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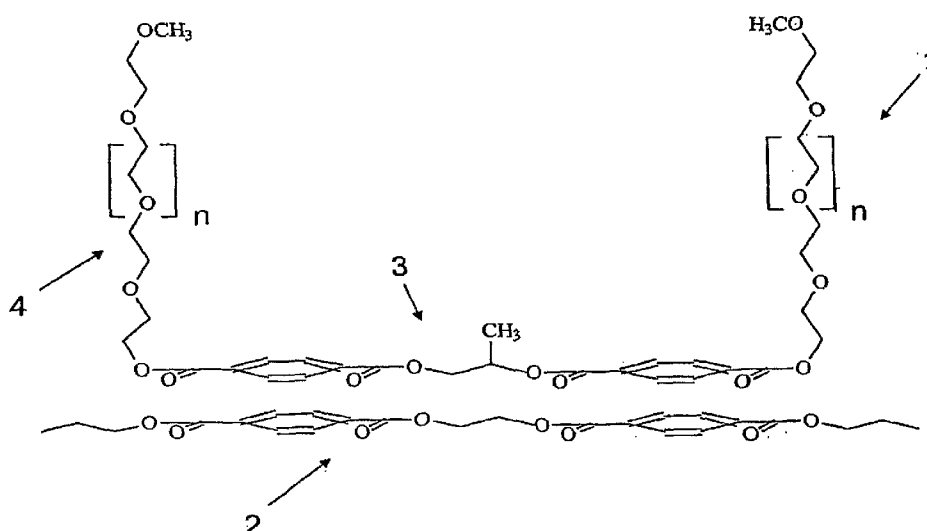
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(54) Title: NONWOVEN FIBROUS STRUCTURE COMPRISING SYNTHETIC FIBERS AND HYDROPHILIZING AGENT



(57) Abstract: A nonwoven fibrous structure comprises a plurality of synthetic fibers. The synthetic fibers may be associated with one or more hydrophilizing agents. A process for making the nonwoven fibrous structure involves association of the synthetic fibers with one or more hydrophilizing agents.



For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

NONWOVEN FIBROUS STRUCTURE COMPRISING SYNTHETIC FIBERS AND HYDROPHILIZING AGENT

FIELD OF THE INVENTION

The present invention relates to fibrous structures comprising synthetic fibers. The synthetic fibers may further be associated with a hydrophilizing agent.

BACKGROUND OF THE INVENTION

Fibrous structures, such as paper webs, are well known in the art and are in common use today for paper towels, toilet tissue, napkins, wet wipes, and the like. Various natural fibers, including cellulose fibers, as well as a variety of synthetic fibers, have been employed in papermaking. Typical tissue paper may be comprised primarily of natural fibers. The overwhelming majority of the natural fibers used in tissue may be derived from trees. Many species may be used, including long fiber containing softwoods (conifer or gymnosperms) and short fiber containing hardwoods (deciduous or angiosperms).

Despite a broad range of natural fiber types, natural fibers derived from trees may be limiting when used exclusively in disposable tissue and towel products. Wood fibers may be high in dry modulus and relatively large in diameter, which may cause their flexural rigidity to be higher than desired for some uses. Such high-rigidity fibers may produce stiff non-soft tissue. Further, wood fibers can have the undesirable characteristic of having a relatively high stiffness when dry, which may negatively affect the softness of the product and may have low stiffness when wet due to hydration, which may cause poor absorbency of the resulting product. Wood-based fibers may also be limiting because the geometry or morphology of the fibers cannot be "engineered" to any great extent.

The use of synthetic fibers that have the ability to thermally fuse to one another and/or to natural fibers is an excellent way to overcome the previously mentioned limitations of natural fibers. Wood-based natural fibers are not thermoplastic and hence cannot thermally bond to other fibers. Synthetic thermoplastic polymers can be formed into fibers with a range of diameters, including very small fibers. Further, synthetic fibers can be formed to be lower modulus than natural fibers. Thus, a synthetic fiber can be made with very low flexural rigidity, which may increase product softness. In addition, functional cross-sections of the synthetic fibers can be micro-engineered during the spinning process. Synthetic fibers can also be

designed to maintain modulus when wetted, and hence webs made with such fibers may resist collapse during absorbency tasks. Further, the use of synthetic fibers can aid in the formation of a web and/or its uniformity. Accordingly, the use of thermally bonded synthetic fibers in tissue and towel products can result in a strong network of highly flexible fibers (good for softness) joined with water-resistant high-stretch bonds (good for softness and wet strength).

The use of synthetic fibers, however, may have some limitations. The synthetic fibers may have a general characteristic of being hydrophobic. As such, the suspension of the hydrophobic synthetic fibers in a fluid carrier during the papermaking process may result in a slurry in which the hydrophobic synthetic fibers have clumped together. A fibrous structure created from such a slurry may demonstrate areas of high stiffness when dry and low stiffness when wet. Thus, the benefits of utilizing synthetic fibers to maintain the modulus of the fibrous structure when wet may not be realized. Additionally, the hydrophobic character of the synthetic fibers may overcome the generally hydrophilic character of the natural fibers. This, in turn, may have a negative impact on the fibrous structure and may result in a decrease in absorbency and/or rate of absorption of the overall structure.

A wide variety of hydrophilizing agents for use in domestic and industrial fabric treatment processes such as laundering, fabric drying in hot air clothes dryers, and the like, are known in the art and are conventionally referred to in those fields as "Soil Release Polymers" (SRP's) or "Soil Release Agents" (SRA's). Various oligomeric or polymeric hydrophilizing agents have been commercialized and are known for their use as soil release compounds in detergent compositions and fabric softener/antistatic articles and compositions. Hydrophilizing agents utilized in laundry applications generally are employed to pre- or post-treat woven fabrics. Woven fabrics pre-treated with hydrophilizing agents may exhibit stain guard characteristics while woven fabrics post-treated with hydrophilizing agents may exhibit stain release characteristics. The woven fabrics may be washed and re-washed and may retain their stain guard and stain release characteristics. Such hydrophilizing agents which comprise an oligomeric or polymeric ester "backbone" are sometimes referred to as "Soil Release Esters" (SRE's).

Hydrophilizing agents may also associate with synthetic fibers in a nonwoven fibrous structure. It has now been found that the use of a hydrophilizing agent to associate with the synthetic fibers of a nonwoven fibrous structure may have the ability to overcome one or more of the above mentioned disadvantages associated with the use of synthetic fibers. It has now been

found that the association of the hydrophilizing agents with synthetic fibers may enable the synthetic fibers to display hydrophilic characteristics thus overcoming the general hydrophobic nature of the synthetic fibers. This may allow for the dispersion of the synthetic fibers throughout the nonwoven fibrous structure instead of clumping together and may help provide a more homogeneous distribution of the fibers in webs which also comprise natural fibers. A uniform distribution of synthetic fibers which have associated with hydrophilizing agents in combination with natural fibers may also result in a fibrous structure that is hydrophilic in nature. A fibrous structure that is hydrophilic in nature may exhibit an increase in the absorbency and/or rate of absorption of fluids. Therefore, the utilization of hydrophilizing agents may result in a positive impact on the absorbency and/or rate of absorption of the nonwoven fibrous structure.

It would be desirable to provide improved fibrous structures comprising synthetic fibers in association with hydrophilizing agents. It would be desirable to provide a fibrous structure in which the synthetic fibers exhibit hydrophilic characteristics. It would be desirable to provide a fibrous structure in which the synthetic fibers are dispersed throughout the fibrous structure. It would be desirable to provide a fibrous structure in which absorbency is not negatively impacted. It would be desirable to provide a fibrous structure in which the rate of absorption is acceptable to consumers of the fibrous structure.

SUMMARY OF THE INVENTION

The present invention relates to a nonwoven fibrous structure comprising a plurality of synthetic fibers and a hydrophilizing agent. The synthetic fibers and hydrophilizing agent may comprise a durable association.

In one example of the present invention, a nonwoven fibrous structure comprising 1) a plurality of synthetic fibers, wherein one or more (or each) of said synthetic fibers comprises a polymer, and 2) a hydrophilizing agent, wherein said polymer and said hydrophilizing agent comprise complementary segments that are associated with one another, is provided.

The synthetic fibers may comprise a polymer. The polymer and the hydrophilizing agent may comprise complementary segments that may associate with one another. At least one of the complementary segments may comprise a polyester segment. The polymer of the synthetic fiber may comprise material selected from the group consisting of polyesters, polyamides,

polyhydroxyalkanoates, polysaccharides and combinations thereof. The fibrous structure may further comprise a plurality of natural fibers.

The hydrophilizing agent may be a copolymer. The hydrophilizing agent may be selected from the group consisting of polyester, poly(ethoxylate), polyethylene oxide, polyoxyethylene, polyethylene glycol, polypropylene glycol, terephthalate, polypropylene oxide, polyethylene terephthalate, polyoxyethylene terephthalate, ethoxylate siloxane and combinations thereof. The hydrophilizing agent may have from about 1 to about 15 ethoxylated groups.

The nonwoven fibrous structure may further comprise binder material. The binder material may be selected from the group consisting of permanent wet strength resins, temporary wet strength resins, dry strength resins, retention aid resins, latex binders and combinations thereof.

The nonwoven fibrous structure may be a component of an article selected from the group consisting of toilet paper, paper towel, napkins, facial tissue, wipes and combinations thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 depicts an artist's conception of the association of a dimeric hydrophilizing agent and a synthetic fiber.

Figure 2 depicts a schematic plan view of an embodiment of a fibrous structure of the present invention in which the synthetic fibers are distributed in a non-random pattern.

Figure 3 depicts a schematic plan view of an embodiment of a fibrous structure of the present invention in which the synthetic fibers and natural fibers are distributed randomly throughout the fibrous structure.

DETAILED DESCRIPTION OF THE INVENTION

As used herein, the following terms have the following meanings.

"Basis weight" refers to the weight (measured in grams) of a unit area (typically measured in square meters) of the fibrous structure, which unit area is taken in the plane of the fibrous structure. The size and shape of the unit area from which the basis weight is measured is dependent upon the relative and absolute sizes and shapes of the regions having different basis weights.

“Binder” and/or “Binder material” refers to the various wet and dry strength resins and retention aid resins known in the paper making art.

“Coarseness” refers to the weight per unit length of fiber expressed as milligrams per 100m, as set forth in TAPPI Method T 234 cm-02.

“Hydrophilizing agent” may be broadly disclosed as comprising oligomeric or polymeric “Backbones” to which are appended hydrophilic substituents. “Oligomeric” herein refers to a polymer molecule with fewer than 10 repeating units such as dimers, trimers, tetramers, etc. “Polymeric” herein refers to a molecule with greater than 10 repeating units. A wide variety of such agents are, as noted above, very well known for use as soil release compounds in the detergency arts. The manufacture of such agents forms no part of this invention. Reference can be made to a series of patents more fully disclosing such compounds, as well as their method of synthesis, as disclosed hereinafter. The present invention employs such compounds, and their equivalents, in the improved nonwoven fibrous structure described herein. Such compounds are usually water-soluble or water-dispersible under the preferred usage conditions herein, e.g., in a fiber slurry comprising an aqueous carrier medium; 20°C – 90°C operating conditions; usage levels of about 0.001% to about 20%, by weight of the fiber weight; weight ratio of hydrophilizing agent : hydrophobic fiber in slurry in the range of from about 0.0001:1 to about 1:1.

“Nonwoven” refers to a fibrous structure made from an assembly of continuous fibers, co-extruded fibers, non-continuous fibers, and combinations thereof, without weaving or knitting, by processes such as spun-bonding, carding, melt-blowing, air-laying, wet-laying, co-form, or other processes known in the art for such purposes. The non-woven structure may comprise one or more layers of such fibrous assemblies, wherein each layer may include continuous fibers, co-extruded fibers, non-continuous fibers, and combinations thereof.

“Unitary fibrous structure” or “fibrous structure” refers to a web arrangement comprising a plurality of synthetic fibers that are inter-entangled to form a single-ply sheet product having certain pre-determined microscopic geometric, physical, and aesthetic properties. The fibrous structure may further comprise natural fibers. The synthetic and/or natural fibers may be layered, as known in the art, in the unitary fibrous structure. The fibrous structure may be non-woven. The fibrous structure may be useful as a web for tissue grades of paper (i.e., sanitary tissue products) such as toilet paper, paper towels, napkins, facial tissue, and sanitary products such as wipes. The fibrous structure may be disposable. The fibrous structure of the present

invention may be incorporated into an article, such as a single or multi-ply sanitary tissue product. The fibrous structure of the present invention may be layered or homogeneous.

Fibrous Structure

The fibrous structure of the present invention may take a number of different forms. The fibrous structure may comprise 100% synthetic fibers or may be a combination of synthetic fibers and natural fibers. In one embodiment of the present invention, the fibrous structure may include one or more layers of a plurality of synthetic fibers mixed with a plurality of natural fibers. The synthetic fiber/natural fiber mix may be relatively homogeneous in that the different fibers may be dispersed generally randomly throughout the layer. The fiber mix may be structured such that the synthetic fibers and natural fibers may be disposed generally non-randomly. In one embodiment, the fibrous structure may include at least one layer comprising a plurality of natural fibers and at least one adjacent layer comprising a plurality of synthetic fibers. In another embodiment, the fibrous structure may include at least one layer that comprises a plurality of synthetic fibers homogeneously mixed with a plurality of natural fibers and at least one adjacent layer that comprises a plurality of natural fibers. In an alternate embodiment, the fibrous structure may include at least one layer that comprises a plurality of natural fibers and at least one adjacent layer that may comprise a mixture of a plurality of synthetic fibers and a plurality of natural fibers in which the synthetic fibers and/or natural fibers may be disposed generally non-randomly. Further, one or more of the layers of mixed natural fibers and synthetic fibers may be subjected to manipulation during or after the formation of the fibrous structure to disperse the layer or layers of mixed synthetic and natural fibers in a predetermined pattern or other non-random pattern. Such a pattern may be a repeating pattern.

Examples of natural fibers may include cellulosic natural fibers, such as fibers from hardwood sources, softwood sources, or other non-wood plants. The natural fibers may comprise cellulose, starch and combinations thereof. Non-limiting examples of suitable cellulosic natural fibers include, but are not limited to, wood pulp, typical northern softwood Kraft, typical southern softwood Kraft, typical CTMP, typical deinked, corn pulp, acacia, eucalyptus, aspen, reed pulp, birch, maple, radiata pine and combinations thereof. Other sources of natural fibers from plants include, but are not limited to, albardine, esparto, wheat, rice, corn, sugar cane, papyrus, jute, reed, sabia, raphia, bamboo, sidal, kenaf, abaca, sunn, rayon, lyocell, cotton, hemp, flax, ramie and combinations thereof. Yet other natural fibers may include fibers from other natural non-plant sources, such as, down, feathers, silk, and combinations thereof.

The natural fibers may be treated or otherwise modified mechanically or chemically to provide desired characteristics or may be in a form that is generally similar to the form in which they can be found in nature. Mechanical and/or chemical manipulation of natural fibers does not exclude them from what are considered natural fibers with respect to the development described herein.

The synthetic fibers can be any material, such as, but not limited to, those selected from the group consisting of polyesters, polypropylenes, polyethylenes, polyethers, polyamides, polyhydroxyalkanoates, polysaccharides, and combinations thereof. The synthetic fiber may comprise a polymer. The polymer may be any material, such as, but not limited to, those materials selected from the group consisting of polyesters, polyamides, polyhydroxyalkanoates, polysaccharides and combinations thereof. More specifically, the material of the polymer segment may be selected from the group consisting of poly(ethylene terephthalate), poly(butylene terephthalate), poly(1,4-cyclohexylenedimethylene terephthalate), isophthalic acid copolymers (e.g., terephthalate cyclohexylene-dimethylene isophthalate copolymer), ethylene glycol copolymers (e.g., ethylene terephthalate cyclohexylene-dimethylene copolymer), polycaprolactone, poly(hydroxyl ether ester), poly(hydroxyl ether amide), polyesteramide, poly(lactic acid), polyhydroxybutyrate, and combinations thereof. The polymer may comprise a segment, such as a polymer segment, that may be complementary to a hydrophilizing agent and/or a segment thereof. The portion of the polymer segment that is complementary to a hydrophilizing agent may facilitate association between the synthetic fiber and the hydrophilizing agent. The complementary segment may comprise a polyester segment. The polyester segment may further comprise a polyethylene terephthalate segment. The complementary segment of the polymer may be located on the surface of the synthetic fiber. Such may be the situation wherein the synthetic fiber may be a bicomponent fiber comprising a core and an outer surface.

Further, the synthetic fibers can be a single component (i.e., single synthetic material or mixture makes up entire fiber), bi-component (i.e., the fiber is divided into regions, the regions including two or more different synthetic materials or mixtures thereof and may include co-extruded fibers) and combinations thereof. It is also possible to use bicomponent fibers, or simply bicomponent or sheath polymers. These bicomponent fibers can be used as a component fiber of the structure, and/or they may be present to act as a binder for the other fibers present in the nonwoven material. Any or all of the synthetic fibers may be treated before, during, or after the process of the present invention to change any desired properties of the fibers. For example,

in certain embodiments, it may be desirable to treat the synthetic fibers before or during the papermaking process to make them more hydrophilic, more wettable, etc.

In certain embodiments of the present invention, it may be desirable to have particular combinations of fibers to provide desired characteristics. For example, it may be desirable to have fibers of certain lengths, widths, coarseness or other characteristics combined in certain layers or separate from each other. The fibers may have an average fiber length of greater than about 0.20 mm. The fibers may have an average fiber length of from about 0.20, 0.30, or 0.40 mm to about 0.60, 0.80, or 10.0 mm. The fibers may have an average fiber width of greater than about 5 micrometers. The fibers may have an average fiber width of from about 5 micrometers to about 50 micrometers. The fibers may have a coarseness of greater than about 5mg/100m. The fibers may have a coarseness of from about 5mg/100m to about 75mg/100 m. Individually, the fibers may have certain desired characteristics.

The fibrous structure may further comprise a binder material. The fibrous structure may comprise from about 0.01% to about 1%, 3%, or 5% by weight of a binder material selected from the group consisting of permanent wet strength resins, temporary wet strength resins, dry strength resins, retention aid resins and combinations thereof.

If permanent wet strength is desired, the binder material may be selected from the group consisting of polyamide-epichlorohydrin, polyacrylamides, styrene-butadiene latexes, insolubilized polyvinyl alcohol, ureaformaldehyde, polyethyleneimine, chitosan polymers and combinations thereof.

If temporary wet strength is desired, the binder material may be selected from the group of starch-based temporary wet strength resins consisting of cationic dialdehyde starch-based resin and dialdehyde starch and combinations thereof. The resin described in US Patent No. 4,981,557 may also be used.

If dry strength is desired, the binder material may be selected from the group consisting of polyacrylamide, starch, polyvinyl alcohol, guar or locust bean gums, polyacrylate latexes, carboxymethyl cellulose and combinations thereof.

A latex binder material may also be utilized. Such a latex binder may have a glass transition temperature from about 0°C, -10°C, or -20°C to about -40°C, -60°C, or -80°C. Examples of latex binders that may be used include, but are not limited to, polymers and copolymers of acrylate esters, referred to generally as acrylic polymers, vinyl acetate-ethylene copolymers, styrene-butadiene copolymers, vinyl chloride polymers, vinylidene chloride

polymers, vinyl chloride-vinylidene chloride copolymers, acrylo-nitrile copolymers, acrylic-ethylene copolymers and combinations thereof. The water emulsions of these latex binders usually contain surfactants. These surfactants may be modified during drying and curing so that they become incapable of rewetting.

Methods of application of the binder material may include aqueous emulsion, wet end addition, spraying and printing. At least an effective amount of binder material may be applied to the fibrous structure. Between about 0.01% and about 1.0%, 3.0% or 5.0% may be retained on the fibrous structure, calculated on a dry fiber weight basis. The binder material may be applied to the fibrous structure in an intermittent pattern generally covering less than about 50% of the surface area of the structure. The binder material may also be applied to the fibrous structure in a pattern to generally cover greater than about 50% of the fibrous structure. The binder material may be disposed on the fibrous structure in a random distribution. Alternatively, the binder material may be disposed on the fibrous structure in a non-random repeating pattern.

Additional information relating to the fibrous structure may be found in U.S. Patent Publication Nos. 2004/0154768 and 2004/0157524, US Patent Nos. 4,588,457; 5,397,435 and 5,405,501.

A variety of products can be made using the fibrous structure of the present invention. The resultant products may be disposable. The resultant products may find use in filters for air, oil and water; vacuum cleaner filters; furnace filters; face masks; coffee filters, tea or coffee bags; thermal insulation materials and sound insulation materials; nonwovens for one-time use sanitary products such as wipes; biodegradable textile fabrics for improved moisture absorption and softness of wear such as microfiber or breathable fabrics; an electrostatically charged, structured web for collecting and removing dust; reinforcements and webs for hard grades of paper, such as wrapping paper, writing paper, newsprint, corrugated paper board, and webs for tissue grades of paper such as toilet paper, paper towel, napkins, and facial tissue; medical uses such as surgical drapes, wound dressing, bandages, and dermal patches. The fibrous structure may also include odor absorbants, termite repellents, insecticides, rodenticides, and the like, for specific uses. The resultant product may absorb water and oil and may find use in oil or water spill clean-up, or controlled water retention and release for agricultural or horticultural applications.

Wipe

The fibrous structure, as described above, may be utilized to form a wipe. "Wipe" may be a general term to describe a piece of material, generally non-woven material, used in cleansing hard surfaces, food, inanimate objects, toys and body parts. In particular, many currently available wipes may be intended for the cleansing of the peri-anal area after defecation. Other wipes may be available for the cleansing of the face or other body parts. Multiple wipes may be attached together by any suitable method to form a mitt.

The material from which a wipe is made should be strong enough to resist tearing during normal use, yet still provide softness to the user's skin, such as a child's tender skin. Additionally, the material should be at least capable of retaining its form for the duration of the user's cleansing experience.

Wipes may be generally of sufficient dimension to allow for convenient handling. Typically, the wipe may be cut and/or folded to such dimensions as part of the manufacturing process. In some instances, the wipe may be cut into individual portions so as to provide separate wipes which are often stacked and interleaved in consumer packaging. In other embodiments, the wipes may be in a web form where the web has been slit and folded to a predetermined width and provided with means (e.g., perforations) to allow individual wipes to be separated from the web by a user. Suitably, an individual wipe may have a length between about 100 mm and about 250 mm and a width between about 140 mm and about 250 mm. In one embodiment, the wipe may be about 200 mm long and about 180 mm wide. The material of the wipe may generally be soft and flexible, potentially having a structured surface to enhance its cleaning performance.

It is also within the scope of the present invention that the wipe may be a laminate of two or more materials. Commercially available laminates, or purposely built laminates would be within the scope of the present invention. The laminated materials may be joined or bonded together in any suitable fashion, such as, but not limited to, ultrasonic bonding, adhesive, glue, fusion bonding, heat bonding, thermal bonding and combinations thereof. In another alternative embodiment of the present invention the wipe may be a laminate comprising one or more layers of nonwoven materials and one or more layers of film. Examples of such optional films, include, but are not limited to, polyolefin films, such as, polyethylene film. An illustrative, but non-limiting example of a nonwoven material which is a laminate is a laminate of a 16 gsm nonwoven polypropylene and a 0.8 mm 20 gsm polyethylene film.

The wipes may also be treated to improve the softness and texture thereof by processes such as hydroentanglement or spunlacing. The wipes may be subjected to various treatments,

such as, but not limited to, physical treatment, such as ring rolling, as described in U.S. Patent No. 5,143,679; structural elongation, as described in U.S. Patent No. 5,518,801; consolidation, as described in U.S. Patent Nos. 5,914,084, 6,114,263, 6,129,801 and 6,383,431; stretch aperturing, as described in U.S. Patent Nos. 5,628,097, 5,658,639 and 5,916,661; differential elongation, as described in WO Publication No. 2003/0028165A1; and other solid state formation technologies as described in U.S. Publication Nos. 2004/0131820A1 and 2004/0265534A1 and zone activation and the like; chemical treatment, such as, but not limited to, rendering part or all of the substrate hydrophobic, and/or hydrophilic, and the like; thermal treatment, such as, but not limited to, softening of fibers by heating, thermal bonding and the like; and combinations thereof.

The wipe may have a basis weight between about 15, 30, 40, 45, 65, 75 or 100 grams/m² and about 200, 300, 400 or 500 grams/m². The wipe may have a basis weight between about 40 or 45 grams/m² and about 65, 75, or 100 grams/m².

In one embodiment of the present invention the surface of wipe may be essentially flat. In another embodiment of the present invention the surface of the wipe may optionally contain raised and/or lowered portions. These can be in the form of logos, indicia, trademarks, geometric patterns, images of the surfaces that the substrate is intended to clean (i.e., infant's body, face, etc.). They may be randomly arranged on the surface of the wipe or be in a repetitive pattern of some form.

In another embodiment of the present invention the wipe may be biodegradable. For example the wipe could be made from a biodegradable material such as a polyesteramide, or high wet strength cellulose.

Hydrophilizing Agent

Figure 1 is illustrative, but not limiting, of an artist's conception at the molecular level of a hydrophilizing agent 1 having a dimeric "backbone," a complementary segment 3, and hydrophilic substituents 4, associated with a complementary segment of a synthetic fiber 2, wherein n may be from about 1 to about 15.

While not intending to be limited by theory, it is surmised that the hydrophilizing agent becomes associated with one or more surfaces of the hydrophobic synthetic fiber. The association between the hydrophilizing agent and the synthetic fiber may be a durable association. The association of the hydrophilizing agent with the synthetic fibers may provide for the synthetic fibers to exhibit hydrophilic characteristics as opposed to the hydrophobic

characteristics displayed by the synthetic fibers alone. It is further surmised that the hydrophobicity of synthetic fibers alone may generally cause the synthetic fibers to clump together during the webmaking process or within a fibrous structure. Whatever the reason, it has now been found that the association of a hydrophilizing agent with the synthetic fibers may provide for the dispersion of the synthetic fibers in a fibrous structure. For example, during a wet laid papermaking process, there may be a dispersion of the synthetic fibers in a fluid carrier which may then promote the dispersion of the synthetic fibers in the fibrous structure. Natural fibers may optionally be present in the dispersion as the natural fibers may not interfere with the association of the hydrophilizing agent to the synthetic fibers. The hydrophilizing agent may associate with the natural fibers; however, this association will not prevent the hydrophilizing agent from associating with the synthetic fibers.

Hydrophilizing agents can include a variety of charged anionic or cationic species as well as noncharged monomer units. The anionic and cationic polymers may enhance both the deposition and the wettability of the synthetic fibers. Hydrophilizing agents comprising cationic functionalities are disclosed in US 4,956,447. The structure of the hydrophilizing agents may be linear, branched or even star-shaped. Structures and charge distributions may be tailored for application to different fiber or textile types.

The hydrophilizing agent may associate with the synthetic fibers by a correspondence between the hydrophilizing agent and the surface characteristics of the synthetic fibers. This correspondence may be based on physical characteristics of the synthetic fibers and hydrophilizing agent. Such physical characteristics may include, but are not limited to, degree of crystallinity and molecular weight. Correspondence between the physical characteristics of the hydrophilizing agents and the synthetic fibers may aid in the durability of the association formed between the hydrophilizing agents and the synthetic fibers. It has been found that an association based upon physical characteristics may be durable wherein the hydrophilizing agent may not wash off from the synthetic fibers. As such, the hydrophilizing agents of the present invention may be distinguished from typical surfactants. The bond between the synthetic fibers and the hydrophilizing agent may be durable. The synthetic fibers may exhibit a durable wettability. The synthetic fibers may exhibit a mean contact angle of less than about 72° . The synthetic fibers may exhibit a mean contact angle of less than about 72° and after a 10 minute water wash the mean contact angle of the synthetic fibers may remain below about 72° . The synthetic fibers may exhibit a mean contact angle following a 10 minute water wash of less than about 66° , 63° ,

60°, 55° or 50°. The synthetic fibers exhibiting such mean contact angles may be associated with a hydrophilizing agent. The bond between the synthetic fibers and the hydrophilizing agent may be durable and the hydrophilizing agent may not be washed off the synthetic fibers after a single insult of fluid. A surfactant, on the other hand, is unable to form such a durable bond and may be washed off the synthetic fibers upon a single insult of fluid. Furthermore, a fibrous structure comprising synthetic fibers and a hydrophilizing agent may demonstrate a sustainable wettability, as detailed herein, whereas a fibrous structure comprising synthetic fibers and a surfactant may not exhibit a sustainable wettability. A more permanent association may be made between the hydrophilizing agent and the synthetic fibers by heating the combination of the hydrophilizing agent and the synthetic fibers above the melting temperature of the hydrophilizing agent.

Hydrophilizing agents may comprise greater than about 3 ppm of a hydrophilizing agent/synthetic fiber and/or natural fiber combination. Hydrophilizing agents may generally comprise from about 10, 20, 30 or 40 ppm to about 50, 60, 80 or 100 ppm of a hydrophilizing agent/synthetic fiber and/or natural fibers combination. The compositions herein may comprise greater than about 0.001% of a hydrophilizing agent. The compositions herein may comprise from about 0.001% to about 2%, 5%, 10% or 20% of a hydrophilizing agent.

The hydrophilizing agent may comprise a segment that may be complementary to the polymer of the synthetic fibers. The complementary segment may comprise a polyester segment. The polyester segment may comprise a polyethylene terephthalate segment. The hydrophilizing agent may be oligomeric or polymeric. The hydrophilizing agent may be a copolymer of ethoxylate siloxane. The hydrophilizing agent may be soil release agent. Such a hydrophilizing agent may be a polymer. Polymeric hydrophilizing agents useful in the present invention may include, but are not limited to, materials selected from the group consisting of polyester, poly(ethoxylate), polyethylene oxide, polyoxyethylene, polyethylene glycol, polypropylene glycol, terephthalate, polypropylene oxide, polyethylene terephthalate, polyoxyethylene terephthalate, ethoxylate siloxane and combinations thereof. Polyesters of terephthalic and other aromatic dicarboxylic acids having soil release properties such as polyethylene terephthalate/polyoxyethylene terephthalate and polyethylene terephthalate/polyethylene glycol polymers, among other polyester polymers, may be utilized as the hydrophilizing agent in the fibrous structure. As noted above, a wide variety of hydrophilizing agents, also known as SRP's, SRA's, and SRE's, are well-recognized materials in the detergency arts, and many are available

commercially or by synthesis schemes disclosed in multiple patents of The Procter & Gamble Company and various manufacturers.

Higher molecular weight (e.g., 40,000 to 50,000 M.W.) polyesters containing random or block ethylene terephthalate/polyethylene glycol (PEG) terephthalate units have been used as soil release agents in laundry cleaning compositions. See U.S. Patent Nos. 3,893,929; 3,959,230 and 3,962,152. Sulfonated linear terephthalate ester oligomers are disclosed in U.S. 4,968,451. Nonionic end-capped 1,2-propylene/polyoxyethylene terephthalate polyesters are disclosed in U.S. 4,711,730 and nonionic-capped block polyester oligomeric compounds are disclosed in U.S. 4,702,857. Partly- and fully- anionic-end-capped oligomeric esters are disclosed further in U.S. 4,721,580 and anionic, especially sulfoaroyl, end-capped terephthalate esters are disclosed in U.S. 4,877,896 and U.S. 5,415,807.

U.S. 4,427,557 discloses low molecular weight copolyesters (M.W. 2,000 to 10,000) which can be used in aqueous dispersions to impart soil release properties to polyester fibers. The copolyesters are formed by the reaction of ethylene glycol, a PEG having an average molecular weight of 200 to 1000, an aromatic dicarboxylic acid (e.g., dimethyl terephthalate), and a sulfonated aromatic dicarboxylic acid (e.g., dimethyl 5-sulfoisophthalate). The PEG can be replaced in part with monoalkylethers of PEG such as the methyl, ethyl and butyl ethers.

A hydrophilizing agent may be a copolymer having blocks of terephthalate and polyethylene oxide. More specifically, these polymers may comprise repeating units of ethylene and/or propylene terephthalate and polyethylene oxide terephthalate at a molar ratio of ethylene terephthalate units to polyethylene oxide terephthalate units of from about 25:75 to about 35:65, said polyethylene oxide terephthalate containing polyethylene oxide blocks having molecular weights of from about 300 to about 2000. The molecular weight of this polymeric hydrophilizing agent may be in the range of from about 5,000 to about 55,000.

Another polymeric hydrophilizing agent may be a crystallizable polyester with repeat units of ethylene terephthalate units comprising from about 10% to about 15% by weight of ethylene terephthalate units together with from about 10% to about 50% by weight of polyoxyethylene terephthalate units, derived from a polyoxyethylene glycol of average molecular weight of from about 300 to about 6,000, and the molar ratio of ethylene terephthalate units to polyoxyethylene terephthalate units in the crystallizable polymeric compound may be between 2:1 and 6:1. Examples of this polymer include the commercially available materials ZELCON[®] 4780 (from DuPont) and MILEASE[®] T (from ICI).

In another embodiment, the poly(ethoxylate) regions may be tailored to have from about 1 to about 9, 12, or 15 ethoxylated groups and any other number of ethoxylated groups within the range of from about 1 to about 15. The number of poly(ethoxylated) regions may be tailored to enhance the wettability of the synthetic fibers. Wettability of the synthetic fibers may be increased as the number of ethoxylated groups increases in the poly(ethoxylate) regions. Optionally, additional copolymers such as, but not limited to, polyethylene glycol and polypropylene glycol, may be used to control the crystallinity of the hydrophilizing agents.

In an alternative embodiment, the hydrophilizing agents provided by the invention may be illustrated by one comprising from about 25% to about 100% by weight of an ester having the empirical formula $(\text{CAP})_x(\text{EG/PG})_{y'}(\text{DEG})_{y''}(\text{PEG})_{y'''}(\text{T})_z(\text{SIP})_q$; wherein (CAP) represents the sodium salt form of said end-capping units i); (EG/PG) represents said oxyethyleneoxy and oxy-1,2-propyleneoxy units ii); (DEG) represents said di(oxyethylene)oxy units iii); (PEG) represents said poly(oxyethylene)oxy units iv); (T) represents said terephthaloyl units v); (SIP) represents the sodium salt form of 5-sulfoisophthaloyl units vi); x is from about 1 to 2; y' is from about 0.5 to about 66; y'' is from 0 to about 50; y''' is from 0 to about 50; y'+y''+y''' totals from about 0.5 to about 66; z is from about 1.5 to about 40; and q is from about 0.05 to about 26; wherein x, y', y'', y''', z and q represent the average number of moles of the corresponding units per mole of said ester. Hydrophilizing agents may be those wherein at least about 50% by weight of said ester has a molecular weight ranging from about 500 to about 5,000.

In one embodiment, the hydrophilizing agents may have oxyethyleneoxy:oxy-1,2-propyleneoxy mole ratio ranges from about 0.5:1 to about 10:1; x is about 2, y' is from about 2 to about 27, z is from about 2 to about 20, and q is about 0.4 to about 8. In another embodiment, x is about 2, y' is about 5, z is about 5, and q is about 1.

The hydrophilizing agents may associate with the synthetic fiber surface during the process of re-pulping the fibers. The synthetic fibers may also be provided with a finishing coat of the hydrophilizing agent prior to re-pulping the fibers. Additionally, the hydrophilizing agent may associate with the synthetic fibers as a melt-additive prior to extrusion of the synthetic fibers.

Additional information relating to hydrophilizing agents may be found in U.S. Patent Nos. 4,702,857; 4,861,512; 5,574,179 and 5,843,878.

Method of Making Fibrous Structure

Generally, the process of the present invention for making a unitary fibrous structure may be described in terms of forming a web having a plurality of synthetic fibers disposed in a generally random pattern throughout the fibrous structure. A plurality of natural fibers may also be disposed in a generally random pattern throughout the fibrous structure. In another embodiment, a portion of the synthetic fibers may be redistributed in a non-random repeating pattern. Layered deposition of the fibers, synthetic and natural, is also contemplated by the present invention.

In a typical wet-laid process, the plurality of fibers may be suspended in a fluid carrier. This may also be known as "re-pulping" the fibers. Synthetic fibers may be re-pulped separately from or in combination with natural fibers. In another embodiment, a plurality of synthetic fibers and a plurality of natural fibers may both be added to a re-pulper. A hydrophilizing agent may then be added to the re-pulper to associate with the synthetic fibers. In yet another embodiment, a plurality of synthetic fibers may be added to a re-pulper and mixed with a hydrophilizing agent. This combination may then be mixed with a plurality of natural fibers. As an alternative, the synthetic fibers may associate with a hydrophilizing agent by providing the synthetic fibers with a finishing coat containing a hydrophilizing agent prior to being re-pulped. The synthetic fibers may then be re-pulped and combined with natural fibers. Alternatively, the hydrophilizing agent may associate with the synthetic fibers as a melt-additive prior to extrusion of the fibers.

In yet another embodiment, the process may be air-laid in which a plurality of synthetic fibers associated with a hydrophilizing agent are placed directly into the papermaking machinery. In such an embodiment, a plurality of natural fibers may also be placed directly into the papermaking machinery. In addition to wet-laid and air-laid, other methods may include, but are not limited to, melt-blown, spun-bond, carded, co-form, adhesive bonding, needle punched, hydroentangled, lamination or other processes known in the art for such purposes. Combinations of the methods can also be used.

The resulting fibrous structure may comprise natural and synthetic fibers dispersed generally randomly throughout the layer. Alternatively, the natural and synthetic fibers may be more structured such that the synthetic fibers and natural fibers may be disposed generally non-randomly. In one embodiment, the fibrous structure may include at least one layer comprising a plurality of natural fibers and at least one adjacent layer comprising a plurality of synthetic fibers. In another embodiment, the fibrous structure may include at least one layer that

comprises a plurality of synthetic fibers homogeneously mixed with natural fibers and at least one adjacent layer that comprises a plurality of natural fibers. In an alternate embodiment, the fibrous structure may include at least one layer that comprises a plurality of natural fibers and at least one adjacent layer that comprises a mixture of a plurality of synthetic fibers and a plurality of natural fibers in which the synthetic fibers and/or natural fibers may be disposed generally non-randomly. Further, one or more of the layers of mixed natural fibers and synthetic fibers may be redistributed in a predetermined pattern or other non-random pattern.

Figure 2 schematically shows one embodiment of the fibrous structure 100 wherein the natural fibers 110 are randomly distributed throughout the structure, and the synthetic fibers 120 are redistributed in a non-random repeating pattern. Figure 3 illustrates a fibrous structure 100 that may comprise a plurality of natural fibers 110 and a plurality of synthetic fibers 120 randomly distributed throughout the fibrous structure.

The following illustrates the practice of the invention, but is not intended to be limiting thereof.

Example 1:

Four different handsheets using Northern Softwood Kraft and CoPET/PET (isophthalic acid copolymers) fibers with or without different hydrophilizing agents are prepared and tested for their impact on Horizontal Absorptive Capacity (H.A.C.) as determined by the Horizontal Full Sheet (HFS) test method described below.

All values below are an average of four separate handsheets.

As shown in the following Table, synthetic fiber addition has a negative impact (~8% loss) on Horizontal Absorptive Capacity (H.A.C.). Addition of hydrophilizing agents makes the synthetic fibers hydrophilic enough to recover the loss in absorptive capacity.

	Basis Weight, g/m ²	H.A.C. g/g	H.A.C. Ratio
Sample A (Base)	26.7	11.55	1.00
Sample B	28.3	10.60	0.92
Sample C	27.2	11.77	1.02
Sample D	27.6	11.68	1.01

Sample A 100% Northern Softwood Kraft (Control sample with cellulosic fibers only)

Sample B About 70% Northern Softwood Kraft and about 30% CoPET/PET

Sample C About 70% Northern Softwood Kraft and about 30% CoPET/PET
and about 40 ppm TexCareTM SRN-240

Sample D About 70% Northern Softwood Kraft and about 30% CoPET/PET
and about 50 ppm TexCare™ SRN-100

CoPET/PET fibers are commercially available from Fiber Innovation Technology, Inc., Johnson City, TN. The CoPET/PET fibers as used in this example are designated as T-235 by Fiber Innovation Technology. TexCare SRN-100 and TexCare SRN-240 are commercially available from Clairant GmbH, Division Functional Chemicals, Frankfurt am Main.

H.A.C. Ratio = H.A.C. of the Sample/H.A.C. of the Base Sample A

For this Example, the HFS procedure is modified. Four inch (10.2 cm) by 4 inch (10.2 cm) paper samples are used rather than 11 inch (27.9 cm) by 11 inch (27.9 cm) samples as described in the procedure.

Example 2:

A pilot scale Fourdrinier papermaking machine is used in the present example. A 3%, by weight, aqueous slurry of Northern Softwood Kraft (NSK) is made up in a conventional re-pulper. The NSK slurry is refined gently and a 2% solution of a permanent wet strength resin (i.e., Kymene 557LX which is marketed by Hercules Inc., Wilmington, Del.) is added to the NSK stock pipe at a rate of 1%, by weight of the dry fibers. The adsorption of Kymene 557LX to NSK is enhanced by an in-line mixer. A 1% solution of Carboxy Methyl Cellulose (CMC) is added after the in-line mixer at a rate of 0.2%, by weight of the dry fibers, to enhance the dry strength of the fibrous substrate. A 3%, by weight, aqueous slurry of Eucalyptus fibers is made up in a conventional re-pulper.

The NSK slurry and the Eucalyptus fibers are layered in a head box and deposited onto a Fourdrinier wire as different layers to form an embryonic web. Dewatering occurs through the Fourdrinier wire and is assisted by a deflector and vacuum boxes. The Fourdrinier wire is of a 5-shed, satin weave configuration having 84 machine-direction and 76 cross-machine-direction monofilaments per inch, respectively. The wet embryonic web is transferred from the Fourdrinier wire, at a fiber consistency of about 18% at the point of transfer, to a photo-polymer fabric having 150 Linear Idaho cells per square inch, 20 percent knuckle areas and 17 mils of photo-polymer depth. Further de-watering is accomplished by vacuum assisted drainage until the web has a fiber consistency of about 22%. The patterned web is pre-dried by air blow-through to a fiber consistency of about 56% by weight. The web is then adhered to the surface of a Yankee dryer with a sprayed creping adhesive comprising 0.25% aqueous solution of

Polyvinyl Alcohol (PVA). The fiber consistency is increased to an estimated 96% before dry creping the web with a scalpel blade. The scalpel blade has a bevel angle of about 25 degrees and is positioned with respect to the Yankee dryer to provide an impact angle of about 81 degrees; the Yankee dryer is operated at about 600 fpm (feet per minute) (about 183 meters per minute). The dry web is formed into roll at a speed of 560 fpm (171 meters per minutes).

Two plies of the web are formed into paper towel products by embossing and laminating them together using PVA adhesive. The paper towel has about 40 g/m² basis weight and contains 70% by weight Northern Softwood Kraft and 30% by weight Eucalyptus furnish. The resulting paper towel has an absorptive capacity of 26.3 gram/gram. The resulting paper towel may also provide a Horizontal Rate Capacity (HRC) value, determined according to the test method described herein. In this example, the HRC value is 0.57 g/sec.

Example 3:

A paper towel is made by a method similar to that of Example 2, but replacing 10% by weight of Eucalyptus by 10% by weight of 6mm in length and about 20 microns in diameter synthetic bicomponent polyester fibers. The polyester fibers as used in this example are available from Fiber Innovation Technology and are designated as T-201. Forty ppm TexCareTM SRN-240 is added to the Eucalyptus-synthetic fiber pulp mixture. The paper towel has about 40 g/m² basis weight and contains 70% by weight Northern Softwood Kraft in one layer and a mixture of 20% by weight Eucalyptus and 10% by weight of the 6mm long synthetic fibers in the other layer. The resulting paper towel has an absorptive capacity of 26.3 gram/gram. The resulting HRC value for this paper towel is 0.56 g/sec.

Example 4:

A paper towel is made by a method similar to that of Example 2, but replacing 5% by weight of Eucalyptus by 5% by weight of 6mm synthetic bicomponent polyester fibers. The polyester fibers of this example are available from Fiber Innovation Technology and are designated as T-201. Forty ppm TexCareTM SRN-240 is added to the Eucalyptus-synthetic fiber pulp mixture. The paper towel has about 40 g/m² basis weight and contains 70% by weight Northern Softwood Kraft in one layer and a mixture of 25% by weight Eucalyptus and 5% by weight of the 6mm long synthetic fibers in the other layer. The resulting paper towel has an absorptive capacity of 26.2 gram/gram. The resulting HRC value for this paper towel is 0.57 g/sec.

Horizontal Full Sheet (HFS) Test Method

The Horizontal Full Sheet (HFS) test method determines the amount of distilled water absorbed and retained by the fibrous structure of the present invention. This method is performed by first weighing a sample of the fibrous structure to be tested (referred to herein as the "dry weight of the sample"), then thoroughly wetting the sample, draining the wetted sample in a horizontal position and then reweighing (referred to herein as "wet weight of the sample"). The absorptive capacity of the sample is then computed as the amount of water retained in units of grams of water absorbed by the sample. When evaluating different fibrous structure samples, the same size of fibrous structure is used for all samples tested.

The apparatus for determining the HFS capacity of fibrous structures comprises the following:

- 1) An electronic balance with a sensitivity of at least ± 0.01 grams and a minimum capacity of 1200 grams. The balance should be positioned on a balance table and slab to minimize the vibration effects of floor/benchtop weighing. The balance should also have a special balance pan to be able to handle the size of the sample tested (i.e.; a fibrous structure sample of about 11 in. (27.9 cm) by 11 in. (27.9 cm)). The balance pan can be made out of a variety of materials. Plexiglass is a common material used.
- 2) A sample support rack and sample support cover is also required. Both the rack and cover are comprised of a lightweight metal frame, strung with 0.012 in. (0.305 cm) diameter monofilament so as to form a grid of 0.5 inch squares (1.27 cm²). The size of the support rack and cover is such that the sample size can be conveniently placed between the two.

The HFS test is performed in an environment maintained at $23 \pm 1^\circ \text{C}$ and $50 \pm 2\%$ relative humidity. A water reservoir or tub is filled with distilled water at $23 \pm 1^\circ \text{C}$ to a depth of 3 inches (7.6 cm).

The fibrous structure sample to be tested is carefully weighed on the balance to the nearest 0.01 grams. The dry weight of the sample is reported to the nearest 0.01 grams. The empty sample support rack is placed on the balance with the special balance pan described above. The balance is then zeroed (tared). The sample is carefully placed on the sample support rack. The support rack cover is placed on top of the support rack. The sample (now sandwiched

between the rack and cover) is submerged in the water reservoir. After the sample is submerged for 60 seconds, the sample support rack and cover are gently raised out of the reservoir.

The sample, support rack and cover are allowed to drain horizontally for 120 ± 5 seconds, taking care not to excessively shake or vibrate the sample. While the sample is draining, the rack cover is carefully removed and all excess water is wiped from the support rack. The wet sample and the support rack are weighed on the previously tared balance. The weight is recorded to the nearest 0.01g. This is the wet weight of the sample.

The gram per fibrous structure sample absorptive capacity of the sample is defined as (wet weight of the sample - dry weight of the sample). The horizontal absorbent capacity (HAC) is defined as: $\text{absorbent capacity} = (\text{wet weight of the sample} - \text{dry weight of the sample}) / (\text{dry weight of the sample})$ and has a unit of gram/gram.

Horizontal Rate Capacity (HRC)

Horizontal Rate Capacity (HRC) is an absorbency rate test that measures the quantity of water taken up by a paper sample in a two second time period. The value is reported in grams of water per second. The instrument used to carry out the HRC measurement comprises a pump, pressure gauge, inlet shunt, rotometer, reservoir, sump, outlet shunt, water supply tube, sample holder, sample, balance, and tubing. The instrument is illustrated in U.S. Pat. No. 5,908,707 issued to Cabell et al. the disclosure of which is incorporated herein by reference for the purposes of showing the instrument used to carry out the HRC measurement.

In this method, the sample (cut using a 3 in. (7.6 cm) diameter cutting die) is placed horizontally in a holder suspended from an electronic balance. The holder is made up of a lightweight frame measuring approximately 7 in. by 7 in. (17 cm by 17 cm), with lightweight nylon monofilament strung through the frame to form a grid of 0.5 in. (1.27 cm) squares. The nylon monofilament for stringing the support rack should be 0.069. ± 0.005 in. (0.175 cm. ± 0.0127 cm) in diameter (e.g., Berkley Trilene Line 2 lb test clear). The electronic balance used should be capable of measuring to the nearest 0.001 g. (e.g., Sartorius L420P+).

The sample in the holder is centered above a water supply tube. The water supply is a plastic tube having a 0.312 inch (0.79 cm) inside diameter containing distilled water at $23^\circ \pm 1^\circ$ C. The supply tube is connected to a fluid reservoir at zero hydrostatic head relative to the test sample. The water supply tube is connected to the reservoir using plastic (e.g., Tygon.RTM.)

tubing. The height of the nylon monofilament of the sample holder is located 0.125 in. $\pm 1/64$ in. (0.32 cm. ± 0.04 cm) above the top of the water supply tube.

The water height in the reservoir should be level with the top of the water supply tube. The water in the reservoir is continuously circulated using a water pump circulation rate of 85-93 ml/second using a water pump (e.g., Cole-Palmer Masterflex 7518-02) with #6409-15 plastic tubing. The circulation rate is measured by a rotometer tube (e.g., Cole-Palmer N092-04 having stainless steel valves and float). This circulation rate through the rotometer creates a head pressure of 2.5 ± 0.5 psi as measured by an Ashcroft glycerine filled gauge.

Before conducting this measurement, the samples should be conditioned to $23^{\circ} \pm 1^{\circ}$ C. and $50 \pm 2\%$ Relative Humidity for 2 hours. The HRC test is also performed in these controlled environmental conditions.

To start the absorbent rate measurement, the 3 in. (7.62 cm) sample is placed on the sample holder. Its weight is recorded in 1 second intervals for a total of 5 seconds. The weight is averaged (herein referred to as "Average Sample Dry Weight"). Next, the circulating water is shunted to the sample water supply for 0.5 seconds by shunting through the valve. The weight reading on the electronic balance is monitored. When the weight begins to increase from zero a stop watch is started. At 2.0 seconds the sample water supply is shunted to the inlet of the circulating pump to break contact between the sample and the water in the supply tube.

The shunt is performed by diverting through the valve. The minimum shunt time is at least 5 seconds. The weight of the sample and absorbed water is recorded to the nearest 0.001 g. at time equals 11.0, 12.0, 13.0, 14.0 and 15.0 seconds. The five measurements are averaged and recorded as "Average Sample Wet Weight".

The increase in weight of the sample as a result of water being absorbed from the tube to the sample is used to determine the absorbency rate. In this case, the rate (grams of water per second) is calculated as:

$$(\text{Average Sample Wet Weight} - \text{Average Sample Dry Weight}) / 2 \text{ seconds}$$

It is understood by one skilled in the art that the timing, pulsing sequences, and electronic weight measurement can be computer automated.

Method of Detection of Association of Hydrophilizing Agent and Synthetic Fibers

A nonwoven fibrous structure may be analyzed for the association of synthetic fibers and a hydrophilizing agent in a variety of ways. The fibrous structure may be separated into its component parts which may include synthetic fibers and natural fibers. The synthetic fibers and

natural fibers may be separated from each other by any suitable method known to one of ordinary skill in the art.

A method of analyzing the association of synthetic fibers and hydrophilizing agent may include the utilization of the Wilhelmy balance technique. In such a method, the analysis is performed by mounting an individual fiber, such as a synthetic fiber separated from the fibrous structure as discussed above, vertically and measuring the force of water as a function of position as the fiber dips into the water. The contact angle is calculated from the regressed force data and fiber diameter. As an example of such a method, the following table may illustrate the mean contact angle for fibers taken from two handsheets. The numbers presented are an average of three fibers of each sample type in triplicate. The mean contact angle for the two fibers types is statistically different and may indicate that a hydrophilizing agent has associated with the synthetic fibers of Sample B and has therefore made the fibers more hydrophilic than those of Sample A.

	Fiber Diameter (μm)	Mean Contact Angle	Standard Deviation
Sample A	14.36	73.4°	2.4°
Sample B	15.04	56.4	2.8

Sample A: About 70% Northern Softwood Kraft cellulose fibers and about 30% CoPET/PET fibers.

Sample B: About 70% Northern Softwood Kraft cellulose fibers and about 30% CoPET/PET fibers and about 40ppm TexCare™ SRN-240.

Another method for analyzing the association of synthetic fibers and hydrophilizing agent may include the separation of the fibers as described. The synthetic fibers may then undergo an extraction process, such as a solvent extraction, to remove any surface coatings, elements, contaminants, etc from the synthetic fibers to result in "clean" synthetic fibers. The solvent extract may be analyzed by any suitable method known to one of ordinary skill, including, but not limited to, liquid chromatography, mass spectrometry, static time-of-flight secondary ion mass spectrometry, etc. to determine the presence of a hydrophilizing agent, such as a hydrophilizing agent comprising a polyester segment. The synthetic fibers and the hydrophilizing agent may be analyzed to determine the actual synthetic fiber and the actual hydrophilizing agent present in the fibrous structure. The presence of both synthetic fibers and hydrophilizing agent characterizes the association of the synthetic fibers with the hydrophilizing agent.

Method of Determining Durability of Association of Hydrophilizing Agent and Synthetic Fibers

Synthetic fibers may be analyzed for the durability of the association of the synthetic fibers and a hydrophilizing agent. A method for determining the durability of the association may relate to the wettability of the synthetic fibers. Contact angle measurement of a liquid, such as water, in contact with the synthetic fibers may provide for a determination of the durability of the association between a synthetic fiber and a hydrophilizing agent. A wettable synthetic fiber may demonstrate the association of the synthetic fiber and a hydrophilizing agent. A demonstration of the wettability of the synthetic fiber following multiple washings may demonstrate the durability wettability of the association of the synthetic fiber and a hydrophilizing agent.

The synthetic fibers may be dried at about 80°C in an air flow oven for about 24 hours. The synthetic fibers may be placed in a beaker and washed in warm water (about 60°C) for two hours with gentle stirring to remove any residual process aids. The ratio of fibers to water volume may be about 1:200. After washing, the fibers may be collected and dried overnight at room temperature. The synthetic fibers may be separated into four groups, with each group weighing about 36 grams, and placed in an air flow oven for about 10 hours. Four aliquots, each about 5 grams, may be separated out and may be treated with a hydrophilizing agent and a surfactant at two varying levels, such as 40 ppm and 400 ppm. Therefore, one aliquot of 5 grams of synthetic fibers may be soaked in about 40 ppm of a hydrophilizing agent for about 10 minutes. A second aliquot of 5 grams of synthetic fibers may be soaked in about 400 ppm of a hydrophilizing agent for about 10 minutes. A third aliquot of about 5 grams of synthetic fibers may be soaked in about 40 ppm of a surfactant for about 10 minutes. A fourth aliquot of 5 grams of synthetic fibers may be soaked in about 400 ppm of a surfactant for about 10 minutes. The ratio of each treatment group of synthetic fibers to treatment is 5g : 100 ml of solution. The four groups of synthetic fibers may be dried post-treatment at room temperature. After drying, the four groups of synthetic fibers may be subjected to about 10 minutes of water washing using double distilled water at about 45°C.

A method of analyzing the association of synthetic fibers and hydrophilizing agent or surfactant may include the utilization of the Wilhelmy balance technique. In such a method, the analysis is performed by mounting an individual fiber vertically and measuring the force of water as a function of position as the fiber dips into the water. The contact angle is calculated from the regressed force data and fiber diameter. As an example of such a method, the following table

may illustrate the mean contact angle for synthetic fibers that have been subjected to the above various treatments and wash steps. The numbers presented are an average of two fibers of each sample type in triplicate.

Sample	Treatment	Water Wash	Mean Contact Angle (°)	Standard Deviation (°)	Fiber Diameter (μm)
1	40 ppm Hydrophilizing Agent	None	54.9	1.8	13.40
2	400 ppm Hydrophilizing Agent	None	52.2	1.7	15.14
3	40 ppm Surfactant	None	71.3	1.9	14.06
4	400 ppm Surfactant	None	60.9	2.3	14.78
5	40 ppm Hydrophilizing Agent	10 Minutes	62.2	1.9	13.45
6	400 ppm Hydrophilizing Agent	10 Minutes	66.1	1.8	15.13
7	40 ppm Surfactant	10 Minutes	80.0	2.1	14.78
8	400 ppm Surfactant	10 Minutes	82.4	1.8	13.73
9	No treatment	10 Minutes	72.2	2.2	14.88

The synthetic fibers used for each sample are bicomponent fibers of CoPET/PET. The hydrophilizing agent utilized is TexCare™ SRN-240 and the surfactant utilized is Triton-X 100 as available from The Dow Chemical Company.

As demonstrated by the above table, the synthetic fibers treated with a hydrophilizing agent may demonstrate lower contact angles and, therefore, durable wettability post washing when compared to the post washing synthetic fibers treated with a surfactant.

Sustainable Wettability

A nonwoven fibrous structure may be analyzed for sustainable wettability in the following manner. The sample fibrous structure may be placed on an absorbent pad. Multiple insults of test liquid may be applied to the fibrous structure at timed intervals. Each insult of liquid may be considered as a strike-through. The strike-through times may then be recorded without changing the absorbent pad.

In one example, a nonwoven fibrous structure exhibits sustainable wettability if after saturating the fibrous structure with water (test liquid) multiple times (at least ten (10) times or

more), the fibrous structure still exhibits an HRC value of at least about 0.1 g/sec and/or at least about 0.2 g/sec and/or at least about 0.3 g/sec and/or at least about 0.4 g/sec and/or at least about 0.5 g/sec.

All documents cited in the Detailed Description of the Invention are, in relevant part, incorporated herein by reference; the citation of any document is not to be construed as an admission that it is prior art with respect to the present invention. To the extent that any meaning or definition of a term in this written document conflicts with any meaning or definition of the term in a document incorporated by reference, the meaning or definition assigned to the term in this written document shall govern.

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."

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 within the scope of this invention.

What is claimed is:

1. A nonwoven fibrous structure characterized in that said fibrous structure comprises a plurality of synthetic fibers, wherein one or more of said synthetic fibers comprises a polymer, and a hydrophilizing agent wherein said polymer and said hydrophilizing agent comprise a durable association.
2. The fibrous structure according to Claim 1 wherein said polymer and said hydrophilizing agent comprise complementary segments that are associated with one another.
3. The fibrous structure according to Claim 2 wherein at least one of said complementary segments comprises a polyester segment.
4. The fibrous structure according to Claim 3 wherein said polyester segment comprises a polyethylene terephthalate segment.
5. The fibrous structure according to Claim 2 wherein said complementary segment of said polymer comprises a polyester segment and said complementary segment of said hydrophilizing agent comprises a polyester segment.
6. The fibrous structure of any of the preceding claims wherein said polymer comprises a material selected from the group consisting of polyesters, polyamides, polyhydroxyalkanoates, polysaccharides and combinations thereof.
7. The fibrous structure of any of the preceding claims wherein said hydrophilizing agent comprises a material selected from the group consisting of polyester, poly(ethoxylate), polyethylene oxide, polyoxyethylene, polyethylene glycol, polypropylene glycol, terephthalate, polypropylene oxide, polyethylene terephthalate, polyoxyethylene terephthalate, ethoxylate siloxane and combinations thereof.
8. The fibrous structure of any of the preceding claims wherein said hydrophilizing agent comprises from about 1 to about 15 ethoxylated moieties.

9. The fibrous structure of any of the preceding claims further comprising a plurality of natural fibers.
10. The fibrous structure of any of the preceding claims wherein said fibrous structure further comprises a binder material.
11. The fibrous structure of any of the preceding claims wherein said fibrous structure is a component of an article selected from the group consisting of toilet paper, paper towel, napkin, facial tissue, wipe, and combinations thereof.
12. The fibrous structure of any of the preceding claims wherein the fibrous structure exhibits sustainable wettability.
13. The fibrous structure of any of the preceding claims wherein the synthetic fibers comprise a mean contact angle less than about 72° and after a 10 minute water wash said mean contact angle remains below about 72° .

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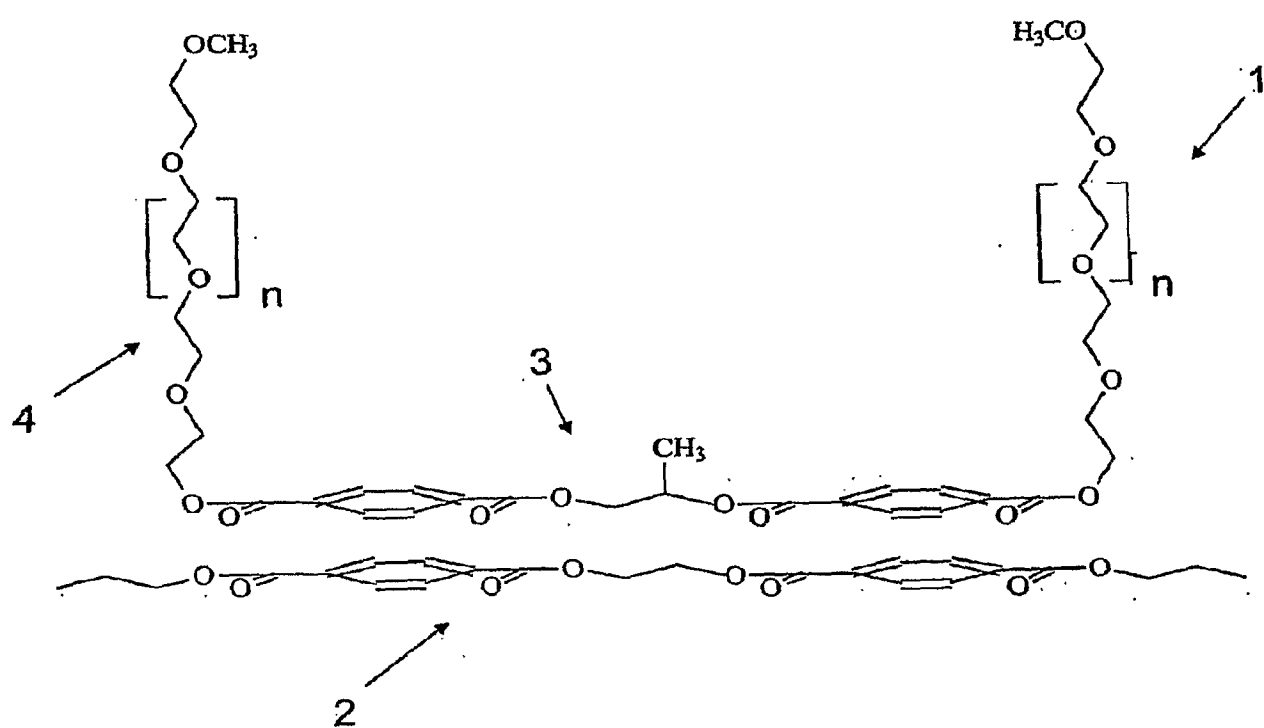


Fig. 1

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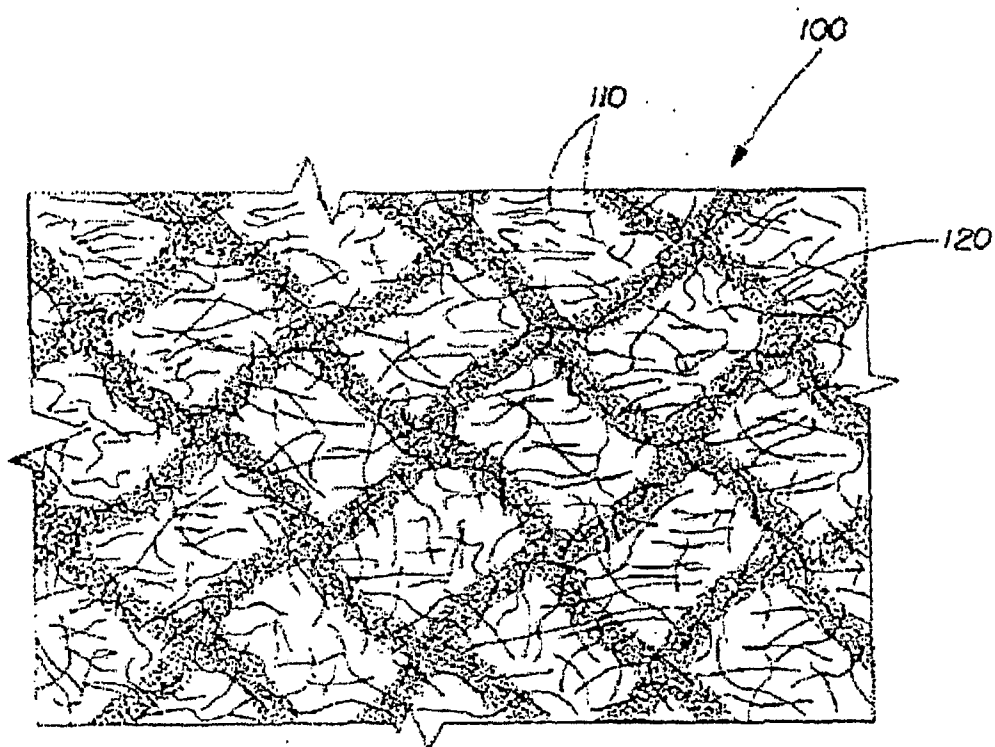


Fig. 2

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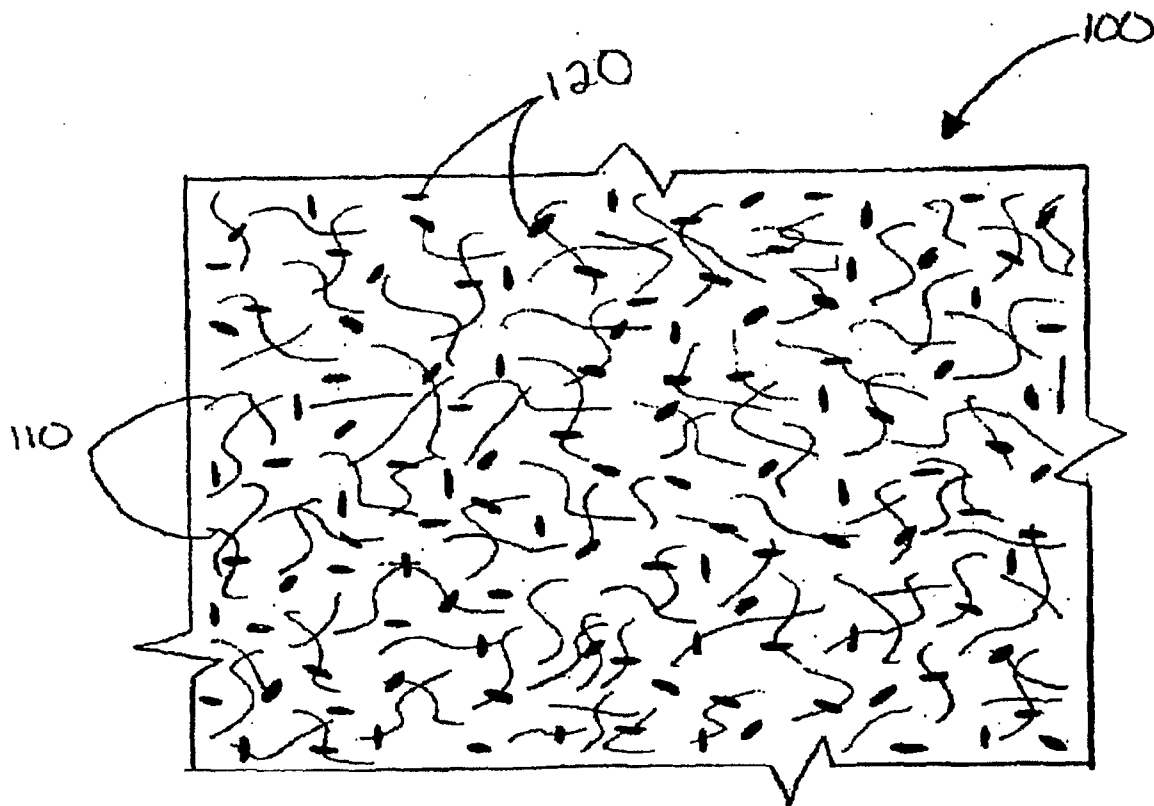


Fig. 3