is contained each grip. Align specimen vertically within the upper and lower jaws, then close the upper grip. Verify specimen is aligned, then close lower grip. The specimen should be fairly straight between grips, with no more than 5.0 g of force on the load cell. Start the tensile tester and data collection. Repeat testing in like fashion for all four CD and four MD specimens.

Program the software to calculate the following from the constructed force (g) verses extension (in) curve:

Tensile Strength is the maximum peak force (g) divided by the specimen width (1 in), and reported as g/in to the nearest 1 g/in.

The Tensile Strength (g/in) is calculated for the four CD unitary specimens and the four MD unitary specimens. Calculate an average for each parameter separately for the CD and MD specimens.

Calculations:

Tensile Ratio = MD Tensile Strength (g/in) / CD Tensile Strength (g/in)

The dimensions and values disclosed herein are not to be understood as being strictly limited to the exact numerical values recited. Instead, unless otherwise specified, each such dimension is intended to mean both the recited value and a functionally equivalent range surrounding that value. For example, a dimension disclosed as "40 mm" is intended to mean "about 40 mm."

Every document cited herein, including any cross referenced or related patent or application, is hereby incorporated herein by reference in its entirety unless expressly excluded or otherwise limited. The citation of any document is not an admission that it is prior art with respect to any invention disclosed or claimed herein or that it alone, or in any combination with any other reference or references, teaches, suggests or discloses any such invention. Further, to the extent that any meaning or definition of a term in this document conflicts with any meaning or definition of the same term in a document incorporated by reference, the meaning or definition assigned to that term in this document shall govern.

While particular embodiments of the present invention have been illustrated and described, it would be obvious to those skilled in the art that various other changes and modifications can be made without departing from the spirit and scope of the invention. It is therefore intended to cover in the appended claims all such changes and modifications that are

5 within the scope of this invention.

CLAIMS

What is claimed is:

1. A fibrous structure comprising a plurality of filaments comprising one or more polysaccharides, wherein the fibrous structure exhibits a Tensile Ratio of 2 or less as measured according to the Dry Tensile Strength Test Method described herein.
2. The fibrous structure according to Claim 1 wherein at least one of the one or more polysaccharides is selected from the group consisting of: starch, starch derivatives, starch copolymers, chitosan, chitosan derivatives, chitosan copolymers, cellulose, cellulose derivatives, cellulose copolymers, hemicellulose, hemicellulose derivatives, hemicellulose copolymers, and mixtures thereof, preferably wherein at least one of the one or more polysaccharides is selected from the group consisting of: starch, starch derivatives, starch copolymers, and mixtures thereof, more preferably wherein the at least one polysaccharide comprises ethoxylated starch or acid-thinned starch.
3. The fibrous structure according to Claim 1 or 2 wherein at least one of the filaments further comprises a hydroxyl polymer selected from the group consisting of: polyvinyl alcohol, polyvinyl alcohol derivatives, polyvinyl alcohol copolymers, gums, arabinans, galactans, proteins, and mixtures thereof.
4. The fibrous structure according to any of the preceding claims wherein at least one of the filaments further comprises a polymer selected from the group consisting of: polyacrylamide and its derivatives; polyacrylic acid, polymethacrylic acid, and their esters; polyethyleneimine; copolymers made from mixtures of monomers of the aforementioned polymers; and mixtures thereof, preferably wherein the polymer exhibits a weight average molecular weight of greater than 500,000 g/mol, more preferably wherein the polymer comprises polyacrylamide.
5. The fibrous structure according to any of the preceding claims wherein at least one of the filaments further comprises a surfactant, preferably wherein the surfactant comprises a sulfosuccinate surfactant.
6. The fibrous structure according to any of the preceding claims wherein the fibrous structure exhibits a basis weight of from 10 g/m² to 120 g/m².

7. The fibrous structure according to any of the preceding claims wherein the fibrous structure further comprises one or more solid additives.
8. The fibrous structure according to any of the preceding claims wherein at least one of the one or more solid additives comprises a fiber, preferably wherein the fiber comprises a pulp fiber, more preferably wherein the pulp fiber is selected from the group consisting of hardwood pulp fibers, softwood pulp fibers, and mixtures thereof, even more preferably wherein the pulp fiber comprises a eucalyptus pulp fiber or a chemically treated pulp fiber.
9. The fibrous structure according to Claim 7 wherein one or more of the solid additives are present on a surface of the fibrous structure.
10. The fibrous structure according to Claim 9 wherein the fibrous structure further comprises a scrim connected to the surface of the fibrous structure such that the solid additives are positioned between the scrim and the surface of the fibrous structure, more preferably wherein the scrim material is bonded to the surface of the fibrous structure at one or more bond sites, even more preferably wherein the one or more bond sites comprises a thermal bond or a pressure bond.
11. The fibrous structure according to Claim 10 wherein the scrim material is bonded to the surface of the fibrous structure by a plurality of discrete bond sites.
12. The fibrous structure according to any of the preceding claims wherein the fibrous structure is embossed.
13. The fibrous structure according to any of the preceding claims wherein the fibrous structure exhibits a density of less than 0.60 g/cm^3 .
14. A single- or multi-ply sanitary tissue product comprising a fibrous structure according to any of the preceding claims.

15. A method for making a fibrous structure according to any of the preceding claims, the method comprising the steps of:

- a. providing a plurality of filaments from a filament source; and
- b. collecting the filaments on a collection device to form a fibrous structure such that the fibrous structure exhibits a Tensile Ratio of 2 or less as measured according to the Tensile Ratio Test Method described herein, preferably wherein the method further comprises the step of:
 - c. providing a plurality of solid additives from a solid additive source such that the solid additives are collected on a surface of the fibrous structure, more preferably wherein the method further comprises the steps of:
 - d. providing a scrim of material; and
 - e. bonding the scrim of material to the surface of the fibrous structure such that the solid additives are position between the scrim material and the surface of the fibrous structure.

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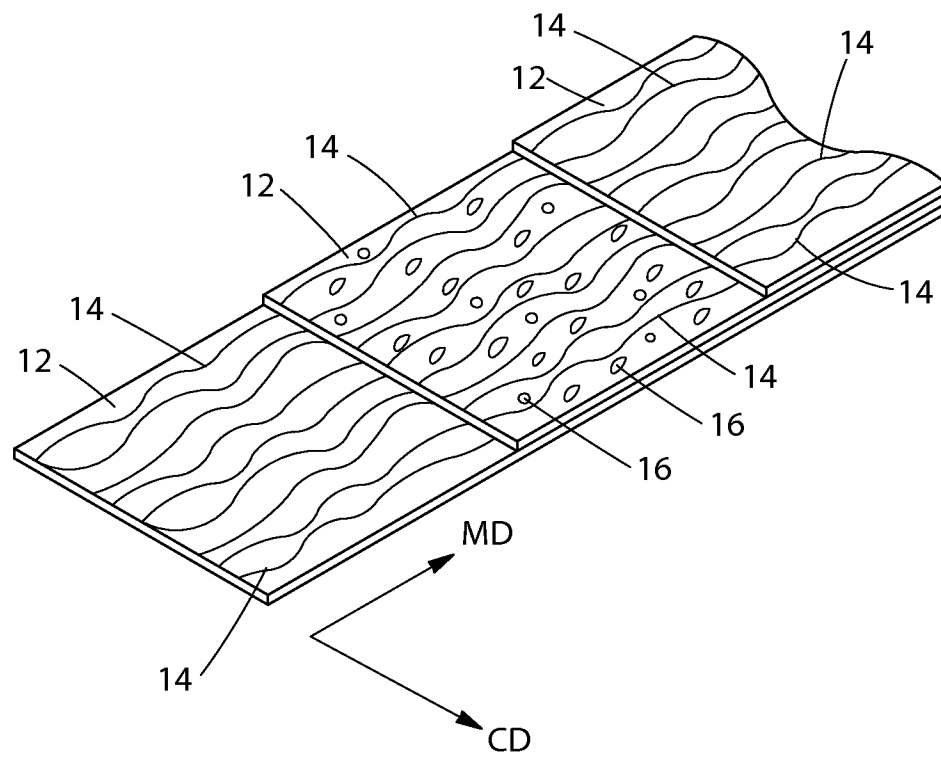


Fig. 1
Prior Art

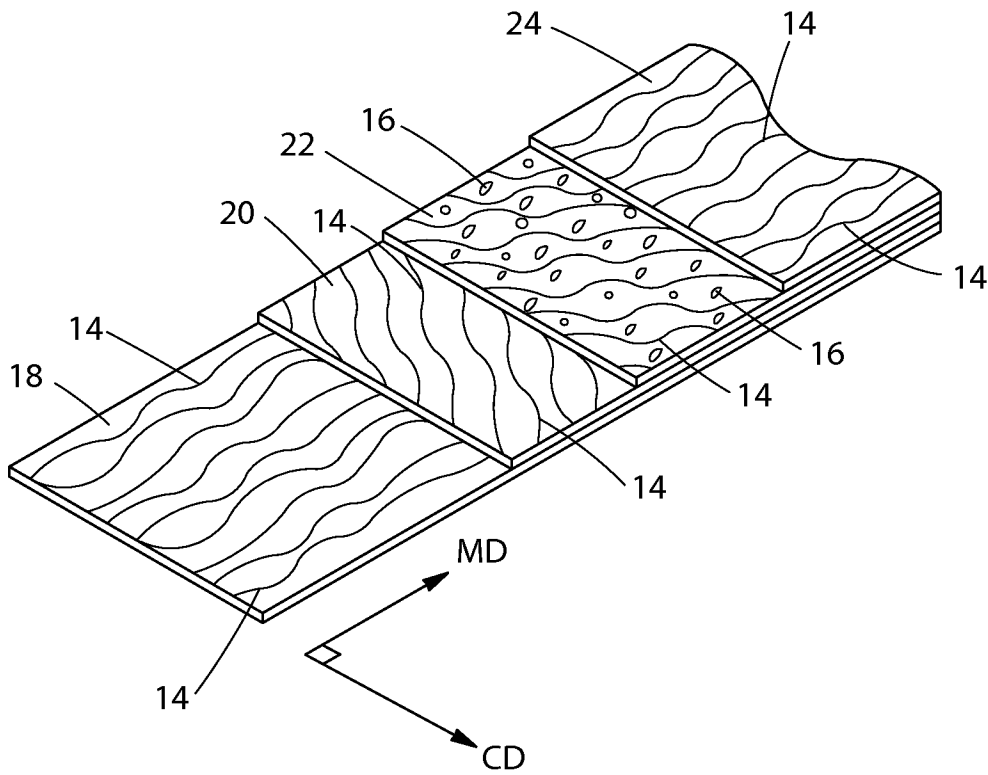


Fig. 2

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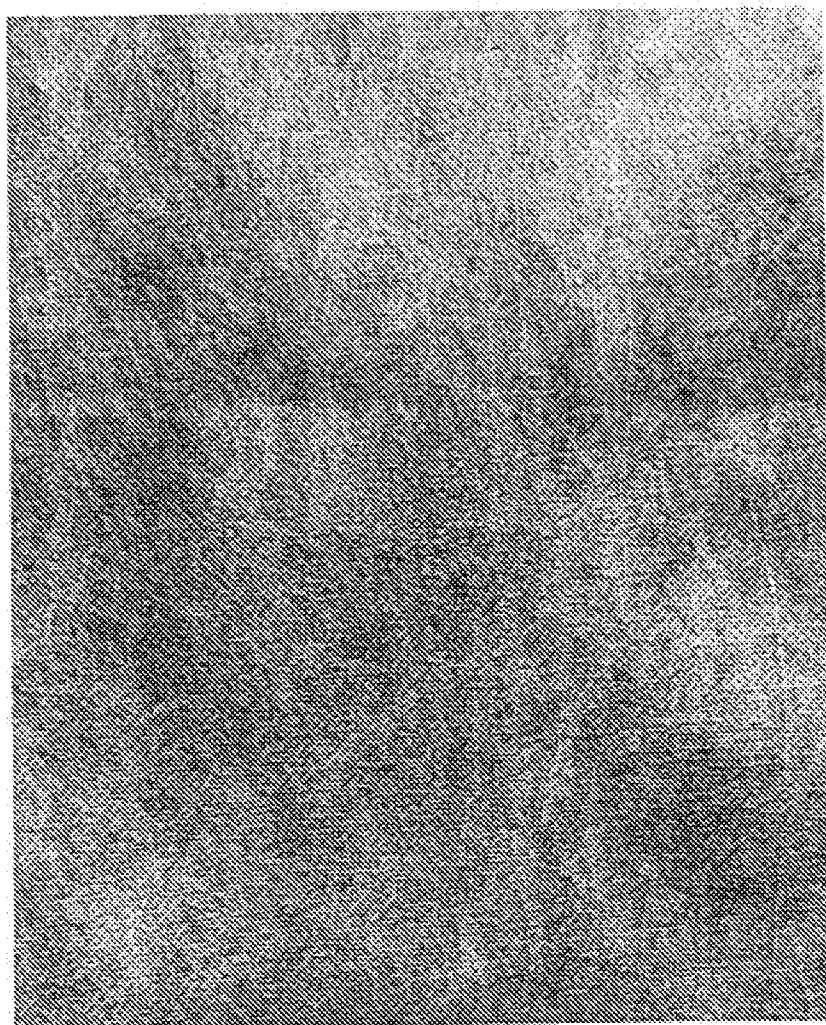


Fig. 3

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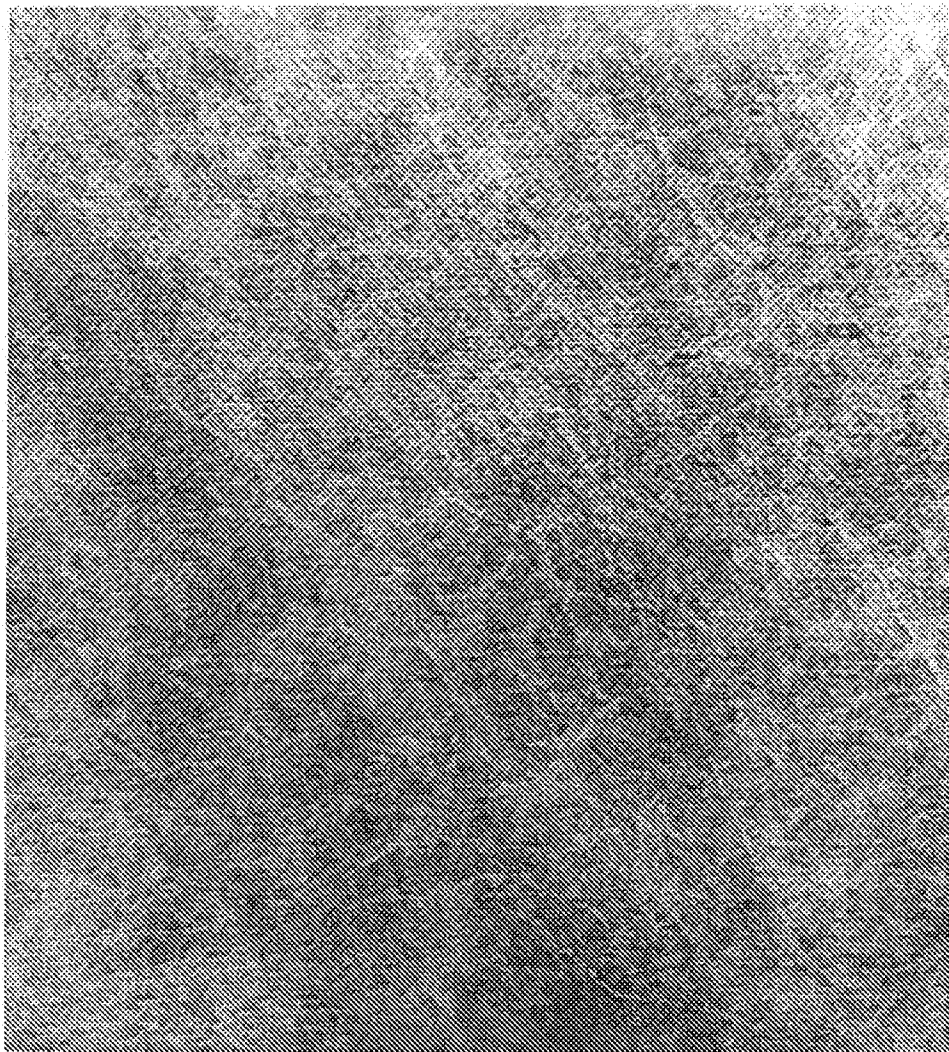


Fig. 4

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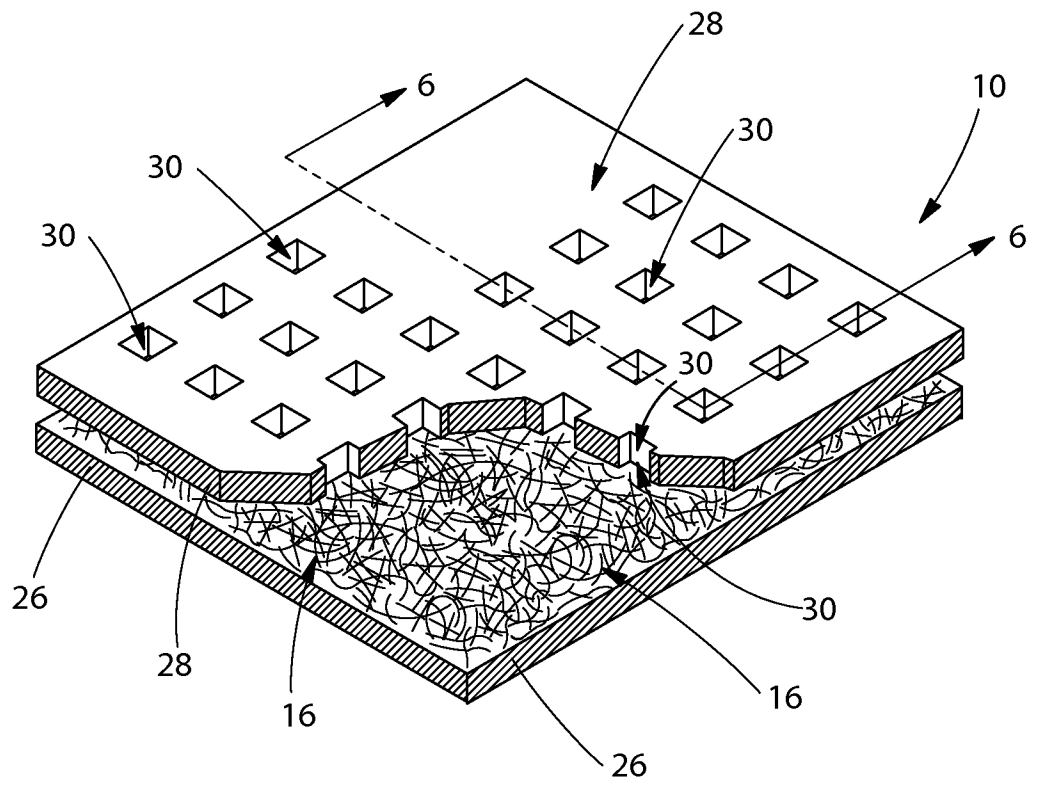


Fig. 5

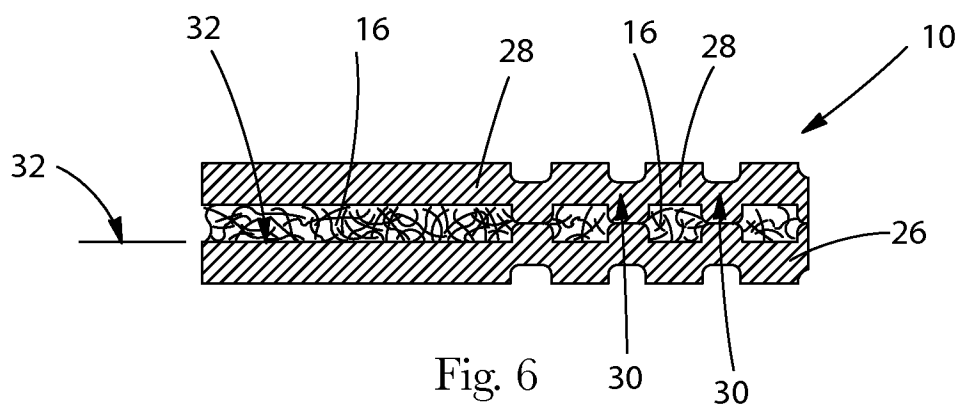
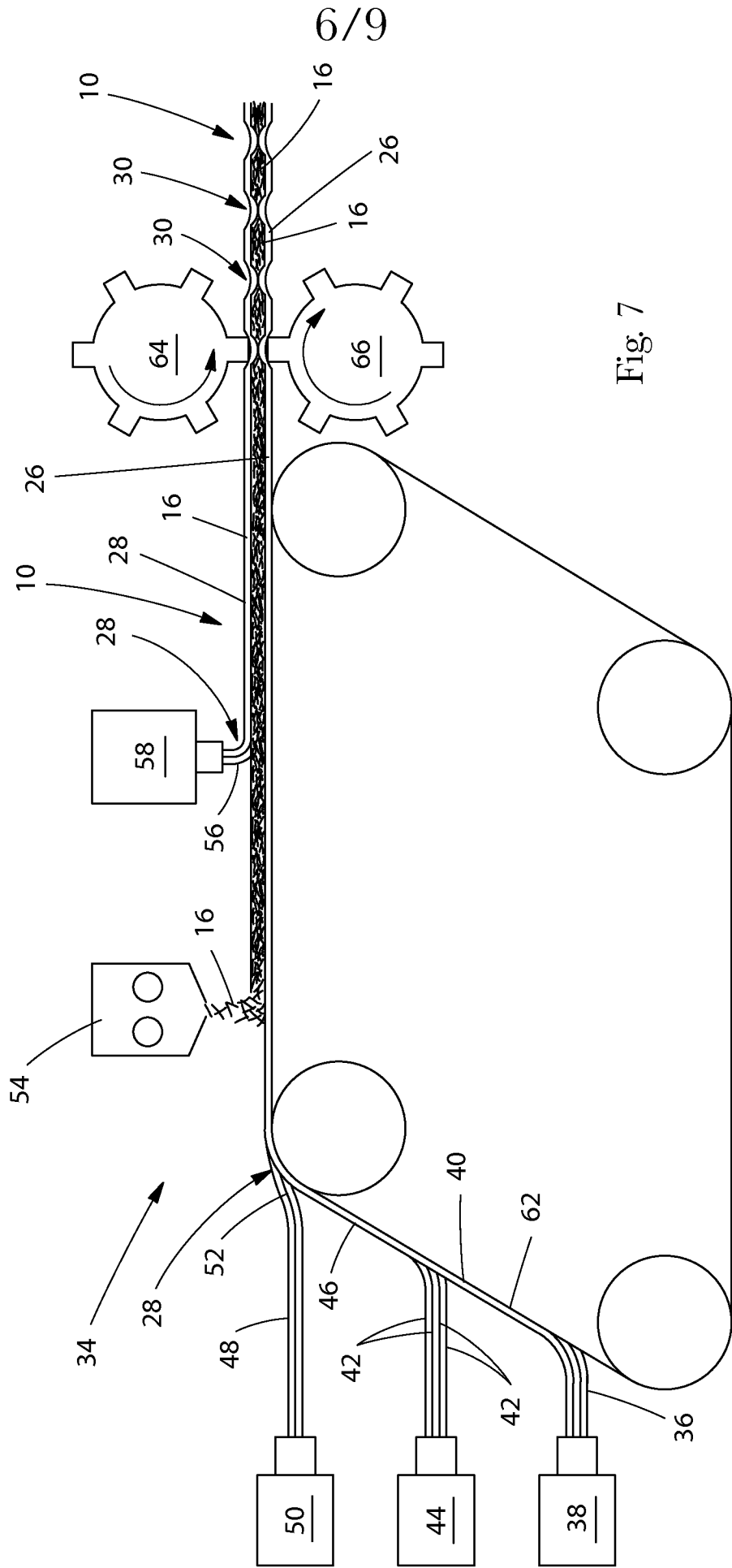


Fig. 6



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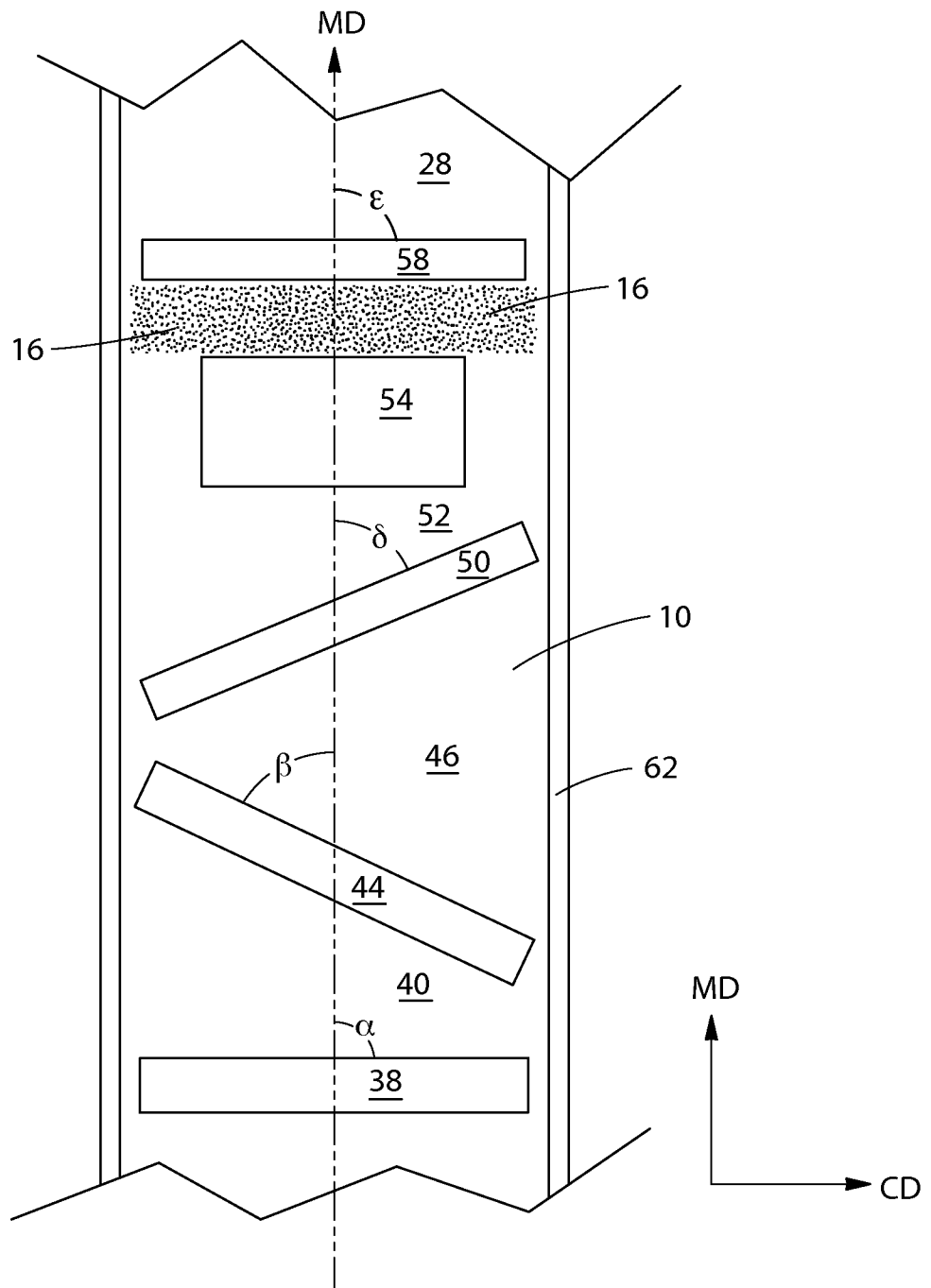


Fig. 8

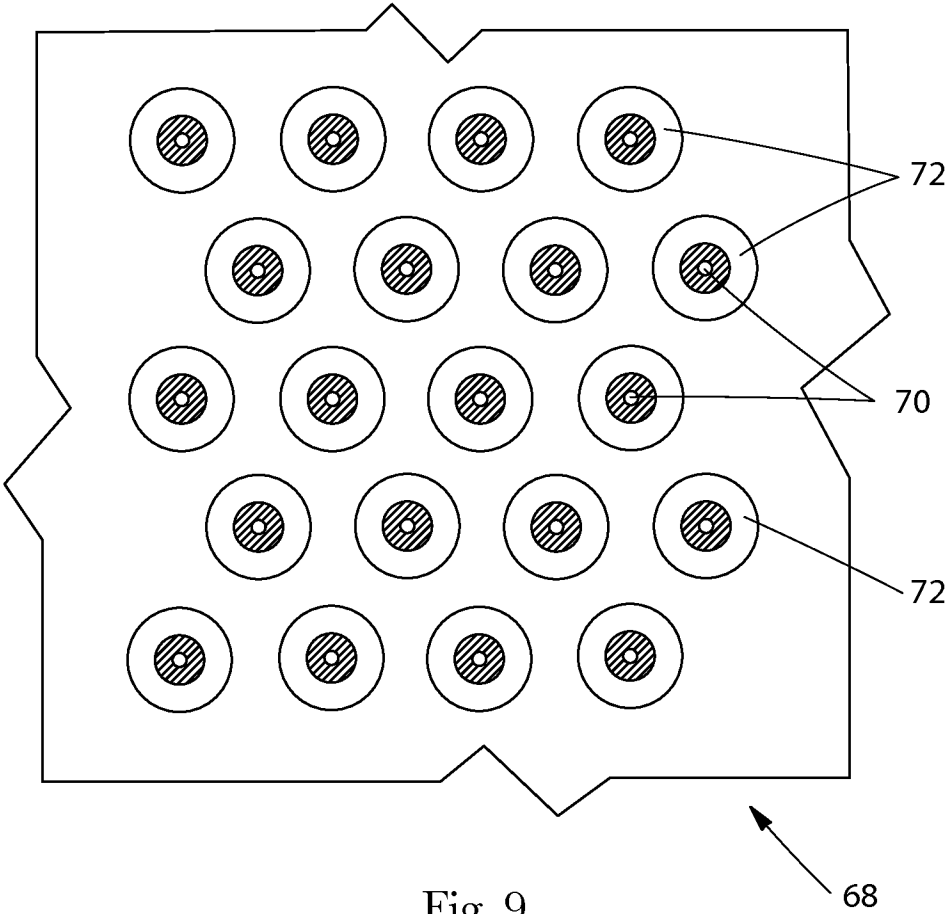


Fig. 9

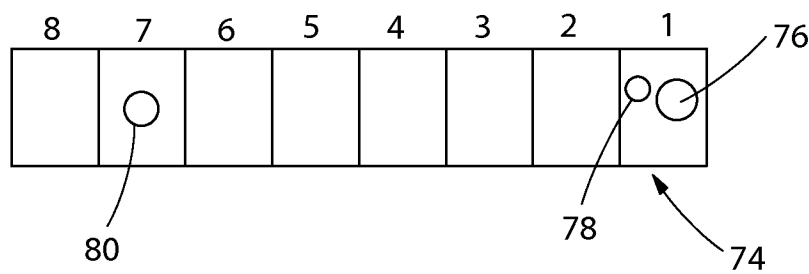


Fig. 10A

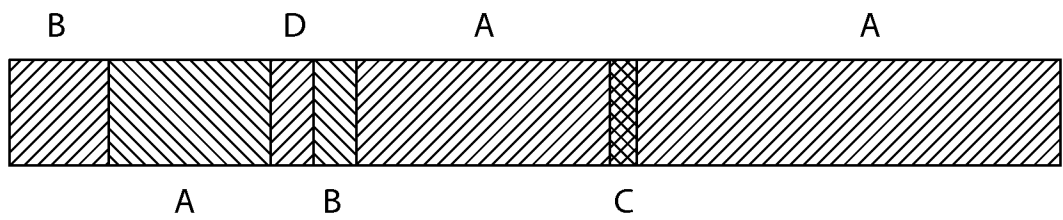


Fig. 10B

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/027004

A. CLASSIFICATION OF SUBJECT MATTER

INV. D21H27/00 D21H13/20 D21H15/06 D21H21/52
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
D21H

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

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

EP0-Internal, WPI Data

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Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	claims 1-15 ----- -/--	1-15



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"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

13 May 2013

Date of mailing of the international search report

28/05/2013

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Ponsaud, Philippe

INTERNATIONAL SEARCH REPORT

International application No
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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