SOFT FIBROUS STRUCTURE

Inventor: Diego Antonio Hernandez-Munoa, Liberty Township, OH (US)

Correspondence Address:
THE PROCTER & GAMBLE COMPANY
INTELLECTUAL PROPERTY DIVISION
WINTON HILL TECHNICAL CENTER - BOX 161
6110 CENTER HILL AVENUE
CINCINNATI, OH 45224 (US)

Assignee: The Procter & Gamble Company

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ABSTRACT
Fibrous structures, especially to through-air-dried fibrous structures, that exhibit a Slip Stick coefficient of Friction of less than about 0.023 and a B Compressibility of from about 15 to about 50 and/or fibrous structures, especially through-air-dried fibrous structures, that exhibit a Slip Stick Coefficient of Friction of less than about 0.0175 are provided.
SOFT FIBROUS STRUCTURE
CROSS REFERENCE TO RELATED APPLICATION

In one aspect of the present invention, a fibrous structure that exhibits a Slip Stick Coefficient of Friction of less than about 0.023 and/or less than about 0.021 and/or less than about 0.0190 and/or less than about 0.0175 is provided.

In another aspect of the present invention, a fibrous structure that exhibits a Slip Stick Coefficient of Friction of less than about 0.023 and a B Compressibility of from about 15 to about 50.

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

Accordingly, the present invention provides a fibrous structure that exhibits a Slip Stick Coefficient of Friction of less than about 0.023, a fibrous structure that exhibits a Slip Stick Coefficient of Friction of less than about 0.023 and a B Compressibility of from about 15 to about 50, and a single- or multi-ply sanitary tissue product comprising a fibrous structure according to the present invention.

BACKGROUND OF THE INVENTION

It is well known in the art that the softness of a fibrous structure or a sanitary tissue product, especially a through-air-dried fibrous structure, that exhibit a Slip Stick Coefficient of Friction of less than about 0.023 and a B Compressibility of from about 15 to about 50 and/or fibrous structures, especially through-air-dried fibrous structures, which exhibit a Slip Stick Coefficient of Friction of less than about 0.0175.

Attempts by formulators to overcome the inverse relationships, especially the softness to total tensile strength have included adding cationic silicones to sanitary tissue products and/or fibrous structures making up such products. See for example U.S. Pat. No. 5,059,282 to Ampulski et al.

Formulators have deposited various softening agents, including silicone materials, onto the external surfaces of fibrous structures to try to deliver the consumer desired softness and/or smoothness. Such prior art fibrous structures exhibited Coefficients of Friction of about 0.72 to about 1.07 or Slip Stick Coefficients of Friction of from about least about 0.0207 or B Compressibility of less than or equal to 17.

Prior formulators have failed to develop a fibrous structure, especially a through-air-dried fibrous structure, which exhibits a Slip Stick Coefficient of Friction of less than about 0.023 and a B Compressibility of from about 15 to about 50 and/or fibrous structures, especially through-air-dried fibrous structures, which exhibit a Slip Stick Coefficient of Friction of less than about 0.0175. Accordingly, there exists a long felt need to provide a fibrous structure, especially a through-air-dried fibrous structure, that exhibits a Slip Stick Coefficient of Friction of less than about 0.023 and B Compressibility of from about 15 to about 50 and/or fibrous structures, especially through-air-dried fibrous structures, that exhibit a Slip Stick Coefficient of Friction of less than about 0.0175.

SUMMARY OF THE INVENTION

The present invention fulfills the need described above by providing a fibrous structure, especially a through-air-dried fibrous structure, which exhibits a Slip Stick Coefficient of Friction of less than about 0.023 and, optionally, a B Compressibility of from about 15 to about 50.

In addition to the various wood pulp fibers, other cellulosic fibers such as cotton linters, rayon, and bagasse can be used in this invention. Synthetic fibers, such as polymeric fibers, can also be used. Elastomeric polymers,
polypropylene, polyethylene, polyester, polyolefin, and nylon, can be used. The polymeric fibers can be produced by spunbond processes, meltblown processes, and other suitable methods known in the art. One exemplary polyethylene fiber that can be utilized is Pulpex®, available from Hercules, Inc. (Wilmington, Del.).

[0014] In addition to the above, fibers and/or filaments made from polymers, specifically hydroxyl polymers may be used in the present invention. Nonlimiting examples of suitable hydroxyl polymers include polyvinyl alcohol, starch, starch derivatives, chitosan, chitosan derivatives, cellulose derivatives, gums, arabinans, galactans and mixtures thereof.

[0015] An embryonic fibrous web can be typically prepared from an aqueous dispersion of papermaking fibers, though dispersions in liquids other than water can be used. The fibers can be dispersed in the carrier liquid to have a consistency of from about 0.1% to about 0.3%. It is believed that the present invention can also be applicable to moist forming operations where the fibers are dispersed in a carrier liquid to have a consistency less than about 50%, more preferably less than about 10%.

[0016] “Sanitary tissue product” as used herein means a soft, low density (i.e., <about 0.15 g/cm³) web useful as a wiping implement for post-urinary and post-bowel movement cleaning (toilet tissue), for otorhinolaryngological discharges (facial tissue and/or hankies), and multi-functional absorbent and cleaning uses (absorbent towels). The properties and values thereof discussed herein with respect to the fibrous structures described herein may also be present in the sanitary tissue products incorporating such fibrous structures.

[0017] “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, pp. 107-121.

[0018] “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.

[0019] “Caliper” as used herein means the macroscopic thickness of a sample. Caliper of a sample of fibrous structure and/or sanitary tissue product according to the present invention are obtained on a VIR Electronic Thickness Tester Model II available from Thwing-Albert Instrument Company, Philadelphia, Pa. The caliper measurement can be repeated and recorded at least five (5) times so that an average caliper can be calculated. The result is reported in millimeters.

[0020] “Smoothness” and/or “Physiological Surface Smoothness” as used herein is a factor (hereinafter the PSS Factor and/or SMD Factor) derived from scanning machine direction fibrous structure and/or sanitary tissue product samples with a profilometer having a diamond stylus, the profilometer being installed in a surface test apparatus such as, for example, is described in the 1991 International paper Physics Conference. TAPPI Book 1, article entitled “Methods for the Measurement of the Mechanical Properties of Tissue Paper” by Ampulski et al. found at page 19, and/or in U.S. Pat. No. 5,059,282 issued to Ampulski et al., both of which are incorporated herein by reference. The smoothness and/or the inverse of smoothness (i.e., roughness) can also be measured using a Kato Surface Tester KES-FB4 which is available from Kato Tekko Co., LTD., Karato-Chou, Nishi-kiiyo, Minami-Ku, Koyota, Japan. Alternatively, the smoothness of a fibrous structure and/or sanitary tissue product according to the present invention may be measured using a Primos Optical Profiler/3D Surface Analyzer commercially available from GF Messtechnik, Berlin, Germany. It is desirable that fibrous structures and/or sanitary tissue products comprising such fibrous structures exhibit a smoothness of greater than about 500 and/or from about 500 to about 1200 and/or from about 550 to about 1000 and/or from about 600 to about 950 and/or from about 650 to about 900.

[0021] “Slip Stick Coefficient of Friction” (S&S COF) is defined as the mean deviation of the coefficient of friction. Like the coefficient of friction, it is dimensionless. This test is performed on a KES-FB4 Surface Analyzer from Kato Tekko Co. with a modified friction probe. The probe sleds is a two centimeter diameter, 40 to 60 micron glass frit obtained from Ace Glass Company. The normal force of the probe was 19.6 grams. The details of the procedure are described in “Methods for the Measurement of the Mechanical Properties of Tissue Paper” by Ampulski, et. al., 1991 International Paper Physics Conference, page 19, incorporated herein by reference.

[0022] In one embodiment, the fibrous structure exhibits a Slip Stick Coefficient of Friction of from about 0.010 to about 0.021 and/or from about 0.0135 to about 0.0190 and/or from about 0.0135 to about 0.0175.

[0023] “Total Dry Tensile Strength” or “TDT” of a fibrous structure and/or sanitary tissue product comprising such fibrous structure is measured as follows. One (1) inch by five (5) inch (2.5 cm x 12.7 cm) strips of fibrous structure and/or paper product comprising such fibrous structure are provided. The strip is placed on an electronic tensile tester Model 1122 commercially available from Instron Corp., Canton, Mass. in a conditioned room at a temperature of 73°F ±4°F (about 28°C ±2.2°C) and a relative humidity of 50% ±10%. The crosshead speed of the tensile tester is 2.0 inches per minute (about 5.1 cm/minute) and the gauge length is 4.0 inches (about 10.2 cm). The TDT is the arithmetic total of MD and CD tensile strengths of the strips.

[0024] “Wet Burst Strength” as used herein is a measure of the ability of a fibrous structure and/or a paper product incorporating a fibrous structure to absorb energy, when wet and subjected to deformation normal to the plane of the fibrous structure and/or paper product. Wet burst strength may be measured using a Thwing-Albert Burst Tester Cat. No. 177 equipped with a 2000 g load cell commercially available from Thwing-Albert Instrument Company, Philadelphia, Pa. In one embodiment, the fibrous structures of the present invention and/or sanitary tissue products comprising such fibrous structures may have a wet burst strength of greater than about 10 g/cm and/or from about 12 g/cm to about 394 g/cm and/or from about 13 g/cm to about 197 g/cm and/or from about 15 g/cm to about 197 g/cm and/or from about 15 g/cm to about 78 g/cm.
“Basis Weight” as used herein is the weight per unit area of a sample reported in lbs/3000 ft² or g/m². Basis weight is measured by preparing one or more samples of a certain area (m²) and weighing the sample(s) of a fibrous structure according to the present invention and/or a paper product comprising such fibrous structure on a top loading balance with a minimum resolution of 0.01 g. The balance is protected from air drafts and other disturbances using a draft shield. Weights are recorded when the readings on the balance become constant. The average weight (g) is calculated and the average area of the samples (m²). The basis weight (g/m²) is calculated by dividing the average weight (g) by the average area of the samples (m²). In one embodiment, the fibrous structures of the present invention and/or sanitary tissue products comprising such fibrous structures have a basis weight of from about 12 g/m² to about 120 g/m² and/or from about 14 g/m² to about 80 g/m² and/or from about 17 g/m² to about 70 g/m² and/or from about 20 g/m² to about 60 g/m². Typically, a single ply of the fibrous structure has a basis weight of from about 12 g/m² to about 50 g/m².

“Machine Direction” or “MD” as used herein means the direction parallel to the flow of the fibrous structure through the 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 paper product comprising the fibrous structure.

“Apparent Density” or “Density” as used herein means the basis weight of a sample divided by the caliper with appropriate conversions incorporated therein. Apparent density used herein has the units g/cm³.

“Total Dry Tensile Strength” as used herein means the geometric mean of the machine and cross-machine breaking strengths in grams per cm of sample width. Mathematically, this is the square root of the product of the machine and cross-machine direction breaking strengths in grams per cm of sample width. In one embodiment, the fibrous structures of the present invention and/or sanitary tissue products comprising such fibrous structures have a total dry tensile of greater than about 39 g/cm and/or greater than about 59 g/cm and/or from about 63 g/cm to about 1575 g/cm and/or from about 78 g/cm to about 985 g/cm and/or from about 78 g/cm to about 394 g/cm and/or from about 98 g/cm to about 335 g/cm. Typically a single ply of the fibrous structure has a total dry tensile of from about 39 g/cm to about 590 g/cm.

“Flexibility” as used herein means the slope of the secant of the graph-curve derived from force vs. stretch % data which secant passes through the origin (0% stretch, 0 force) and through the point on the graph-curve where the force per centimeter of width is 20 grams.

“Total Flexibility” as used herein means the geometric mean of the machine-direction flexibility and cross-machine-direction flexibility. Mathematically, this is the square root of the product of the machine-direction flexibility and cross-machine-direction flexibility in grams per cm.

“WABY Factor” as used herein means the ratio of Total Flexibility to Total Tensile Strength. The WABY Factor has been determined to be a factor which characterizes embodiments of the invention as being strong yet having high bulk softness. This ratio is hereby dubbed the WABY Factor. For instance, a sample having a Total Flexibility of 20 g/cm, and a Total Tensile Strength of 154 g/cm has a WABY Factor of 0.13. It is desirable that fibrous structures and/or sanitary tissue products comprising such fibrous structures exhibit a WABY factor less than about 0.2 and/or from about 0.05 to about 0.15 and/or from about 0.06 to about 0.13 and/or from about 0.06 to about 0.11.

Briefly, tactile perceivable softness of tissue paper is inversely related to its WABY Factor. Also, note that the WABY Factor is dimensionless because both Flexibility and Total Tensile Strength as defined above are in g/cm, their ratio is dimensionless.

“B Compressibility” as used herein means the intercept of a curve generated by plotting weight versus thickness resulting from a compression test.

“Lint” as used herein is measured in accordance with the procedure set forth in commonly assigned U.S. Pat. No. 5,814,188 issued Sep. 29, 1998 to Vinson et al., and incorporated herein by reference.

The fibrous structures and/or sanitary tissue products employing the fibrous structures of the present invention may be characterized as being within a multi-parametric domain defined by empirically determined ranges of one or more and/or two or more and/or three or more of the following parameters: 1) Caliper; 2) Physiological Surface Smoothness; 3) Slip Stick Coefficient of Friction; 4) Total Tensile Strength; 5) Flexibility; 6) Basis Weight; 7) Wet Burst Strength; 8) Coefficient of Friction; 9) WABY Factor and/or 10) B Compressibility.

It has surprisingly been found that fibrous structures and sanitary tissue products incorporating such fibrous structures that exhibit, in addition to a Slip Stick Coefficient of Friction less than about 0.023, a Coefficient of Friction of from about 0.65 to about 0.83 and/or from about 0.65 to about 0.81 and/or from about 0.71 to about 0.81 and/or a B Compressibility of from about 15 to about 50 and/or from about 20 to about 40 exhibit enhanced softness and/or smoothness as compared to known fibrous structures.

As used herein, the articles “a” and “an” when used herein, for example, “an anionic 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 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.

Fibrous Structure

The fibrous structures and/or tissue paper of the present invention can be made by different methods. Non-limiting examples of fibrous structure types and/or tissue paper types include conventionally pressed and/or felt-pressed tissue paper; pattern densified tissue paper; pattern densified tissue paper either
with a patterned forming wire and/or a patterned fabric/resin belt; high-bulk, uncompacted tissue paper and creped or uncreped tissue paper. The tissue paper may be of a homogenous and/or single layered or multilayered construction; and tissue paper products made therefrom may be of a single-ply or multi-ply construction.

[0043] Further, the fibrous structures of the present invention and/or sanitary tissue products incorporating the same may be creped or uncreped.

[0044] Further yet, the sanitary tissue products incorporating the fibrous structures of the present invention may incorporate dry fibers via an air laid process and/or latex binding agents via a wet laid process.

[0045] Conventional converting methods may be used to convert dried rolls of fibrous structure according to the present invention into one-ply and/or multi-ply sanitary tissue products. Nonlimiting examples of such converting methods include embossing including high pressure embossing, dry creping, ply bonding, calendaring and/or other mechanical treatments to the fibrous structures.

[0046] The fibrous structure may be made with a fibrous furnish that produces a single layer embryonic fibrous web or a fibrous furnish that produces a multi-layer embryonic fibrous web.

[0047] The properties described herein may be for a single ply of the fibrous structure and/or a single ply sanitary tissue product and/or for a multi-ply sanitary tissue product that incorporates at least one ply comprising the fibrous structure of the present invention.

[0048] Fiber Furnish

[0049] In one embodiment, the fibrous structure is produced from a fiber furnish. In another embodiment, the fibrous structure is produced from a melt blown and/or spun bonded and/or rotary die process. The fiber furnish of the present invention comprises one or more fibers and typically one or more optional ingredients.

[0050] Optional Ingredients

[0051] The fibrous structures of the present invention may comprise an optional ingredient selected from the group consisting of permanent wet strength resins, chemical softeners, such as silicones, particularly cationic silicones, and/or quaternary ammonium compounds, temporary wet strength resins, dry strength resins, wetting agents, lint resisting agents, absorbency-enhancing agents, immobilizing agents, especially in combination with emollient lotion compositions, antiviral agents including organic acids, anti-bacterial agents, polyelesters, antimigration agents, polyhydroxy plasticizers, fillers (clays), humectants and mixtures thereof. Such optional ingredients may be added to the fiber furnish, the embryonic fibrous web and/or the dried fibrous structure. Such optional ingredients may be present in the fibrous structure at any level based on the dry weight of the fibrous structure.

[0052] The optional ingredients may be applied to the fiber furnish and/or the embryonic fibrous web and/or the dried fibrous structure and/or the sanitary tissue product of the present invention. Further, the optional ingredients, such as other chemical softeners, more particularly, lotions, especially, transferable lotions may be applied to the dried fibrous structure and/or sanitary tissue product after the any cationic silicone, if any, has been applied thereto.

[0053] The optional ingredients may be present in the fibrous structure and/or sanitary tissue product of the present invention at a level of from about 0.001% to about 50% and/or from about 0.001% to about 30% and/or from about 0.001% to about 22% and/or from about 0.01% to about 5% and/or from about 0.03% to about 3% and/or from about 0.05 to about 2% and/or from about 0.1% to about 1% by weight, on a dry fibrous structure or sanitary tissue product basis.

[0054] Chemical Softeners

[0055] Nonlimiting examples of suitable chemical softeners include silicones, especially cationic silicones, more preferably cationic silicones that comprise one or more polysiloxane units, preferably polydimethylsiloxane units of formula —[(CH₃)₂SiO]ₙ— having a degree of polymerization, n, of from 1 to 1000, preferably of from 20 to 500, more preferably of from 50 to 300, most preferably from 100 to 200, and organosilicone-free units comprising at least one diquaternary unit. In a preferred embodiment of the present invention, the selected cationic silicone polymer has from 0.05 to 1.0 mole fraction, more preferably from 0.2 to 0.95 mole fraction, most preferably 0.5 to 0.9 mole fraction of the organosilicone-free units selected from cationic divalent organic moieties. The cationic divalent organic moiety is preferably selected from N,N,N',N'-tetramethyl-1,6-hexanediarnonium units.

[0056] The selected cationic silicone polymer can also contain from 0 to 0.95 mole fraction, preferably from 0.001 to 0.5 mole fraction, more preferably from 0.05 to 0.2 mole fraction of the total of organosilicone-free units, polyalkylenoxide amines of the following formula:

$$[\text{–Y}–\text{O(C₃H₇O)}ₙ\text{–Y–}$$

[0057] wherein Y is a divalent organic group comprising a secondary or tertiary amine, preferably a C₃ to C₅ alkylamine residue, a is from 2 to 4, and b is from 0 to 100. The polyalkylenoxide blocks may be made up of ethylene oxide (a=2), propylene oxide (a=3), butylene oxide (a=4) and mixtures thereof, in a random or block fashion.

[0058] Such polyalkylenoxide amine-containing units can be obtained by introducing in the silicone polymer structure, compounds such as those sold under the trade-name Jeffamine® from Huntsman Corporation. A preferred Jeffamine is Jeffamine ED-2003.

[0059] The selected cationic silicone polymer can also contain from 0, preferably from 0.001 to 0.2 mole fraction, of the total of organosilicone-free units, of —NR₃— wherein R is alkyl, hydroxalkyl or phenyl. These units can be thought of as end-caps.

[0060] Moreover the selected cationic silicone polymer generally contains anions, selected from inorganic and organic anions, more preferably selected from saturated and unsaturated C₇-C₂₀, carboxylates and mixtures thereof, to balance the charge of the quaternary moieties, thus the cationic silicone polymer also comprises such anions in a quaternary charge-balancing proportion.

[0061] Conceptually, the selected cationic silicone polymers herein can helpfully be thought of as non-crosslinked
or “linear” block copolymers including non-fabric-substantive but surface energy modifying “loops” made up of the polysiloxane units, and fabric-substantive “hooks”. One preferred class of the selected cationic polymers (illustrated by Structure 1 hereinafter) can be thought of as comprising a single loop and two hooks; another, very highly preferred, comprises two or more, preferably three or more “loops” and two or more, preferably three or more “hooks” (illustrated by Structures 2a and 2b hereinafter), and yet another (illustrated by Structure 3 hereinafter) comprises two “loops” pendant from a single “hook”.

Of particular interest in the present selection of cationic silicone polymers is that the “hooks” contain no silicone and that each “hook” comprises at least two quaternary nitrogen atoms.

Also of interest in the present selection of preferred cationic silicone polymers is that the quaternary nitrogen is preferentially located in the “backbone” of the “linear” polymer, in contradistinction from alternate and less preferred structures in which the quaternary nitrogen is incorporated into a moiety or moieties which form a “pendant” or “dangling” structure off the “backbone”.

The structures are completed by terminal moieties which can be noncharged or charged. Moreover a certain proportion of nonquaternary silicone-free moieties can be present, for example the moiety [—Y —O(—C₆H₄O)ₙ —Y—] as described hereinafore.

Of course the conceptual model presented is not intended to be limiting of other moieties, for example connector moieties, which can be present in the selected cationic silicone polymers provided that they do not substantially disrupt the intended function as tissue benefit agents.

In more detail, the cationic silicone polymers herein have one or more polysiloxane units and one or more quaternary nitrogen moieties, including polymers wherein the cationic silicone polymer has the formula:

\[
Z-X-\text{oc}_{6}H_{2}-\text{r}^{1}-\text{sio}_{2}\text{sio}_{2}-\text{si-ri-ar}c_{6}H_{2}-\text{ox}_{2}-X-Z
\]

wherein:

\[
[0068]\text{R}^{1}\text{ is independently selected from the group consisting of: } C_{1-22} \text{ alkyl, } C_{2-22} \text{ alkenyl, } C_{6-22} \text{ alklylaryl, arylyl, cycloalkyl, and mixtures thereof;}\]

\[
[0069]\text{R}^{2}\text{ is independently selected from the group consisting of: } \text{divalent organic moieties that may contain one or more oxygen atoms (such moieties preferably consist essentially of } C \text{ and } H \text{ or of } C, H \text{ and } O;\]

\[
[0070]\text{X}\text{ is independently selected from the group consisting of ring-opened epoxides;}\]

\[
[0071]\text{R}^{3}\text{ is independently selected from polyether groups having the formula:}\]

\[
-M^{1}(\text{CH}_{2}-\text{o})_{n} M^{2}
\]

\[
[0072]\text{wherein } M^{1}\text{ is a divalent hydrocarbon residue; } M^{2}\text{ is independently selected from the group consisting of: } H, C_{1-22} \text{ alkyl, } C_{2-22} \text{ alkenyl, } C_{6-22} \text{ alklylaryl, arylyl, cycloalkyl, } C_{1-22} \text{ hydroxyalkyl, polyalkyleneoxide, (poly)alkoxy alkyl, and mixtures thereof;}\]

\[
[0073]\text{Z}\text{ is independently selected from the group consisting of: } \text{monovalent organic moieties comprising at least one quaternized nitrogen atom;}\]

\[
[0074]\text{a}\text{ is from } 2 \text{ to } 4; \text{b}\text{ is from } 0 \text{ to } 100; \text{c}\text{ is from } 1 \text{ to } 1000, \text{preferably greater than } 20, \text{more preferably greater than } 50, \text{preferably less than } 500, \text{and most preferably less than } 300; \text{d}\text{ is from } 0 \text{ to } 100; \text{n}\text{ is the number of positive charges associated with the cationic silicone polymer, which is greater than or equal to } 2; \text{and } A\text{ is a monovalent anion;}\]

\[
[0076]\text{In a preferred embodiment of the Structure 1 cationic silicone polymers, } Z\text{ is independently selected from the group consisting of:}\]

\[
(i)
\begin{align*}
N & \text{r}_{12} \\
R^{13} & \text{r}_{14}
\end{align*}
\]

\[
(ii)
\begin{align*}
N & \text{r}_{12} \\
\text{CH}_{2}-\text{r}_{15} & \text{r}^{16} \\
\text{r}_{14} & \text{r}_{17}
\end{align*}
\]

\[
(iii)
\begin{align*}
N & \text{r}_{12} \\
\text{r}_{14} & \text{r}^{16} \\
\text{r}^{17} & \text{r}^{18}
\end{align*}
\]
(iv) monovalent aromatic or aliphatic heterocyclic group, substituted or unsubstituted, containing at least one quaternized nitrogen atom;

[0078] wherein:

[0079] \( R_{12}, R_{13}, R_{14} \) are the same or different, and are selected from the group consisting of: \( C_{1-22} \) alkyl, \( C_{1-22} \) alkenyl, \( C_{0-22} \) alkylaryl, aryl, cycloalkyl, \( C_{1-22} \) hydroxyalkyl, polyalkyleneoxide, (poly)alkoxy alkyl, and mixtures thereof;

[0080] \( R^5 \) is \(-O- \) or \( NR_{15} \);

[0081] \( R^6 \) is a divalent hydrocarbon residue;

[0082] \( R^7, R^8, R^9 \) are the same or different, and are selected from the group consisting of: \( H, C_{1-22} \) alkyl, \( C_{2-22} \) alkenyl, \( C_{0-22} \) alkylaryl, aryl, cycloalkyl, \( C_{1-22} \) hydroxyalkyl, polyalkyleneoxide, (poly)alkoxy alkyl, and mixtures thereof; and \( e \) is from 1 to 6.

[0083] In a highly preferred embodiment, the cationic silicone polymers herein have one or more polysiloxane units and one or more quaternary nitrogen moieties, including polymers wherein the cationic silicone polymer has the formula: (Structure 2a)

[0084] STRUCTURE 2a: Cationic silicone polymer composed of alternating units of:

[0085] (i) a polysiloxane of the following formula

\[
\left[ X \text{--O--C}_n H_{2n+1} R^2 \left( \begin{array}{c}
\text{R}^1 \text{--O--Si} {\text{R}}^3 \text{--Si} {\text{R}}^4 \text{--C}_n H_{2n+1} \text{--O--C}_n H_{2n+1} \end{array} \right) \right]_n
\]

and

[0086] (ii) a divalent organic moiety comprising at least two quaternized nitrogen atoms.

[0088] Note that Structure 2a comprises the alternating combination of both the polysiloxane of the depicted formula and the divalent organic moiety, and that the divalent organic moiety is organosilicone-free corresponding to a preferred “hook” in the above description.

[0089] In this preferred cationic silicone polymer, \( R^1 \) is independently selected from the group consisting of: \( C_{1-22} \) alkyl, \( C_{2-22} \) alkenyl, \( C_{0-22} \) alkylaryl, aryl, cycloalkyl, and mixtures thereof,

[0090] \( R^2 \) is independently selected from the group consisting of: divalent organic moieties that may contain one or more oxygen atoms; \( X \) is independently selected from the group consisting of ring-opened epoxides; \( R^3 \) is independently selected from polyether groups having the formula:

\[ M^+(CH_2)_{2n} O-M^+ \]

\[ \text{wherein } M^+ \text{ is a divalent hydrocarbon residue; } M^2 \]

[0091] is independently selected from the group consisting of \( H, C_{1-22} \) alkyl, \( C_{2-22} \) alkenyl, \( C_{0-22} \) alkylaryl, aryl, cycloalkyl, \( C_{1-22} \) hydroxyalkyl, polyalkyleneoxide, (poly)alkoxy alkyl, and mixtures thereof; \( a \) is from 2 to 4; \( b \) is from 0 to 100; \( c \) is from 1 to 1000, preferably greater than 20, more preferably greater than 50, preferably less than 500, more preferably less than 300, most preferably from 100 to 200; and \( d \) is from 0 to 100.

[0092] In an even more highly preferred embodiment of the Structure 2a cationic silicone polymer, the cationic silicone polymer has the formula Structure 2b wherein the polysiloxane (i) of the formula described above in Structure 2a is present with (ii) a cationic divalent organic moiety is selected from the group consisting of:

(a)

(b)

(c)

\[
\left[ \begin{array}{c}
\text{R}^4 \text{--N--Z}^1 \text{--N} \text{--R}^6 \text{--N} \text{--Z}^2 \text{--N} \text{--R}^8 \text{--N} \text{--Z}^3 \text{--R}^{10} \\
\text{R}^5 \text{--R}^7 \text{--R}^9 \\
\text{R}^5 \text{--R}^{11}
\end{array} \right]_n
\]

\[ 4mAn; \]

[0093] (d) a divalent aromatic or aliphatic heterocyclic group, substituted or unsubstituted, containing at least one quaternized nitrogen atom; and

[0094] (iii) optionally, a polyalkyleneoxide amine of formula:

[0095] \( \text{ti} [-Y-O(--C}_n H_{2n} \text{O})_b Y-] \)

[0096] \( Y \) is a divalent organic group comprising a secondary or tertiary amine, preferably a \( C_1 \) to \( C_8 \) alkylenamine.
residue; a is from 2 to 4; b is from 0 to 100; the polyalkyleneoxide blocks may be made up of ethylene oxide (a=2), propylene oxide (a=3), butylene oxide (a=4) and mixtures thereof, in a random or block fashion; and

(iv) optionally, a cationic monovalent organic moiety, to be used as an end-group, selected from the group consisting of:

![Chemical structure diagram](image)

(v) monovalent aromatic or aliphatic heterocyclic group, substituted or unsubstituted, containing at least one quaternized nitrogen atom; and

![Chemical structure diagram](image)

R1, R3, R9, R10, R11 are the same or different, and are selected from the group consisting of: C1-22 alkyl, C2-22 alkenyl, C6-22 alkylaryl, C2-22 hydroxyalkyl, polyalkyleneoxide, (poly)alkoxy alkyl groups, and mixtures thereof; and

![Chemical structure diagram](image)

R12, R13, R14 are the same or different, and are selected from the group consisting of: C1-22 alkyl, C2-22 alkenyl, C6-22 alkylaryl, C1-22 hydroxyalkyl, polyalkyleneoxide, (poly)alkoxy alkyl groups, and mixtures thereof; and

![Chemical structure diagram](image)

R1 is independently selected from the group consisting of: C1-22 alkyl, C2-22 alkenyl, C6-22 alkylaryl, aryalkyl, cycloalkyl, and mixtures thereof; and

Note that Structure 2b comprises the alternating combination of both the polysiloxane of the depicted formula and the divalent organic moiety, and that the divalent organic moiety is organosilicone-free corresponding to a preferred “hook” in the above general description. Structure 2b moreover includes embodiments in which the optional polyalkyleneoxide and/or end group moieties are either present or absent.

In yet another embodiment, the cationic silicone polymers herein have one or more polysiloxane units and one or more quaternary nitrogen moieties, and including polymers wherein the cationic silicone polymer has the formula: (Structure 3)

![Chemical structure diagram](image)
[0112] \( R^2 \) is independently selected from the group consisting of: divalent organic moieties that may contain one or more oxygen atoms;

[0113] \( X \) is independently selected from the group consisting of ring-opened epoxides;

[0114] \( R^3 \) is independently selected from polyether groups having the formula:

\[-M^1(\text{alkyl}, \text{C}_6 \text{H}_{12})_nM^2-\]

[0115] wherein \( M^1 \) is a divalent hydrocarbon residue; \( M^2 \) is independently selected from the group consisting of \( H \), \( \text{C}_9 \text{H}_{18} \) alkyl, \( \text{C}_{2-22} \) alkenyl, \( \text{C}_{2-22} \) alkylaryl, \( \text{aryl} \), cycloalkyl, hydroxyalkyl, polyalkyleneoxide, (poly)alkoxy alkyl, and mixtures thereof;

[0116] \( X \) is independently selected from the group consisting of ring-opened epoxides;

[0117] \( W \) is independently selected from the group consisting of divalent organic moieties comprising at least one quaternized nitrogen atom;

[0118] \( a \) is from 2 to 4; \( b \) is from 0 to 100; \( c \) is from 1 to 1000, preferably greater than 20, more preferably greater than 50, preferably less than 500, more preferably less than 300, most preferably from 100 to 200; \( d \) is from 0 to 100; \( n \) is the number of positive charges associated with the cationic silicone polymer, which is greater than or equal to 1; and \( A \) is a monovalent anion, in other words, a suitable counterion.

[0119] In preferred cationic silicone polymers of Structure 3, \( W \) is selected from the group consisting of:

\[
\begin{align*}
\text{(a)} & \quad R^4 \quad \text{N} \quad Z^1 \quad \text{N} \quad R^5 \quad 2mA; \\
\text{(b)} & \quad \text{N} \quad Z^1 \quad \text{N} \quad R^4 \quad R^5 \quad 2mA; \\
\text{(c)} & \quad R^4 \quad Z^1 \quad \text{N} \quad \text{N} \quad R^5 \quad R^6 \quad R^7 \quad R^8 \quad R^9 \quad R^{10} \quad 4mA;
\end{align*}
\]

[0120] (d) a divalent aromatic or aliphatic heterocyclic group, substituted or unsubstituted, containing at least one quaternized nitrogen atom; and

[0121] wherein

[0122] \( R^1, R^2, R^3, R^4, R^5, R^7, R^8, R^9, R^{10}, R^{11} \) are the same or different, and are selected from consisting of: \( \text{C}_1-\text{C}_5 \) alkyl, \( \text{C}_{2-22} \) alkenyl, \( \text{C}_{2-22} \) alkylaryl, \( \text{aryl} \), cycloalkyl, \( \text{C}_{1-22} \) hydroxyalkyl, polyalkyleneoxide, (poly)alkoxy alkyl, and mixtures thereof; or in which \( R^4 \) and \( R^5 \), or \( R^6 \) and \( R^7 \), or \( R^8 \) and \( R^{10} \), or \( R^9 \) and \( R^{13} \) may be components of a bridging alkylene group; and

[0123] \( Z^1 \) and \( Z^2 \) are the same or different divalent hydrocarbon groups with at least 2 carbon atoms, optionally containing a hydroxy group, and which may be interrupted by one or several ether, ester or amide groups.

[0124] The cationic silicone polymer may be applied to the embryonic fibrous web and/or applied to a dried fibrous structure and/or before and/or concurrently and/or after converting one or more dried fibrous structures into a sanitary tissue product. Nonlimiting examples of suitable processes for applying the cationic silicone polymer to the fibrous structure include spraying, including but not limited to using a spraying disk, onto the embryonic fibrous web and/or dried fibrous structure before it is wound into a roll of paper, extruding, especially via slot extrusion, onto the embryonic web and/or dried fibrous structure, and/or by printing, especially gravure printing, onto the embryonic fibrous web and/or dried fibrous structure and/or sanitary tissue product.

[0125] The cationic silicone polymer may be applied to the embryonic fibrous web and/or dried fibrous structure and/or sanitary tissue product in a homogeneous and/or patterned and/or inhomogeneous fashion.

[0126] The cationic silicone polymer can be applied to the embryonic fibrous web and/or fibrous structure and/or sanitary tissue product of the present invention as it is being made on a papermaking machine or the like while it is wet (i.e., prior to final drying) or dry (i.e., after final drying).

[0127] In one embodiment, an aqueous mixture containing the cationic silicone polymer is sprayed onto the embryonic fibrous web and/or fibrous structure and/or sanitary tissue product as it courses through the papermaking machine: for example, and not by way of limitation, referring to a papermaking machine of the general configuration disclosed in U.S. Pat. No. 3,301,746, either before the predryer, or after the predryer, or after the Yankee dryer/creeping station although the fibrous structure is preferably creped after the cationic silicone polymer is applied.

[0128] The cationic silicone polymer can be applied to the embryonic fibrous web in an aqueous solution, emulsion, or suspension. The cationic silicone polymer can also be applied in a solution containing a suitable, nonaqueous solvent, in which the cationic silicone polymer dissolves with which the cationic silicone polymer is miscible: for example, hexane. The cationic silicone polymer may be supplied in neat form or, preferably, emulsified with a suitable surfactant emulsifier. The cationic silicone polymer can be applied after embryonic fibrous web formation has been effected. In a typical process, the embryonic fibrous web is formed and then dewowered prior to cationic silicone polymer application in order to reduce the loss of cationic silicone polymer due to drainage of free water. The cationic silicone polymer can be applied to the wet embryonic fibrous web at a fiber consistency of greater than about 15% in the manufacture of conventionally pressed tissue paper; and to a wet embryonic fibrous web having a fiber consistency of between about 20% and about 35% in the manufacture of tissue paper in papermaking machines wherein the
newly formed embryonic fibrous web is transferred from a fine mesh Fourdrinier to a relatively coarse imprinting/carrier fabric and/or belt.

[0129] Methods of applying the cationic silicone polymer to the embryonic fibrous web and/or dried fibrous structure and/or sanitary tissue product include spraying, slot extrusion and gravure printing. Other methods include deposition of the cationic silicone polymer onto a forming wire or fabric or belt which is then contacted by the embryonic fibrous web and/or dried fibrous structure and/or sanitary tissue product. Equipment suitable for spraying cationic silicone polymer-containing liquids onto embryonic fibrous webs and/or dried fibrous structures and/or sanitary tissue products includes external mix, air atomizing nozzles such as the 2 mm nozzle available from V.H. Systems, Inc., Tucker, Ga. Equipment suitable for applying cationic silicone polymer-containing liquids onto embryonic fibrous webs and/or dried fibrous structures and/or sanitary tissue products includes rotogravure printers.

[0130] The cationic silicone polymer can be applied uniformly to the embryonic fibrous web and/or dried fibrous structure and/or sanitary tissue product. A uniform distribution is desirable so that substantially the entire sheet benefits from the tactile effect of the cationic silicone polymer. Continuous and patterned distributions are both within the scope of the invention and meet the above criteria.

[0131] Application methods described herein for the cationic silicone polymer can be used with dry or wet embryonic fibrous webs and/or fibrous structures and/or sanitary tissue products.

[0132] Exemplary art related to the addition of silicone materials to the fibrous structure during its formation includes U.S. Pat. No. 5,089,282 issued to Ampulski, et. al. on Oct. 22, 1991 incorporated herein by reference. The Ampulski patent discloses for a process for adding a polycarbosilane compound to a wet tissue web ("fibrous structure") preferably at a fiber consistency between about 20% and about 35%. Such a method represents an advance in some respects over the addition of chemicals into the slurry vats supplying the papermaking machine. For example, such means target the application to one of the web surfaces as opposed to distributing the additive onto all of the fibers of the furnish.

[0133] Considerable art has been devised to apply silicones and/or other chemical softeners to already-dried paper webs ("fibrous structures") either at the so-called dry end of the papermaking machine or in a separate converting operation subsequent to the papermaking step. Exemplary art from this field includes U.S. Pat. No. 5,215,626 issued to Ampulski, et. al. on Jun. 1, 1993; U.S. Pat. No. 5,246,545 issued to Ampulski, et. al. on Sep. 21, 1993; and U.S. Pat. No. 5,252,545 issued to Warner, et. al. on Jun. 11, 1996, all incorporated herein by reference. The U.S. Pat. No. 5,215,626 discloses a method for preparing soft tissue paper by applying a polysiloxane to a dry web ("fibrous structure"). The U.S. Pat. No. 5,246,545 discloses a method of utilizing a heated transfer surface. Finally, the Warner Patent discloses methods of application including roll coating and extrusion for applying particular compositions to the surface of a dry tissue web ("fibrous structure").

[0134] The cationic silicone may be applied to one or both surfaces of an embryonic web and/or dried fibrous structure and/or sanitary tissue product such that one or both external surfaces of a resulting sanitary tissue product incorporating the fibrous structure has the cationic silicone polymer present thereon.

[0135] In one embodiment, the cationic silicone may be applied to one surface of an embryonic web and/or dried fibrous structure and/or sanitary tissue product such that the cationic silicone passes through the embryonic web and/or dried fibrous structure and/or sanitary tissue product such that both surfaces of an embryonic web and/or fibrous structure and/or sanitary tissue product have cationic silicone present thereon.

[0136] The fibrous structure of the present invention and/or sanitary tissue product incorporating such fibrous structure may comprise from about 0.0001% to about 10% and/or from about 0.001% to about 5% and/or from about 0.001% to about 2% and/or from about 0.005% to about 1.5% by dry weight of the fibrous structure or sanitary tissue product of the cationic silicone polymer.

[0137] Reference is made to the following patents and patent applications which do also disclose cationic silicone polymers suitable for use in the present invention:WO 02/06 403;W O 02/18528,EP 1 199 350;DE OS 100 36 533;WO

[0138] Synthesis Example—When not otherwise known or available in commerce, the cationic silicone polymers herein can be prepared by conventional techniques as disclosed in WO 02/18528.

[0139] Other silicone compounds besides the cationic silicones discussed above can be used as chemical softeners. Nonlimiting examples of such other silicone compounds that are suitable for the present invention include silicone emulsions, particularly aminosilicones. Suitable aminosilicones are available under the tradename AF2130, which is commercially available from Wacker Silicones.

[0140] Processes of the Present Invention:

[0141] The fibrous structure of the present invention may be made by any suitable papermaking process.

[0142] A nonlimiting example of a suitable papermaking process for making the fibrous structure of the present invention is described as follows.

[0143] In one embodiment, a fiber furnish is prepared by mixing one or more fibers with water. One or more additional optional ingredients may be added to the fiber furnish. The fiber furnish may then be put into a headbox, which may be a layered headbox, of a papermaking machine. The fiber furnish may then be deposited on a porous surface to form a single layer or a multi-layer embryonic fibrous web. The cationic silicone polymer and/or optional ingredients may be added to the embryonic fibrous web by spraying and/or extruding and/or printing and/or by any other suitable process known to those of ordinary skill in the art. The embryonic web may then be transferred to a through-air drying belt and/or a Yankee dryer such that the embryonic fibrous web is dried via through-air drying and/or via the Yankee dryer. From the through-air drying belt, if there is one present, the fibrous structure may be transferred to a Yankee dryer. From the Yankee dryer, the fibrous structure may be transferred to a rewinder to form a roll of dried
fibrous structure. During this transfer step, the cationic silicone polymer and/or optional ingredients may be applied to the dried fibrous structure. The fibrous structure may be converted into various paper products, particularly sanitary tissue products, both in single-ply forms and/or in multi-ply forms. During the converting step, the cationic silicone polymer may be applied to the fibrous structure. Accordingly, the cationic silicone polymer may be applied before and/or concurrently with and/or after the converting step.

[0144] Test Methods

[0145] A. Coefficient of Friction


[0147] The substrate used for the friction evaluation, as disclosed herein, is a laboratory prepared handsheet prepared according to TAPPI standard T-205 incorporated herein by reference. The friction is measured on the smooth side of the handsheet (the side which is dried against a metal plate according to the method).

[0148] The substrate is advanced at 1 mm/sec constant rate for the measurement and the friction probe is modified from the standard instrument probe to a two centimeter diameter 40-60 micron glass frit.

[0149] When using a 19.6 g normal force on the probe and the heretofore specified translation rate for the substrate, the coefficient of friction can be calculated by dividing the frictional force by the normal force. The frictional force is the lateral force on the probe during the scanning, an output of the instrument.

[0150] The average of coefficient of friction obtained by a single scan in the forward direction and a single scan in the reverse direction is reported as the coefficient of friction for the specimen.

[0151] B. Physiological Surface Smoothness

[0152] Physiological surface smoothness as used herein is a factor (hereinafter the PSS Factor) derived from scanning machine-direction tissue paper samples with a profilometer (described below) having a diamond stylus, the profilometer being installed in a surface test apparatus such as, for example, Surface Tester KES-FB-4 which is available from KATO TECH CO., LTD., Karato-Cho, Nishihiyo, Minami-Ku, Koyota, Japan. In this tester, a sample of tissue is mounted on a motorized drum, and a stylus is gravitationally biased towards the drum at the 12 o’clock position. The drum is rotated to provide a sample velocity of one (1) millimeter per second, and moves the sample 2 cm. with respect to the probe. Thus, the probe scans a 2 cm length of the sample. The profilometer comprises means for counter-balancing the stylus to provide a normal force of 270 mg. Basically, the instrument senses the up and down displacements (in mm) of the stylus as a 2 cm length of sample is scanned under the profilometer probe. The resulting stylus-amplitude vs. stylus-distance-scanned data are digitized, and then converted to a stylus-amplitude vs. frequency spectrum by performing a Fourier Transform using the Proc Spectra standard program available from SAS Institute Inc., Post Office Box 10066, Raleigh, N.C. 27605. This identifies spectral components in the sample’s topography; and the frequency spectral data are then adjusted for human tactile responsiveness as quantified and reported by Verrillo (Ronald T. Verrillo, “Effect of Contractor Area on the Vibratotactile Threshold”, The Journal of the Acoustical Society of America, 35, 1962 (1963)). However, whereas Verrillo’s data are in the time domain (i.e., cycles per second), and physiological surface smoothness is related to finger-to-sample velocity, Verrillo-type data are converted to a spatial domain (i.e., cycles per millimeter) using 65 mm/sec as a standard finger-to-sample velocity factor. Finally, the data are integrated from zero (0) to ten (10) cycles per millimeter. The result is the PSS Factor. Graphically, the PSS Factor is the area under the Verrillo-adjusted frequency (cycles/mm) vs. stylus amplitude curve between zero (0) and ten (10) cycles per millimeter. Preferably, PSS Factors are average values derived from scanning multiple samples (e.g., ten samples), both forward and backward.

[0153] The profilometer described above comprises, more specifically, a Gould Surfanaqlyzer Equipment Controller #21-1330-20428, Probe #21-3100-465, Diamond stylus tip (0.0127 mm radius) #21-0120-00 and stylus tip extender #22-0129-00 all available from Federal Products, Providence, R.I. The profilometer probe assembly is fitted with a counterbalance, and set up as depicted in FIG. 22 of U.S. Pat. No. 4,300,981 (referenced hereinbefore).

[0154] C. Slip Stick Coefficient of Friction

[0155] Slip Stick Coefficient of Friction (hereinafter S & S COF) is defined as the mean deviation of the coefficient of friction. It is dimensionless. It may be determined using commercially available test apparatus such as, for example, the Kato Surface Tester identified above which has been fitted with a stylus which is configured and disposed to slide on the surface of the sample being scanned: for example, a fritted glass disk. When a sample is scanned as described above, the instrument senses the lateral force on the stylus as the sample is moved thereunder: i.e., scanned. The lateral force is called the frictional force; and the ratio of frictional force to stylus weight is the coefficient of friction, COF. The instrument then calculates and reports the S & S COF for each scan of each sample.

[0156] D. B Compressibility Test

[0157] A circular sample (single ply or multi-ply) of a fibrous structure and/or a sanitary tissue product to be tested having a 2.5 inch diameter is placed on a Thwing-Albert Compressibility Tester, commercially available from Thwing-Albert. A weight of up to 1500 g is placed on the sample at a test speed according to the Tester.

[0158] The thickness of the sample is measured/recorded at every 1 g of weight. The paired data (weight (X) vs. thickness (Y)) is then placed in an X-Y graph using Microsoft Excel Program.

[0159] After the X-Y graph is created, a trendline that is logarithmic which has an equation:

\[ Y = M \exp(\frac{X}{B}) \]

wherein M is the slope of the curve and B is the intercept. B is the B Compressibility value of the fibrous structures and/or sanitary tissue products incorporating such fibrous structures of the present invention.
NONLIMITING EXAMPLES

[0161] The following nonlimiting examples employ a cationic silicone polymer in accordance with the present invention. The cationic silicone polymer is used typically in the form of an emulsion containing an amine oxide, a nonionic surfactant, ethanol and water. In one embodiment, the emulsion is formed as follows: 24.39 g of cationic silicone solution (80% cationic silicone polymer/20% ethanol) is mixed with 6.05 g C12-15 EO3 (4) with a normal laboratory blade mixer. After 10 minutes, 6.7 g of ethanol is added. After another 10 minutes, 8.71 g of C12-14 alkyl dimethyl amine oxide 31% active solution in water (2) is added. Another 10 minutes, 54.2 g of demineralized water are quickly added to the mixture, under continuous stirring. The pH of the emulsion is brought to pH 7.5 with 0.8 g 0.1M HCl. The emulsion can be diluted to about 10-20% cationic silicone polymer concentration.

Example 1

A Nonlimiting Embodiment of a Fibrous Structure, such as a Facial Tissue, in accordance with the present invention is prepared as follows.

[0162] An aqueous slurry of Northern Softwood Kraft (NSK) of about 3% consistency is made up using a conventional pulper and is passed through a stock pipe toward the headbox of the Fourdriner. A 1% dispersion of Hercules’ Kynene 557 LX is prepared and is added to the NSK stock pipe at a rate sufficient to deliver about 0.8% Kynene 557 LX based on the dry weight of the ultimate sanitary tissue paper. The absorption of the permanent wet strength resin is enhanced by passing the treated slurry through an in-line mixer. An aqueous solution of Carboxymethyl cellulose (CMC) dissolved in water and diluted to a solution strength of 1% is added to the NSK stock pipe after the in-line mixer at a rate of about 0.1% CMC by weight based on the dry weight of the ultimate sanitary tissue paper. The aqueous slurry of NSK fibers passes through a centrifugal stock pump to aid in distributing the CMC. An aqueous dispersion of DiTallow Dimethyl Ammonium Methyl Sulfate (DTDMAMS) (170° F/76.6° C) at a concentration of 1% by weight is added to the NSK stock pipe at a rate of about 0.1% by weight DTDMAMS based on the dry weight of the ultimate sanitary tissue paper.

[0163] An aqueous slurry of acacia pulp fibers (from PT Tei—Indonesia) of about 1.5% by weight is made up using a conventional repulper and is passed through a stock pipe toward the headbox of the Fourdriner. The Acacia furnish joins the NSK slurry at the fan pump where both are diluted with water to about 0.2% consistency.

[0164] An aqueous slurry of Acacia pulp fibers (from PT Tei—Indonesia) of about 3% by weight is made up using a conventional repulper. The Acacia slurry passes to the second fan pump where it is diluted with white water to a consistency of about 0.2%.

[0165] The slurries of NSK, acacia and acacia are directed into a multi-channeled headbox suitably equipped with layering leaves to maintain the streams as separate layers until discharged onto a traveling Fourdriner wire. A three-chambered headbox is used. The acacia slurry containing 48% of the dry weight of the ultimate sanitary tissue paper is directed to the chamber leading to the layer in contact with the wire, while the NSK/acacia slurry comprising 52% (27-35% NSK and 17-25% acacia) of the dry weight of the ultimate paper is directed to the chamber leading to the center and inside layer. The NSK/acacia and acacia slurries are combined at the discharge of the headbox into a composite slurry.

[0166] The composite slurry is discharged onto the traveling Fourdriner wire and is dewatered assisted by a deflector and vacuum boxes.

[0167] The embryonic wet web is transferred from the Fourdriner wire, at a fiber consistency of about 17% by weight at the point of transfer, to a patterned, drying fabric. The drying fabric is designed to yield a pattern-densified tissue with discontinuous low-density deflected areas arranged within a continuous network of high density (knuckle) areas. This drying fabric is formed by casting an impervious resin surface onto a fiber mesh supporting fabric. The supporting fabric is a 48s/52 filament, dual layer mesh. The thickness of the resin cast is about 9 mil above the supporting fabric. The knuckle area is about 35-50% and the open cells remain at a frequency of about 10-87 per cm².

[0168] Further de-watering is accomplished by vacuum assisted drainage until the web has a fiber consistency of about 23-27%.

[0169] While remaining in contact with the patterned forming fabric, the patterned web is pre-dried by air blown through to a fiber consistency of about 60% by weight.

[0170] The semi-dry web is then adhered to the surface of a Yankee dryer with a sprayed creping adhesive comprising a 0.250% aqueous solution of polyvinyl alcohol. The creping adhesive is delivered to the Yankee surface at a rate of 0.1% adhesive solids based on the dry weight of the web. The fiber consistency is increased to about 98% before the web is dry creped from the Yankee with a doctor blade. After the doctor blade, the web is calendared across all its width with a steel to rubber calendar roll operating at a loading of 2-3.5 MPa.

[0171] The resulting tissue has a basis weight of about 20-25 g/m²; a 1-ply total dry tensile between 225 and 300 g/cm, a 1-ply wet burst between 30 and 65 gr/cm and a 2-ply caliper of about 0.035-0.05 cm. The resulting tissue is then combined with a like sheet to form a two-ply, creped, pattern-densified tissue so that the acacia fibers face the outside and it is subjected to calendaring between two smooth steel calendar rolls. The cationic silicone polymer emulsion is then slot extruded onto both sides in contact with a human's skin, at an add-on amount of approximately 0.8-1.0 g/m² of emulsion per side, equivalent to a total add-on level of 0.7-1.0% by weight of silicone per ply, based on the total weight of fibers. Product is then ply-bonded using a mechanical plybond wheel to ensure that both plies stay together. The resulting two-ply tissue has a) a total basis weight of about 39-50 g/m²; b) a 2-ply total dry tensile between 450 and 550 gr/cm; c) a 2-ply wet burst between 55 and 120 gr/cm; d) a 4-ply caliper of about 0.05 and 0.09 cm; e) a slip-stick coefficient of friction (MMD) of about 0.0146-0.0172; f) a Coefficient of Friction (MII) of about 0.734-0.742; g) a B Compressibility of 29-31; h) a calculated WABY factor of about 0.0786-0.0836; i) a PAA of about 720-770; and j) a lint of about 9-12 lint units.
The resultant tissue paper is judged significantly softer than an untreated tissue sample by a panel of expert judges.

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 considered as an admission that it is prior art with respect to the present invention.

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 fibrous structure that exhibits a Slip Stick Coefficient of Friction of less than about 0.0175.
2. The fibrous structure according to claim 1 wherein the fibrous structure exhibits a Slip Stick Coefficient of Friction of from about 0.0135 to about 0.0175.
3. The fibrous structure according to claim 1 wherein the fibrous structure further exhibits a B compressibility of from about 15 to about 50.
4. The fibrous structure according to claim 3 wherein the fibrous structure further exhibits a Coefficient of Friction of from about 0.65 to about 0.83.
5. The fibrous structure according to claim 4 wherein the fibrous structure exhibits a Coefficient of Friction of from about 0.65 to about 0.81.
6. The fibrous structure according to claim 3 wherein the fibrous structure exhibits a B Compressibility of from about 20 to about 40.
7. The fibrous structure according to claim 1 wherein the fibrous structure comprises hardwood fibers.
8. The fibrous structure according to claim 7 wherein the fibrous structure comprises tropical hardwood fibers.
9. The fibrous structure according to claim 8 wherein the tropical hardwood fiber comprises Acacia fibers, Eucalyptus fibers and mixtures thereof.
10. The fibrous structure according to claim 1 wherein the fibrous structure comprises softwood fibers.
11. The fibrous structure according to claim 1 wherein the fibrous structure comprises a chemical softener.
12. The fibrous structure according to claim 11 wherein the chemical softener is selected from the group consisting of: silicone compounds, quaternary ammonium compounds and mixtures thereof.
13. The fibrous structure according to claim 12 wherein the silicone compounds comprise a cationic silicone polymer comprising one or more polysiloxane units and one or more non-pendant quaternary nitrogen moieties.
14. The fibrous structure according to claim 13 wherein the cationic silicone polymer comprises at least 2 or more polysiloxane units and at least 2 or more quaternary nitrogen moieties.
15. The fibrous structure according to claim 1 wherein the fibrous structure exhibits a WABY factor of less than about 0.2.
16. The fibrous structure according to claim 1 wherein the fibrous structure exhibits a smoothness of greater than about 500.
17. A single- or multi-ply sanitary tissue product selected from the group consisting of facial tissue products, handkerchiefs, toilet tissue products, paper towel products and mixtures thereof, comprising a fibrous structure according to claim 1.
18. A fibrous structure that exhibits a Slip Stick Coefficient of Friction of less than about 0.023 and a B Compressibility of from about 15 to about 50.
19. The fibrous structure according to claim 18 wherein the fibrous structure further exhibits a WABY factor of less than about 0.2.
20. The fibrous structure according to claim 18 wherein the fibrous structure exhibits a Coefficient of Friction of from about 0.65 to about 0.83.
21. The fibrous structure according to claim 18 wherein the fibrous structure comprises a chemical softener.
22. A single- or multi-ply sanitary tissue product selected from the group consisting of facial tissue products, handkerchiefs, toilet tissue products, paper towel products and mixtures thereof, comprising a fibrous structure according to claim 18.