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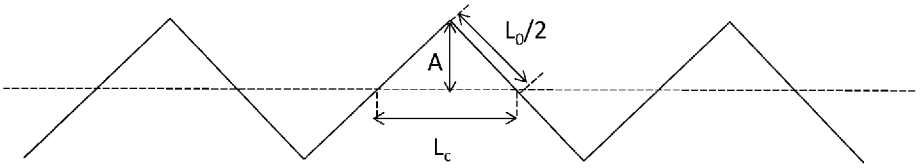


Figure 1

(57) Abstract: Sliver containing cellulose acetate staple fibres is obtained that exhibits good fibre to fibre cohesion energy and can be successfully drawn and made into spun yarns. Such slivers can be made of cellulose acetate staple fibres that have of round shape, a denier of less than 3.0, a crimp frequency per inch (CPI) from 5 to 30, a good fibre to fibre coefficient of friction and have a low static charge. The textile fabrics made from spun yarns have plant-based renewable resources by containing the cellulose acetate staple fibres, and can exhibit a thermoplastic behaviour to impart better dimensional stability to a textile fabric. The low denier of the cellulose acetate fibres can impart a feel similar to that of cotton, yet can be successfully processed through carding machines to form cohesive slivers and retain their integrity throughout the drawing process, allowing them to be formed into spun yarns.

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SLIVERS CONTAINING CELLULOSE ACETATE FOR SPUN YARNS

FIELD OF THE INVENTION

[0001] This invention relates to slivers containing cellulose acetate staple fibers to make rovings and spun yarns for textile fabrics, and more particularly, to slivers having good fiber-to-fiber cohesion energy.

BACKGROUND

[0002] Textile fabrics consisting of spun yarns are widely used in a variety of applications. These fabrics are formed by weaving, knitting, crocheting, knotting, or felting yarn made of natural and/or synthetic materials, such as, for example, polyesters, polyamides, acrylics, polyurethanes, glass, wool, polypropylene, silk, cashmere, sisal, flax, hemp, cotton, a variety of regenerated cellulosic materials, such as viscose, Modal, and Lyocell, and is often formed as a blend of two or more of these materials.

[0003] While the use of regenerated cellulosic materials has the advantage of originating from plant based renewable resources (cellulose), they do no exhibit thermoplastic behavior. Typically, textile fabrics containing regenerated cellulosic materials, cottons, hemp or flax are blended with a heat settable material such as a polyester or nylon which are thermoplastic to provide the dimensional stability needed for a textile fabric, such as low shrinkage, low twist, and low skew. Alternatively, textile fabrics without such thermoplastic materials need to be resin treated and/or pre-shrunk to impart dimensional stability. It would be desirable to provide a textile fabric blend with a material that originates from a plant based renewable resource and exhibits the heat setting behavior of a thermoplastic material without the need for resin treating and/or pre-shrinking.

[0004] Even if the material of choice meets end use performance requirements, it is not likely to be adopted into a textile fabric market if it cannot be processed on existing equipment used to make spun yarn. A significant portion of the spun yarn market uses a ring spinning process from

rovings made from drawn slivers of staple fibers obtained through a carding process. The staple fiber should be suited to be carded into cohesive slivers that can be ring spun into yarn, all using conventional and existing equipment. Key to the success of such a material is its ability to be carded successfully and drawn into slivers of adequate uniformity and strength. The staple fibers used to make the slivers should be capable of imparting a cohesiveness to the sliver to retain the integrity and shape of the sliver, yet have a sufficiently low dynamic coefficient of friction to allow the sliver to be easily drafted.

[0005] The replacement material should also have a soft feel closer to that of cotton rather than the synthetic feel of polyester, polypropylene, or polyethylene fibers. Fibers having a low denier are better suited to achieve a softer feel, however, low denier fibers are more difficult to process. To separate and efficiently orient the fibers in a carding operation, and to assist in retaining the sliver integrity, a crimp is imparted to the fiber which normally does not have a significant impact on the strength of higher denier fibers. However, as the denier drops below 3, the application of crimp can weaken the tenacity of the fiber to a point where the fibers easily break, forming a dust like lint that results in both fiber loss and frequent shut down of machinery to clean out rapidly accumulating lint.

[0006] It would be desirable to utilize a replacement material for regenerated cellulose that, as a material, originates from a plant based renewable resource, has a thermoplastic behavior to impart better dimensional stability to a textile fabric compared the same textile fabric containing regenerated cellulose, has a low denier to impart a feel similar to that of cotton, and with the right combination of properties to be processed through carding machines to form cohesive slivers and successfully formed into spun yarns. In particular, slivers made from such CA staple fibers should have good cohesive energy to enable their formation into carded slivers and retain their integrity throughout the drawing processes.

SUMMARY OF THE INVENTION

[0007] There is now provided a carded sliver comprising CA staple fibers having a round shape, a denier of less than 3.0, a crimp frequency per inch (CPI) from 5 to 30, and wherein said sliver has a fiber-to-fiber cohesion energy of at least 10,000 joules.

[0008] There is also provided a spun yarn obtained from one or more carded slivers, at least one of said carded slivers comprising CA staple fibers having a round shape, a denier of less than 3.0, a crimp frequency per inch (CPI) from 5 to 30, and wherein said sliver has a fiber-to-fiber cohesion energy of at least 10,000 Joules.

[0009] The invention also includes a textile fabric fabric obtained from spun yarn, said yarn obtained from carded slivers comprising CA staple fibers (CA staple fibers) containing a quantity of spin finish, and wherein the textile fabric contains no spin finish or a quantity of spin finish that is less than said quantity on the CA staple fibers, said staple CA staple fibers having round shape, a denier (DPF) of less than 3.0, a crimp frequency per inch (CPI) from 5 to 30, wherein said one or more carded slivers has a fiber-to-fiber cohesion energy of at least 10,000 joules.

[0010] Desirably, the CA staple fibers used to make the carded sliver have an untwisted fiber to fiber coefficient of dynamic friction (F/F CODF) between 0.11 to less than 0.2, as measured on an uncrimped filament yarn by ASTM D3412/3412M-13 with uncrimped filaments of the same composition, shape, and denier as said CA staple fibers. The CA staple fibers used to make the carded sliver also have a static electricity charge of less than 1.0 at 65% relative humidity as determined on a filament yarn.

BRIEF DESCRIPTION OF THE FIGURES

[0011] **Figure 1** relates the different parameters used to determine the crimp amplitude of a crimped fiber.

DETAILED DESCRIPTION

[0012] It has been found that slivers can be successfully formed from CA staple fibers and further processed successfully to spun yarns to make textile fabric. At the same time, the CA staple fibers may be environmentally-friendly, exhibit thermoplastic behavior, have a soft feel similar to that of cotton, and can be processed using both new and existing processing equipment.

[0013] As used herein, textile fabrics are materials made from spun yarn and that are either woven, knitted, crocheted, knotted, embroidered, braided/plaited, laced, or carpet piling. Textile fabrics include geotextile fabrics, carpet pilings, and fabrics (which includes cloth). The geotextile fabrics as used in the context of a textile fabric herein are those that are woven or knitted. Examples of suitable types of textile fabrics formable from the inventive staple fibers can include, but are not limited to, clothing (undergarments, socks, hats, shirts, pants, dresses, scarves, gloves, etc.), bags, baskets, upholstered furnishings, window shades, towels, table cloths, bed coverings, flat surface coverings, in art work, filters, flags, backpacks, tents, handkerchiefs, rags, balloons, kites, sails, parachutes, automotive upholstery, protective clothing such as against heat for firefighters and welders, protective clothing for bullet armor or stab protection, medical textile fabrics such as implants, and agrotextile fabrics for crop protection. A CA staple fiber means a cellulose acetate staple fiber, and a "staple fiber" refers to a fiber cut from a continuous filament or tow band of continuous filaments. A carded sliver, spun yarn, or textile fabric "obtained from" a described element includes any number and type of intervening steps or process operations.

[0014] There is now provided a carded sliver comprising CA staple fibers having a round shape, a denier of less than 3.0, a crimp frequency per inch (CPI) from 5 to 30, and a static electricity charge of less than 1.0 at 65% relative humidity, and wherein said sliver has a fiber-to-fiber cohesion energy of at least 10,000 Joules.

[0015] A carded sliver is continuous bundle or strand of loose untwisted fibers that are aligned generally relatively parallel to each other. This alignment is conducted by subjecting the fibers to a carding process.

[0016] The slivers and spun yarns of the present invention may be formed according to any suitable process. The process of forming slivers from staple fibers starts begins with feeding staple fibers to a carding machine, and optionally blending the CA staple fibers with fibers of other non-cellulose acetate materials. If the CA staple fibers are blended with other natural fibers, those natural fibers may optionally be separated from foreign objects such as dirt, seeds, and other foreign items through a picking process and formed into a lap. The CA staple fibers contained in a bale may be blended with other baled fibers by opening each bale and feeding the fibers to a blending machine. Blending can occur during formation of the lap, in the carding operation, or during the drawing out operation, but desirably into or before the carding process. The staple fibers can be opened and tufted to pull the fibers apart before being fed to the carding machine.

[0017] The carding process can be by hand, or processed through any conventional carding equipment, including drum carders, cottage carders, and industrial carders. Generally, in the carding process, the CA staple fibers along with staple fibers of other materials that are not cellulose acetates (non-CA staple fibers) are placed on a conveyor, or card, and are passed through a number of cylinders (or other movable surfaces) covered with fine wire brushes, metal teeth, or other gripping surfaces. The carding machine can be roller-doffed, fine air-doffed, or coarse air-doffed cards. Typical carding machines consist of one large cylinder with many teeth or fine wire brushes, and a number of smaller rollers encased within a flat having wire brushes that surround at least a portion of the larger roller's surface and moves counter directional to the larger cylinder. As the surfaces move relative to one another, the fibers are mechanically separated and aligned in a substantially parallel direction to each other. The flat and cylinder have small teeth or wire brushes that can get progressively finer or closer together as the fibers are

pulled through the machine. The fibers remain on the cylinder surface and are pulled in the same parallel direction to form a thin web that is fed into a funnel shaped tube, thereby forcing the web to form into a round loose strand or loose rope-like body called a sliver or card sliver.

[0018] Optionally, the card sliver can be combed, which is a desirable operation on natural fibers for very fine yarns intended to make finer fabrics. In combining, fine tooth combs are applied to the sliver to further separate and remove fibers that are too short and further align the fibers parallel to each other.

[0019] The carded sliver is the output of a carding machine that is not yet subjected to combing (if used) and drawing operations. The carded sliver desirably has a total denier of at least 10,000 or least 15,000, or at least 20,000, or at least 25,000, or at least 30,000, or at least 35,000, or at least 40,000, or at least 45,000, or at least 50,000. In general, the sliver total denier would not exceed 200,000, or not exceed 150,000, or not exceed 100,000, or not exceed 80,000, or not exceed 60,000, or not exceed 50,000. For most applications, the sliver will have a total denier of 20,000 to 80,000, or 25,000 to 60,000 or 30,000 to 60,000. If one desires to convert the sliver denier to grains, a conversion factor of 60 grain sliver = 35,000 denier is used.

[0020] Once the carded slivers are formed, after an optional combing step, they are fed to a drawing frame where multiple slivers are combined and drafted (reducing weight per unit length), thereby making them longer and thinner and further straightened and aligned, to make a more uniform sized sliver with enhanced fiber to fiber blending within the sliver. Multiple slivers are usually further combined to make a larger sliver or strand, which can then also be further drawn. The drawing process improves the quality of the slivers by straightening and aligning staple fibers within and producing a more uniform resultant sliver. The drawing process entails passing the slivers, optionally first through guides such as spoons, through several pairs of rollers, with each successive pair of rollers running at a higher speed than the preceding pair so that the slivers are combined, reduced in size, and

substantially drafted as they move down the drawing frame. Upon drawing, the combined finer and drafted sliver product is given a slight twist and wound onto bobbins as rovings.

[0021] The strand, or the roving, can have a total denier of at least 30,000, or at least 40,000, or at least 50,000, or at least 55,000, or at least 60,000. In general, the sliver total denier would not exceed 300,000, or not exceed 200,000, or not exceed 150,000. If one desires to measure the denier in hanks, the conversion factor of 1 hank roving = 5300 denier is used. Typical industry range for roving is 0.3 to 5.0 hank or approx 18,000 to 1000 denier respectively.

[0022] The roving wound onto bobbins can then proceed to the yarn ring spinning operation. There are a variety of other spinning processes from which the sliver from drawing would be used directly without the use of a roving, such as open-end (rotor) spinning, air-jet spinning, air-vortex spinning, and electrostatic spinning. The CA staple fibers of the invention are well suited for any type of spinning process used.

[0023] A common spinning process is the ring spinning process. The roving wound onto bobbins can be passed through yet another set of drafting rolls to lengthen the roving and obtain the desired final thickness, and then fed through a traveler that moves at high speed around a stationary ring encircling another bobbin mounted on a rotating spindle. The yarn moving through the traveler is at a slower speed that the spindle speed, thereby imparting the desired twist to the yarn as it winds onto the bobbin. The traveler oscillates axially to the bobbin to distribute the yarn along the length of the bobbin, and the process accomplishes twist and winding in one step.

[0024] Open-end spinning is also a suitable process, and differs from ring spinning in a variety of ways. In open end spinning, the roving step is omitted, and the slivers are instead fed to the spinner by a stream of air. To accomplish this, the fibers in the sliver must be separated, typically be a rotary beater, and the separated fibers are carried by a stream of air through a tube or duct to a rotor and deposited into a groove on the sides of the rotor. As the

rotor turns, it twists the fibers in the grooves and the twisted yarn so produced is removed from the groove as a constant stream of new separated fibers are fed to the rotor groove.

[0025] The CA staple fibers in the carded slivers are formed from one or more kinds of cellulose acetate. The cellulose acetate may be formed from cellulose diacetate, cellulose triacetate, or mixtures thereof. The cellulose acetate has a degree of substitution in the range of from 1.9 to 2.9. As used herein, the term "degree of substitution" or "DS" refers to the average number of acetyl substituents per anhydroglucose ring of the cellulose polymer, wherein the maximum degree of substitution is 3.0. In some cases, the cellulose acetate used to form fibers as described herein may have an average degree of substitution of at least about 1.95, 2.0, 2.05, 2.1, 2.15, 2.2, 2.25, or 2.3 and/or not more than about 2.9, 2.85, 2.8, 2.75, 2.7, 2.65, 2.6, 2.55, 2.5, 2.45, 2.4, or 2.35, with greater than 90, 91, 92, 93, 94, 95, 96, 97, 98, or 99 percent of the cellulose acetate having a degree of substitution greater than 2.15, 2.2, or 2.25. Desirably, greater than 90 weight percent, or greater than 95%, or greater than 98%, or greater than 99%, and up to 100 wt.% of the total acyl substituents are acetyl substituents (C2). Desirably, the cellulose acetate has no acyl substituents having a carbon number of greater than 2.

[0026] The cellulose acetate may have a weight-average molecular weight (M_w) of not more than 90,000, measured using gel permeation chromatography with N-methyl-2-pyrrolidone (NMP) as the solvent. In some case, the cellulose acetate may have a molecular weight of at least about 10,000, at least about 20,000, 25,000, 30,000, 35,000, 40,000, or 45,000 and/or not more than about 100,000, 95,000, 90,000, 85,000, 80,000, 75,000, 70,000, 65,000, 60,000, or 50,000.

[0027] The cellulose acetate or other CA staple may be formed by any suitable method. In some cases, cellulose acetate may be formed by reacting a cellulosic material such as wood pulp with acetic anhydride and a catalyst in an acidic reaction medium to form a cellulose acetate flake. The flake may

then be dissolved in a solvent, such as acetone or methyl ethyl ketone, to form a "solvent dope," which can be filtered and sent through a spinnerette to form CA staple fibers. In some cases, up to about 1 weight percent or more of titanium dioxide or other delusterant may be added to the dope prior to filtration, depending on the desired properties and ultimate end use of the fibers.

[0028] In some cases, the solvent dope or flake used to form the CA staple fibers may include few or no additives in addition to the cellulose acetate. Such additives can include, but are not limited to, plasticizers, antioxidants, thermal stabilizers, pro-oxidants, acid scavengers, inorganics, pigments, and colorants. In some cases, the CA staple fibers as described herein can include at least about 90, 90.5, 91, 91.5, 92, 92.5, 93, 93.5, 94, 94.5, 95, 95.5, 96, 96.5, 97, 97.5, 98, 98.5, 99, 99.5, 99.9, 99.99, 99.995, or 99.999 percent cellulose acetate, based on the total weight of the fiber. Fibers formed according to the present invention may include not more than about 10, 9.5, 9, 8.5, 8, 7.5, 7, 6.5, 6, 5.5, 5, 4.5, 4, 3.5, 3, 2.5, 2, 1.5, 1, 0.5, 0.1, 0.01, 0.005, or 0.001 weight percent of additives other than cellulose acetate, including the specific additives listed herein.

[0029] At the spinnerette, the solvent dope can be extruded through a plurality of holes to form continuous cellulose acetate filaments. At the spinnerette, filaments may be drawn to form bundles of several hundred, or even thousand, individual filaments. Each of these bundles, or bands, may include at least 100, or at least 150, or at least 200, or at least 250, or at least 300, or at least 350, or at least 400 and/or not more than 1000, or not more than 900, or not more than 850, or not more than 800, or not more than 750, or not more than 700 fibers. The spinnerette may be operated at any speed suitable to produce filaments and bundles having desired size and shape.

[0030] Multiple bundles may be assembled into a tow band such as, for example, a crimped or uncrimped tow band. The tow band may be of any suitable size and, in some embodiments, may have a total denier of at least about 10,000, or at least 15,000, or at least 20,000, or at least 25,000, or at

least 30,000, or at least 35,000, or at least 40,000, or at least 45,000, or at least 50,000, or at least 75,000, or at least 100,000, or at least 150,000, or at least 200,000, or at least 250,000, or at least 300,000. Alternatively, or in addition, the total denier of the tow band can be not more than about 5,000,000, or not more than 4,500,000, or not more than 4,000,000, or not more than 3,500,00, or not more than 3,000,000, or not more than 2,500,000, or not more than 2,000,000, or not more than 1,500,000, or not more than 1,000,000, or not more than 900,000, or not more than 800,000, or not more than 700,000, or not more than 600,00, or not more than 500,000, or not more than 400,000, or not more than 350,000, or not more than 300,000, or not more than 250,000, or not more than 200,000, or not more than 150,000, or not more than 100,000, or not more than 95,000, or not more than 90,000, or not more than 85,000, or not more than 80,000, or not more than 75,000, or not more than 70,000.

[0031] The individual filaments, which are extruded in a generally longitudinally aligned manner and which ultimately form the tow band, are of a particular size. The linear denier per filament (weight in g of 9000m fiber length), or DPF, of the CA filaments in the tow band and of the corresponding staple fibers in the sliver and yarn, are within a range of 0.5 to less than 3, or from 1.0 to less than 3, measured according to ASTM D1577-01 using the FAVIMAT vibroscope procedure. Desirably, the DPF of the filaments, and of the corresponding staple fibers, are within a range of 1.0 to 2.5, or 1.0 to 2.2, or 1.0 to 2.1, or more desirably from 1.0 to 2.0, or 1.0 to less than 2.0, or 1.0 to 1.9, or 1.1 to 1.9.

[0032] The individual filaments discharged from the spinnerette, and the corresponding staple fibers, have a substantially round cross-sectional shape, but in an acetone, solvent-spun process the cross section will somewhat irregular or crenulated due to collapsing of the hardened surface. As used herein, the term “cross-section” generally refers to the transverse cross-section of the filament measured in a direction perpendicular to the direction of elongation of the filament. The cross-section of the filament may be

determined and measured using Quantitative Image Analysis (QIA). Staple fibers may have a cross-section similar to the filaments from which they were formed.

[0033] The cross-sectional shape of an individual filament may also be characterized according to its deviation from a round cross-sectional shape. In some cases, this deviation can be characterized by the shape factor of the filament, which is determined by the following formula: Shape Factor = Perimeter / $(4\pi \times \text{Cross-Sectional Area})^{1/2}$. In some embodiments, the shape factor of the individual cellulose acetate (or other CA staple) filaments can be from 1 to 2, or 1 to 1.8, or 1 to 1.7, or 1 to 1.5, or 1 to 1.4, or 1 to 1.25, or 1 to 1.15, or 1 to 1.1. The shape factor of filament having a perfect round cross-sectional shape is 1. The shape factor can be calculated from the cross-sectional area of a filament, which can be measured using QIA.

[0034] After multiple bundles are assembled into a tow band, it may be passed through a crimping zone wherein a patterned wavelike shape may be imparted to at least a portion, or substantially all, of the individual filaments. Imparting crimp is necessary to allow the staple fibers to be separated and oriented in the carding operation, and to provide a measure of needed cohesion needed to prevent a sliver from falling apart.

[0035] A suitable type of mechanical crimper is a “stuffing box” or “stuffer box” crimper that utilizes a pair of nip rollers to force the tow band into the restriction of stuffer box just downstream of the rolls. The resulting compressive forces on the fiber cause the fibers to buckle, crimp and interlock into a cohesive tow band. Examples of equipment suitable for imparting crimp to the filaments are described in, for example, U.S. Patent Nos. 9,179,709; 2,346,258; 3,353,239; 3,571,870; 3,813,740; 4,004,330; 4,095,318; 5,025,538; 7,152,288; and 7,585,442, each of which is incorporated herein by reference to the extent not inconsistent with the present disclosure. In some cases, the crimping step may be performed at a rate of at least about 50 m/min (75, 100, 125, 150, 175, 200, 225, 250 m/min) and/or not more than about 750 m/min (475, 450, 425, 400, 375, 350, 325, or 300 m/min).

[0036] The low denier CA staple fibers of the invention are susceptible to breakage by the normal frequency of crimps imparted to higher denier fibers typically used in cigarette filter tow. However, as noted above, crimping is necessary component of the fiber to form a cohesive sliver and spun yarn. A low frequency of crimps is necessary to form fibers that exhibit minimal breakage and a high degree of retained tenacity. As used herein, the term "retained tenacity" refers to the ratio of the tenacity of a crimped filament (or staple fiber) to the tenacity of an identical but uncrimped filament (or staple fiber), expressed as a percent. For example, a crimped fiber having a tenacity of 1.3 gram-force/denier (g/denier) would have a retained tenacity of 87 percent if an identical but uncrimped fiber had a tenacity of 1.5 g/denier.

[0037] The cellulose acetate filaments crimped according to the present invention are capable of having a retained tenacity of at least about 60%, or at least 65%, or at least 70%, or at least 75%, or at least 80%, or at least 85%, or at least 90%, or at least 95%. The retained tenacity may be 100 percent in some cases. In some cases, the final CA staple fibers may exhibit similar retained tenacities as compared to identical but uncrimped staple fibers.

[0038] Crimping may be performed such that the final staple fibers have a crimp frequency of at least 5, or least 7, or at least 8, or at least 9, or at least 10, or at least 12, and up to 30, or up to 25, or up to 20, or up to 19 crimps per inch (CPI), measured according to ASTM D3937. Higher CPI than 30 will result in excess breakage and low retained tenacity, resulting in lint formation and fiber loss. Fewer than 5 CPI is insufficient to properly card the fibers or retain the cohesion of the sliver. Desirably, the CPI is from 10 to 20.

[0039] The ratio of the CPI to the DPF is a useful measure to ensure that the proper CPI is imparted for a given DPF and retain the balance of necessary crimp frequency and tenacity for a given DPF. Suitable ratios of CPI:DPF include from 6:1 to 30:1, or 6:1 to 20:1, and especially 6:1 to 14:1, or 7:1 to 12:1.

[0040] When crimped, the crimp amplitude of the fibers may vary and can, for example, be at least about 0.85, or at least 0.90, or at least 0.93, or at

least 0.96, or at least 0.98, or at least 1.00, or at least 1.04 mm. Additionally, or in the alternative, the crimp amplitude of the fibers can be up to 1.75, or up to 1.70, or up to 1.65, or up to 1.55, or up to 1.35, or up to 1.28, or up to 1.24, or up to 1.15, or up to 1.10, or up to 1.03, or up to 0.98 mm.

[0041] Additionally, the final staple fibers may have a crimp ratio of at least about 1:1. As used herein, "crimp ratio" refers to the ratio of the non-crimped tow length to the crimped tow length. In some embodiments, the staple fibers may have a crimp ratio of at least about 1:1, at least about 1.1:1, at least about 1.125:1, at least about 1.15:1, or at least about 1.2:1.

[0042] Crimp amplitude and crimp ratio are measured according to the following calculations, with the dimensions referenced being shown in FIG. 1: Crimped length (L_c) is equal to the reciprocal of crimp frequency (1/crimp frequency), and the crimp ratio is equal to the straight length (L_0) divided by the crimped length (L_0:L_c). The amplitude (A) is calculated geometrically, as shown in FIG. 1, using half of the straight length ($L_0/2$) and half of the crimped length ($L_c/2$). The uncrimped length is simply measured using conventional methods.

[0043] After crimping, the fibers may be dried in a drying zone in order to reduce the moisture (total of water and solvent) content of the tow band. In some cases, the drying zone may be sufficient to reduce the final moisture content of the tow band to not more than about 9, or less than 8.5, or less than 8, or less than 7.5, or less than 7, or less than 6.5, or less than 6 weight percent based on the total weight of the yarn. Typically, the moisture content does not drop below about 3.5 wt.% or below about 4 wt.%. Any suitable type of dryer can be used such as, for example, a forced air oven, a drum dryer, or a heat setting channel. The dryer may be operated at any temperature and pressure conditions that provide the requisite level of drying without damaging the yarn.

[0044] Once dried, the tow band may be fed to the cutting zone, or optionally first baled and the resulting bales may be introduced into a cutting zone, wherein the elongated tow bands may be cut into staple fibers. The

staple fibers of the present invention may be cut to a length that is dependent upon the application needs. Unexpectedly, the cut length also influences the cohesion of the sliver and ability to successfully spin a yarn at a given denier. A successful spun yarn spin at a given denier and staple fiber length may require adjusting the staple cut length at a lower DPF when all other factors are constant. The staple fiber length is generally in the range of at least 5 mm and up to 150 mm. Other examples if desirable cut lengths include a cut length of at least 10 mm, or at least 11 mm, and not more than about 100mm, or not more than 90 mm, or not more than 80 mm, or not more than 60 mm, or not more than 55 mm, or not more than 50 mm, or not more than 45 mm, or not more than 40 mm, or not more than 38 mm, or not more than 35 mm, or not more than 32 mm, or not more than 30 mm, or not more than 28 mm, or not more than 26 mm. Examples of cut length ranges include from 10 to 55 mm, or 10 to 50 mm, or 10 to 45 mm, or from 11 to 38 mm, or from 11 to 26 mm.

[0045] Any suitable type of cutting device may be used that can cut the filaments to a desired length without excessively damaging the fibers. Examples of cutting devices can include, but are not limited to, rotary cutters, guillotines, stretch breaking devices, reciprocating blades, and combinations thereof. Once cut, the staple fibers may be baled or otherwise bagged or packaged for subsequent transportation, storage, and/or use.

[0046] The sliver obtained from the CA staple fibers has a fiber-to-fiber cohesion energy of at least 10,000 Joules (J), or at least 12,000 J, or at least 15,000 J, or at least 17,000 J, or at least 20,000 J. The fiber-to-fiber cohesion energy desirably does not have a cohesion energy of more than 30,000 J to ensure that the sliver can be adequately drawn consistently and without fiber breakage. The sliver fiber-to-fiber cohesion energy is influenced by a number of factors, including cut length, CPI, denier, finish coating level and type to adjust the fiber to fiber and fiber to metal coefficients of dynamic friction, static electricity charges, and fiber material. Fibers made for use in and formed into sliver require a greater F/F CODF relative to fibers for use in or made into

many non-woven applications due to the processes for making the sliver that requires good fiber to fiber cohesion and due to downstream processing of the sliver, such as in drawing operations that subject the slivers to elongation yet require the slivers to maintain their cohesion and integrity. Compared to non-woven applications, the F/F CODF is higher for spun yarn applications in order to retain the cohesive energy and strength of a sliver, but not so high as to cause it to break when drawn and elongated with conventional equipment.

[0047] The fiber-to-fiber cohesion energy of the carded sliver is determined by the rotor ring test. The test instrument and procedure were developed at the institute of Textile Technology, Denkendorf, Germany. A small amount of pre-opened fibers (2-3 grams) is presented to a feed roll turning at 5 revolutions per minute from a feed chute. The feed roll transfers the fibers to the opener roll spinning at 4000 revolutions per minute by means of a carding action between the cylinders. Fibers are transported to the feed zone from the opening roll by the action of the partial vacuum and centrifugal force, and then they deposit into a rotor cup turning at 10,000 revolutions per minute through air transport. A fiber ring is formed in the rotor, which consists mainly of parallel fibers. The energy (joules) required to drive the opening cylinder at a constant speed is measured. Testing is performed at 65% RH and 70°F.

[0048] Examples of suitable fiber-to-fiber cohesion energy of the slivers range from 10,000 J to 30,000 J, or from 10,000 J to 28,000 J, or from 10,000 J to 25,000 J, or from 10,000 J to 23,000 J, or from 10,000 J to 20,000 J, or from 12,000 J to 30,000 J, or from 12,000 J to 28,000 J, or from 12,000 J to 25,000 J, or from 12,000 J to 23,000 J, or from 12,000 J to 20,000 J, or from 15,000 J to 30,000 J, or from 15,000 J to 28,000 J, or from 15,000 J to 25,000 J, or from 15,000 J to 23,000 J, or from 15,000 J to 20,000 J, or from 17,000 J to 30,000 J, or from 17,000 J to 28,000 J, or from 17,000 J to 25,000 J, or from 17,000 J to 23,000 J, or from 17,000 J to 20,000 J.

[0049] An alternative method for describing the cohesive energy to a sliver is to conduct a staple pad friction test on the staple fibers used to make the sliver and calculate the scroop value. The scroop value, measured as the

difference between static and dynamic pulling forces, of the coated fibers described herein can be less than 160 grams-force (g). In some embodiments, the coated staple fibers may exhibit a scroop value of at least about 10, or at least 15, and desirably at least 20, or at least 23, or at least 25, or at least 28, or at least 30, or at least 35, or at least 40, or at least 45, or at least 50, or at least 55, or at least 60, or at least 65, or at least 70, or at least 75, or at least 80, or at least 85, or at least 90, in each case in grams, and desirably not more than 200, or not more than 180, or not more than 160, or not more than 180, or not more than 140, or not more than 120, in each case in grams. Staple fibers with lower cohesion, as indicated by a lower scroop values, do not have sufficient cohesive energy to form slivers that retain their integrity and strength and that can be adequately processed or drawn. Staple fibers having a scroop value in excess of 1 or even 0.8. The static and dynamic coefficients of friction and the resulting scroop value may be calculated from the staple pad friction method described in U.S. Patent No. 5,683,811 and U.S. Patent No. 5,480,710, but using an Instron 5966 series machine or is equivalent, rather than an Instron 1122 machine. The fiber-to-fiber static friction is determined as described in the '710 patent as the maximum threshold pulling force at low pulling speed upon reaching equilibrium pulling behavior, and the fiber-to-fiber dynamic friction is similarly calculated, but is the minimum threshold level of force as the staple pad traverses a slip-stick behavior. The scroop is calculated as the difference between static and dynamic friction pulling forces with units of gram-force.

[0050] A more detailed description for determing the fiber-to-fiber coefficient of friction in the staple pad friction method is as follows. The coefficient of friction test fixture is a fixed horizontal table and a moveable sled. Both the table and sled can be covered with test material. A tow line attaches the sled to a low force load cell with a pulley guiding the tow line during the test. The fixture is mounted to the base of the test instrument and as the crosshead/load cell moves, the sled is pulled across the horizontal table.

[0051] Data is recorded from the load cell during the test and analyzed to determine both static and dynamic friction. Static friction is typically the maximum peak force on the load curve required to initiate movement of the sled and dynamic friction is average force on the load curve recorded throughout the total length of travel of the sled. The staple pad coefficient of friction is defined as the average of the static and dynamic friction forces divided by the mass of the sled, while the scroop value is the difference between the static and dynamic forces.

[0052] The apparatus includes a Mettler Balance, an air-jet type device to assist in disentangling and opening staple fiber sample, a mini-carding machine or equivalent machine capable of orienting staple fiber sample to produce test fiber pad, a universal Tensile/Compression Tester: Instron Model 5966 or equivalent, a fixed steel horizontal table with fixed pulley: 200W x 360L x 13H mm, a steel moveable sled: 63W x 65L x 6H mm steel block weighing 200 grams with hook attachment, a steel weight: 1 kg.

[0053] The fiber specimen preparation and test apparatus setup is as follows:

1. Process approximately 50 grams of cut staple crimped fiber through an air jet to introduce an opening effect on the individual fibers.
2. Take two samples, each weighing approximately 5 grams of the opened fiber, and process through mini-carding machine to form two fiber pads each measuring 75W x 225L x 50Hmm.
3. Using a Universal Tensile/Compression Tester with a 5 to 10kN load cell, attach the coefficient of friction test fixture.
4. Attach with tape sheet 50 grit sand paper to the fixed steel horizontal table.
5. Attach with tape a second sheet of 50 grit sand paper to the bottom of the steel moveable sled and attach the toe line to the load cell of the Universal Tensile/Compression Tester, so that when the load cell mechanism travels upward, the toe line will

pull on the steel moveable sled across the top of the fixed steel horizontal table.

6. Place one sample fiber pad on the sand paper taped to the fixed steel horizontal table.
7. Place the second fiber pad on top of the first pad running lengthways along the length of the length of the fixed steel horizontal table.
8. Place steel moveable sled on top of top fiber pad and set steel weight on top of steel moveable sled.
9. Set up the Universal Tensile/Compression Tester such that the crosshead head and load cell travel at a rate of 150mm/min and the length of travel is 150mm.
10. Test the top fiber pad directionally in a forward direction, then turn the pad 180 degrees and repeat the test so that the pad has been tested twice in opposite directions.
11. Flip the top fiber pad and repeat step 10.
12. Record and report the static and dynamic friction forces and calculate coefficient of friction as stated above.

[0054] Coated staple fibers of the present invention may exhibit a fiber-to-fiber staple pad friction coefficient of friction of at least 0.20, or at least 0.25, or at least 0.30, and desirably at least 0.35, or at least 0.4, or at least 0.45, or at least 0.55, or at least 0.6, and/or not more than about 0.9, or not more than 0.85, and desirably not more than 0.80, or not more than 0.75, or not more than 0.70, or not more than 0.65, or not more than 0.6, or not more than 0.55. Staple fibers having a fiber to fiber staple pad friction above 0.9 are problematic in that the fibers tend to break, thereby increasing short fiber content, and below 0.2 a sliver cannot be formed or a sliver with poor integrity that cannot be wound or drawn is formed.

[0055] Additionally, or in the alternative, the coated staple fibers may exhibit a fiber-to-metal staple pad friction coefficient of friction of at least about 0.10, 0.15, 0.20, or 0.25 and/or not more than about 0.55, 0.50, 0.45, 0.40,

0.35, or 0.30, measured as described in U.S. Patent No. 5,683,811, the entire disclosure of which is incorporated herein by reference to the extent not inconsistent with the description herein.

[0056] In one embodiment, the CA staple fibers contained in the carded sliver, spun yarn, and textile fabric have an untwisted F/F CODF (also called a fiber to fiber sliding friction) between 0.11 to 0.20 as measured by ASTM D3412/3412M-13 on filament yarn. To determine the F/F CODF of the fibers of a sliver, uncrimped continuous filaments are formed that have the same composition, denier, shape, and CPI as the filaments used to make the CA staple fiber, or if available, the continuous filaments used to make the CA staple fiber are used, and formed into a filament yarn, and conditioned at 70°F and 65% relative humidity for 24 hours before testing. The filament yarn is measured according to ASTM D3412/3412M – 13, with the exception that only 1 twist is used, the rate is at 20 m/min, and the yarn is tested on a Constant Tension Transport with Electronic Drive (CTT-E) set up according to Fig. 1 in the ASTM procedure at an input tension of 10 grams. The values obtained by this method are deemed to be the F/F CODF of the CA staple fibers in the sliver.

[0057] If the sliver has a F/F CODF below 0.11, the sliver likely will not retain its integrity in the drawing process and will pull apart, particularly if more than 10 wt.% of CA staple fiber is used in the blend of staple fibers. If the sliver has a F/F CODF of greater than 0.20, the drawing process will tend to exceed the tenacity of the sliver especially as the CA staple fiber content increases. Desirably, the F/F CODF is from 0.11 to 0.20, or from 0.11 to less than 0.20, or from 0.11 to 0.19, or from 0.11 to 0.18, or from 0.11 to 0.17, or from 0.11 to 0.16, or from 0.11 to 0.15, or from 0.12 to 0.20, or from 0.12 to less than 0.20, or from 0.12 to 0.19, or from 0.12 to 0.18, or from 0.12 to 0.17, or from 0.12 to 0.16, or from 0.12 to 0.15.

[0058] In addition to having the desirably F/F CODF, the CA staple fibers contained in the carded sliver, spun yarn, and textile fabric also desirably have a fiber to metal coefficient of dynamic friction (F/M CODF), as measured

on filament yarn, of less than 0.80. To determine the F/M CODF of the fibers of a sliver, the continuous filaments used to make the CA staple fiber are formed into a filament yarn, conditioned at 70°F and 65% relative humidity for 24 hours, and measured according to ASTM D3108/D3108M – 13 at 100 m/min, with an input tension of 10 grams, and on a CTT-E instrument set up according Fig. 2 in the ASTM D3412/3412M – 13 procedure.

[0059] Frictional forces are exerted through the fiber to metal contact at many stages of the sliver to spun yarn stages, including as the carding machine, drawing, roving, and spinning. These frictional forces can result in fiber fibrillation and weakening of the fiber to the point of breakage, resulting in the development of short fiber content and in some cases sliver breakage, especially at higher CA staple fiber content. Desirably, the F/M CODF not more than 0.70, or not more than 0.65, or not more than 0.60, or not more than 0.59, or not more than 55, or not more than 0.52, or nor more than 0.50, or not more than 0.48, or not more than 0.47. Desirable ranges include 0.30 to 0.80, or 0.30 to 0.70, or 0.30 to 0.65, or 0.30 to 0.60, or 0.40 to 0.80, or 0.40 to 0.70, or 0.40 to 0.65, or 0.40 to 0.60, or 0.45 to 0.80, or 0.45 to 0.70, or 0.45 to 0.65, or 0.45 to 0.60, or 0.48 to 0.80, or 0.48 to 0.70, or 0.48 to 0.65, or 0.48 to 0.60, or 0.50 to 0.80, or 0.50 to 0.70, or 0.50 to 0.65, or 0.50 to 0.60.

[0060] Static electricity can be a nuisance to the user of the textile fabric and can cause processing problems in the production of spun yarns and textile fabrics. Since moisture is an excellent anti-static agent, the problem of static build up is particularly evident if the fibers are hydrophobic. In most dry textile fabric processes, fibers and fabrics move at high speeds over various surfaces and against each other, which can generate triboelectric static charges resulting from frictional forces. Static electricity build up on the fibers tends to make the fibers repel each other, leading to a reduction in sliver cohesion and other downstream processing problems for yarn spinning. Additionally, static charges will affect fabric materials handling and is a nuisance to consumers dealing with clinging garments and the small electrical

shocks caused by walking on carpets in even moderate to high humidity conditions.

[0061] Accordingly, in one embodiment, which can include the above stated F/F CODF and/or the F/M CODF, the CA staple fibers used to make the sliver from carded staple fibers have a static electricity charge of less than 1.0 at 65 % relative humidity. The static electricity charge on the CA staple fibers will influence the cohesiveness of the sliver by reducing the fiber to fiber repulsion, and thereby retain the cohesiveness of the sliver. The sliver and carded staple fibers are deemed to have been made with CA staple fibers having a static electricity charge of no more than 1.0 when filaments used to make the staple fibers used in the sliver have a static electricity charge of less than 1.0. The test method for determining the static electricity charge of the CA staple fibers used to make the sliver is as follows. The sample is a filament yarn used to make the staple fibers in the sliver. The filament yarn is exposed to a controlled environment at 65% relative humidity at 70 °F for 24 hours to condition the filament yarn. A two (2) foot section of the filament yarn is secured at one end, the other end is held by hand while rubbing the secured section of the filament yarn back and forth along the whole 2 foot section for 3 cycles using the side of a wooden #2 pencil. The static electricity charge imparted to the filaments are measured using a Simco Electrostatic Fieldmeter Model FMX-003 or equivalent device.

[0062] The static electricity charge is desirably no more than 1.0, or no more than 0.98, or no more than 0.96, or no more than 0.90, or no more than 0.85, or no more than 0.80, or no more than 0.78, or no more than 0.75, or no more than 0.70, or no more than 0.68, or no more than 0.58, or no more than 0.60, or no more than 0.58, or no more than 0.55, or no more than 0.50.

[0063] In addition to the cut length, filament shape, and denier, the F/F CODF, F/M CODF, and static charge on the CA staple fibers can be influenced by the application of a finish on the filaments used to make the CA staple fibers. A finish applied to the CA filaments, also called “fiber finish” or

"spin finish," refers to any suitable type of coating that, when applied to a fiber filament:

1. modifies friction exerted by and on the fiber, and alters the ability of the fibers to move relative to one another and/or relative to a metal surface, or
2. reduces static electricity build up on a fiber, or
3. both.

[0064] Desirably, at least one finish should be applied to the fibers that modifies the fiber to fiber coefficient of friction and optionally the fiber to metal coefficient of friction. The same finish may also have anti-static properties, or a second anti-static finish can be applied.

[0065] Finishes are not the same as adhesives, bonding agents, or other similar chemical additives which, when added to fibers, prevent movement between the fibers by adhering them to one another. Finishes, when applied, continue to permit the movement of the fibers relative to one another and/or relative to other surfaces, but may modify the ease of this movement by increasing or decreasing the frictional forces.

[0066] Accordingly, it is desirable that the CA staple fibers have a coating that modifies the F/F CODF within the stated limits as compared to an identical but uncoated fiber. Although the relatively higher CPI does impart a measure of fiber to fiber dynamic friction, more friction is required when the staple fibers are formed into slivers and spun yarn because a higher cohesive energy is required to impart the necessary integrity to the slivers and the elongation and tenacity strength to the spun yarn. Further, as noted above, fibers made for use in and formed into sliver require a greater F/F CODF relative to fibers for use in or made into many non-woven applications.

[0067] A finish that imparts both an enhanced fiber to fiber coefficient of static and dynamic friction, and an enhanced anti-static electricity build up, applied in one step is desirable so that only one application of finish to the fiber is required. However, the staple fibers may include at least two finishes applied to all or a portion of the staple fiber surface in one step or in multiple

steps at one or more points during the fiber production process. When two or more finishes are applied to the fibers, the finishes may be applied in one step as a blend of two or more different finishes, or the finishes may be applied separately at different steps/locations during the process. For example, in some cases, the staple fibers may be at least partially coated with a spinning or spin finish applied to the filaments at or between filament spinning and before crimping to facilitate the filament spinning and/or crimping steps described previously. The finish, including an anti-static finish, may be added to the fiber at the filament spinning step or between fiber spinning and gathering the filaments into a bundle. Alternatively, or in addition, the finish (which can include an anti-static finish) may be applied at any point at or after filament spinning and before the cutting step, and can be applied to individual filaments, bundles, or the tow band.

[0068] Any suitable method of applying the finish may be used and can include, for example, spraying, wick application, dipping, or use of squeeze, lick, or kiss rollers.

[0069] The cumulative amount of all finish applied will depend on the type of finishes, the fiber denier, cut length, and type of CA used that would impart to the CA staple fibers a F/F CODF and a static electricity charge within the limits described above. When used, the finishes may be of any suitable type and can be present on the filaments, tow band, CA staple fibers, and CA staple fibers present in the sliver and spun yarn in an amount of at least about 0.05, or at least 0.10, or at least 0.15, or at least 0.20, or at least 0.25, or at least 0.30, or at least 0.35, or at least 0.40, or at least 0.45, or at least 0.50, or at least 0.55, or at least 0.60 percent finish-on-yarn (FOY) relative to the weight of the dried CA fiber. Alternatively, or in addition, the cumulative amount of finish may be present in an amount of less than 2.0, or not more than 1.8, or not more than 1.5, or not more than 1.2, or not more than 1.0, or not more than 0.9, or not more than 0.8, or not more than 0.7 percent finish-on-yarn (FOY) based on the total weight of the dried fiber. The amount of finish on the fibers as expressed by weight percent may be determined by

solvent extraction. As used herein "FOY" or "finish on yarn" refers to the amount of finish on the yarn less any added water, and in this context, yarn does not refer to spun yarn, but rather the CA tow band which would be representative of and be the same amount on CA staple fibers, and in the context of a sliver, the percentage would be based on the CA staple fibers in the sliver. One or two or more types of finishes may be used. Desirably, the cumulative amount of finish on the fibers is from 0.10 to 1.0, or 0.10 to 0.90, or 0.10 to 0.80, or 0.10 to 0.70, or 0.15 to 1.0, or 0.15 to 0.90, or 0.15 to 0.80, or 0.15 to 0.70, or 0.20 to 1.0, or 0.20 to 0.90, or 0.20 to 0.80, or 0.20 to 0.70, or 0.25 to 1.0, or 0.25 to 0.90, or 0.25 to 0.80, or 0.25 to 0.70, or 0.30 to 1.0, or 0.30 to 0.90, or 0.30 to 0.80, or 0.30 to 0.70, each as %FOY.

[0070] The anti-static finish may be a cationic, a non-ionic, or an anionic finish and may be in the form of a solution, an emulsion, or a dispersion. The anti-static finish may be an aqueous emulsion and it may or may not include any type of hydrocarbon, oil including silicone oil, waxes, alcohol, glycol, or siloxanes. The specific type of anti-static finish applied to the filaments or fibers may depend, at least in part, on the final application for which the staple fibers will be used. Examples of suitable anti-static finishes can include, but are not limited to, phosphate salts, sulfate salts, ammonium salts, and combinations thereof. Minor amounts of other components, such as surfactants, may also be present in order to enhance the stability and/or processability of the finish, and/or to make it more desirable for the intended end use of the fiber (e.g., non-irritating when the fiber will be contacted with a user's skin). Further, depending on the end use of the CA staple fibers, the finish may be compliant with various Federal and state regulations and can be, for example, non-animal, Proposition 65 compliant, and/or FDA food contact approved.

[0071] The anti-static finish will impact the interaction of the coated fiber with water by modifying the hydrophilicity of the uncoated fiber to make it more hydrophilic. Use of an anti-static finish may impart additional moisture to the fiber itself. In some embodiments, addition of the anti-static finish

results in at least 0.05%, or at least 0.1%, or at least 0.15%, or at least 0.20%, or at least 0.30%, or at least 0.50%, or at least 0.80%, and up to 1.5%, or up to 1.0% moisture added to the fiber.

[0072] The carded slivers made with the CA staple fibers of the invention desirably have a low coefficient of variation. Carded slivers made with other synthetic fibers often have thick and thin spots along the length of the sliver which manifests itself as having weight variations along a unit length of the resultant spun yarn. A carded sliver having a low coefficient of variation will be uniform, made with fibers having a fairly uniform crimp frequency and finish, and have a good coefficient of friction. The slivers containing the CA staple fibers described herein can have a coefficient of variation (CVm) of no more than 4.5%, or not more than 4.2%, or not more than 4.1%, or not more than 4.0%, or not more than 3.8%, or not more than 3.7%, or not more than 3.6%, as measured on 12 mm sections of sliver over 250 liner yards by the ASTM D1425 “Unevenness of Textile Strands Using Capacitance Testing Equipment.” test method.

[0073] Examples of typical ranges of CVm values are from 1 to 4.5, or from 1.5 to 4.5, or from 2 to 4.5, or from 2.5 to 4.5, or from 2.8 to 4.5, or from 2.9 to 4.5, or from 3.0 to 4.5, or from 3.1 to 4.5, or from 3.2 to 4.5, or from 3.3 to 4.5, or from 3.4 to 4.5, or from 3.5 to 4.5, or from 3.6 to 4.5, or from 3.7 to 4.5, or from 3.8 to 4.5, or from 3.9 to 4.5, or from 1 to 4.2, or from 1.5 to 4.2, or from 2 to 4.2, or from 2.5 to 4.2, or from 2.8 to 4.2, or from 2.9 to 4.2, or from 3.0 to 4.2, or from 3.1 to 4.2, or from 3.2 to 4.2, or from 3.3 to 4.2, or from 3.4 to 4.2, or from 3.5 to 4.2, or from 3.6 to 4.2, or from 3.7 to 4.2, or from 3.8 to 4.2, or from 3.9 to 4.2, or from 1 to 4.1, or from 1.5 to 4.1, or from 2 to 4.1, or from 2.5 to 4.1, or from 2.8 to 4.1, or from 2.9 to 4.1, or from 3.0 to 4.1, or from 3.1 to 4.1, or from 3.2 to 4.1, or from 3.3 to 4.1, or from 3.4 to 4.1, or from 3.5 to 4.1, or from 3.6 to 4.1, or from 3.7 to 4.1, or from 3.8 to 4.1, or from 3.9 to 4.1, or from 1 to 4.0, or from 1.5 to 4.0, or from 2 to 4.0, or from 2.5 to 4.0, or from 2.8 to 4.0, or from 2.9 to 4.0, or from 3.0 to 4.0, or from 3.1 to 4.0, or from 3.2 to 4.0, or from 3.3 to 4.0, or from 3.4 to 4.0, or from 3.5 to 4.0, or from 3.6 to

4.0, or from 3.7 to 4.0, or from 3.8 to 4.0, or from 3.9 to 4.0, or from 1 to 3.8, or from 1.5 to 3.8, or from 2 to 3.8, or from 2.5 to 3.8, or from 2.8 to 3.8, or from 2.9 to 3.8, or from 3.0 to 3.8, or from 3.1 to 3.8, or from 3.2 to 3.8, or from 3.3 to 3.8, or from 3.4 to 3.8, or from 3.5 to 3.8, or from 3.6 to 3.8, or from 3.7 to 3.8, or from 1 to 3.7, or from 1.5 to 3.7, or from 2 to 3.7, or from 2.5 to 3.7, or from 2.8 to 3.7, or from 2.9 to 3.7, or from 3.0 to 3.7, or from 3.1 to 3.7, or from 3.2 to 3.7, or from 3.3 to 3.7, or from 3.4 to 3.7, or from 3.5 to 3.7, or from 3.6 to 3.7, or from 1 to 3.6, or from 1.5 to 3.6, or from 2 to 3.6, or from 2.5 to 3.6, or from 2.8 to 3.6, or from 2.9 to 3.6, or from 3.0 to 3.6, or from 3.1 to 3.6, or from 3.2 to 3.6, or from 3.3 to 3.6, or from 3.4 to 3.6, or from 3.5 to 3.6 in each case as a percent.

[0074] Due to the good fiber-to-fiber cohesion energy of the sliver, the short fiber content of the sliver can be minimized. Short fibers are fibers less than ½" long. Carded slivers can be made with a short fiber content of not more than 30%, or not more than 28%, or not more than 26%, or not more than 25%, or not more than 23%, or not more than 20%, or not more than 18%, or not more than 15%, or not more than 13%, or not more than 10%, or not more than 8%, or not more than 6%, or not more than 5%, or not more than 4%, in each case as weight percent, as determined by using the Keisokki Fiber Length Distribution Tester. The tester measures a fiber tuft or beard nipped on a sample comb by an optical method and automatically plots the Fibrogram from which the fiber length distribution of the sample can be derived.

[0075] Alternatively, the carded slivers can be made with a short fiber content of not more than 30%, or not more than 28%, or not more than 26%, or not more than 25%, or not more than 23%, or not more than 20%, or not more than 18%, or not more than 15%, or not more than 13%, or not more than 10%, in each case as weight percent as determined by using the Uster AFIS test method. This test method is more destructive to the fibers than the Keisokki Fiber Length Distribution Tester and will artificially generate

additional short fibers, but even under this test method, the short fiber content can be under 30 wt.%, or under 25 wt.%, or under 20 wt%, or under 15 wt.%.

[0076] The CA staple fibers used in the slivers desirably exhibit high tenacity to avoid breakage and short fiber formation during carding and drawing. For example, in some embodiments, the CA staple fibers used to make the slivers, spun yarn, and textile fabrics may exhibit a tenacity of at least about 0.80, or at least about 0.85, or at least about 0.90, or at least about 0.95, or at least about 1.0, or at least about 1.05, or at least about 1.1, or at least about 1.15, or at least about 1.20, or at least about 1.25, or at least about 1.30 grams-force/denier (g/denier) and/or not more than 2.50, or not more than 2.45, or not more than 2.40, or not more than 2.35, or not more than 2.30, or not more than 2.25, or not more than 2.20, or not more than 2.15, or not more than 2.10, or not more than 2.05, or not more than 2.00, or not more than 1.95, or not more than 1.90, or not more than 1.85, or not more than 1.80, or not more than 1.75, or not more than 1.70, or not more than 1.65, or not more than 1.60, or not more than 1.55, or not more than 1.50, or not more than 1.45, or not more than 1.40 g/denier, measured according to ASTM D3822 on a filament yarn used to make the CA staple fibers having the same composition as the staple fibers, without mixing with other fibers. Examples of suitable ranges of CA staple fiber tenacity include 0.8 to 2.5, or 0.8 to 2.45, or 0.8 to 2.40, or 0.8 to 2.35, or 0.8 to 2.30, or 0.8 to 2.25, or 0.8 to 2.20, or 0.8 to 2.15, or 0.8 to 2.10, or 0.8 to 2.05, or 0.8 to 2.00, or 0.8 to 1.95, or 0.8 to 1.90, or 0.8 to 1.85, or 0.8 to 1.80, or 0.8 to 1.75, or 0.8 to 1.70, or 0.8 to 1.65, or 0.8 to 1.60, or 0.8 to 1.55, or 0.8 to 1.50, or 0.8 to 1.45, or 0.8 to 1.40, 0.9 to 2.5, or 0.9 to 2.45, or 0.9 to 2.40, or 0.9 to 2.35, or 0.9 to 2.30, or 0.9 to 2.25, or 0.9 to 2.20, or 0.9 to 2.15, or 0.9 to 2.10, or 0.9 to 2.05, or 0.9 to 2.00, or 0.9 to 1.95, or 0.9 to 1.90, or 0.9 to 1.85, or 0.9 to 1.80, or 0.9 to 1.75, or 0.9 to 1.70, or 0.9 to 1.65, or 0.9 to 1.60, or 0.9 to 1.55, or 0.9 to 1.50, or 0.9 to 1.45, or 0.9 to 1.40, or 1 to 2.5, or 1 to 2.30, or 1 to 2.00, or 1 to 1.80, or 1 to 1.65, or 1.2 to 2.5, or 1.2 to 2.30, or 1.2 to 2.05, or 1.2 to 1.90,

or 1.2 o 1.70, or 1.3 to 2.5, or 1.3 to 2.30, or 1.3 to 2.15, or 1.3 to 2.00, or 1.3 to 1.85, or 1.3 to 1.70 g/denier.

[0077] The elongation at break of the CA staple fibers used to make the sliver, spun yarn, or textile fabric can be at least 10%, or at least 13, or at least 15, or at least 20, or at least 25 percent and/or not more than about 50, or not more than 45, or not more than 40, or not more than 35, or not more than 30 percent, measured according to ASTM D3822. If the elongation at break is less than 10%, the slivers containing the CA staple fibers are more susceptible to breakage at normal drawing ratios. CA staple fibers having an elongation at break from 10 to 13% can be useful if they also have good tenacity. Examples of more desirable ranges include 13 to 50, or 13 to 45, or 13 to 40, or 13 to 35, or 13 to 30, or 15 to 50, or 15 to 45, or 15 to 40, or 15 to 35, or 15 to 30, or 20 to 50, or 20 to 45, or 20 to 40, or 20 to 35, or 20 to 30, or 25 to 50, or 25 to 45, or 25 to 40, or 25 to 35, or 25 to 30.

[0078] The CA staple fibers having high tenacity and elongation allow sufficient retention of sliver tenacity and elongation to allow them to be formed into slivers and drawn across drawing frames without breakage. The CA staple fiber has a higher or lower tenacity and elongation at break than the fiber with which it is blended. Therefore, the sliver and spun yarn tenacity and elongation at break will be influenced by blend ratio of staple fibers. Slivers and spun yarns made with the CA staple fibers described herein have tenacity retention of at least 50%, or at least 55%, or at least 60%, or at least 65% or at least 70%, or at least 75%, as calculated by the tenacity of the blended sliver or yarn/tenacity of a sliver or yarn made with the 100% of the non-CA fiber used in the blend x 100.

[0079] The CA staple fibers can include little or no plasticizer and will exhibit enhanced biodegradability under industrial, home, and soil conditions, even as compared to CA staple fibers with higher levels of plasticizer.

[0080] In some embodiments, the fibers of the present invention can include not more than 5, or not more than 4.5, or not more than 4, or not more than 3.5, or not more than 3, or not more than 2.5, or not more than 2, or not

more than 1.5, or not more than 1, or not more than 0.5, or not more than 0.25, or not more than 0.10, or nor more than 0.05,or not more than 0.01 wt.% plasticizers, based on the total weight of the fiber, or the fibers may include no added plasticizer. When present, the plasticizer may be incorporated into the fiber itself by being blended with the solvent dope or cellulose acetate flake, or the plasticizer may be applied to the surface of the fiber or filament by spraying, by centrifugal force from a rotating drum apparatus, or by an immersion bath.

[0081] Examples of plasticizers that may be present, and desirably are not present, in or on the fibers can include, but are not limited to, aromatic polycarboxylic acid esters, aliphatic polycarboxylic acid esters, lower fatty acid esters of polyhydric alcohols, and phosphoric acid esters. Further examples can include, but are not limited to, dimethyl phthalate, diethyl phthalate, dibutyl phthalate, dihexyl phthalate, dioctyl phthalate, dimethoxyethyl phthalate, ethyl phthalylethyl glycolate, butyl phthalylbutyl glycolate, levulinic acid esters, dibutyrates of triethylene glycol, tetraethylene glycol, pentaethylene glycol, tetraoctyl pyromellitate, trioctyl trimellitate, dibutyl adipate, dioctyl adipate, dibutyl sebacate, dioctyl sebacate, diethyl azelate, dibutyl azelate, dioctyl azelate, glycerol, trimethylolpropane, pentaerythritol, sorbitol, glycerin triacetate (triacetin), diglycerin tetracetate, triethyl phosphate, tributyl phosphate, tributoxyethyl phosphate, triphenyl phosphate, and tricresyl phosphate, and combinations thereof.

[0082] Additionally, the CA staple fibers of the present invention may not have undergone additional treatment steps designed to enhance the biodegradability of the fibers. For example, the fibers as described herein are desirably not hydroylzed or treated with enyzmes or microorganisms. The fibers may include not more than 1, or nor more than 0.75, or nor more than 0.5, or nor more than 0.25, or nor more than 0.1, or nor more than 0.05, or or nor more than 0.01 weight percent of an adhesive, bonding agent or other modifying agent. In some embodiments, the fibers may not include any adhesive, bonding, or modifying agent and may not be formed from any

substituted or modified cellulose acetate. Modified cellulose acetate may include cellulose acetate that has been modified with a polar substituent, such as a substituent selected from the group consisting of sulfates, phosphates, borates, carbonates, and combinations thereof.

[0083] There is also provided a sliver or spun yarn retaining a substantial portion of its elongation at break by using the CA staple fibers described herein. The elongation at break retention can be at least 60%, or at least 65%, or at least 70%, or at least 75%, or at least 80%, or at least 90%, or at least 95%, and can even exceed the elongation at break of the other blended fiber material. The method for calculating the elongation at break retention is the elongation at break of blended sliver or yarn/elongation at break of sliver or yarn made with 100% of the non-CA fiber used in the blend x 100.

[0084] Spun yarns made with the CA staple fibers can also have a time to break of at least 0.5 seconds, or at least 0.6, or at least 0.65, or at least 0.70, or at least 0.75 seconds, as measured according to ASTM 2256 using for testing purposes a spun yarn made of 100% of the CA staple fibers.

[0085] The spun yarns made with the staple fibers can also have a breaking force of at least 130, or at least 140 or at least 150, and optionally up to 200, or up to 190 g-N, as measured according to ASTM 2256, using for testing purposes a spun yarn made of 100% of the CA staple fibers. Examples of suitable ranges of breaking force include from 130 to 200, or 140 to 200, or 150 to 200, or 130 to 190, or 140 to 190, or 150 to 190 g-N.

[0086] The spun yarns made with the CA staple fibers can also have a breaking work force of at least 600, or at least 650, or at least 700. In addition, or in the alternative, the yarns can have a breaking work force up to 1200, or up to 1100, or up to 1000, or up to 900 gFcm. The breaking work force is measured according to ASTM 2256, using, for testing purposes, a spun yarn made of 100% of the CA staple fibers. Examples of suitable ranges include 600 to 1200, or 650 to 1200, or 700 to 1200, or 600 to 1100, or 650 to 1100, or 700 to 1100, or 600 to 1000, or 650 to 1000, or 700 to 1000 gFcm.

[0087] The spun yarns also exhibit high tenacity. For example, in some embodiments, the spun yarns made with CA staple fibers may exhibit a tenacity of at least about 0.80, or at least about 0.85, or at least about 0.90 gF/denier. In addition, or in the alternative, the spun yarns may have a tenacity of up to 1.1, or 1.0 gF/denier. The tenacity of the spun yarns is measured according to ASTM 2256, using, for testing purposes, a spun yarn made of 100% of the CA staple fibers.

[0088] The elongation at break of the spun yarns containing the CA staple fibers can be at least 10%, or at least 11, or at least 12, or at least 13 percent, or at least 15 percent. In addition, or in the alternative, the elongation at break of the spun yarns can be up to 20%, or up to 15%, or up to 14%. The elongation at break of the spun yarns is measured according to ASTM 2256, using, for testing purposes, a spun yarn made of 100% of the CA staple fibers.

[0089] The tenacity and elongation at break values described above can also be achieved on a spun yarn having a twist multiplier (meaning twists per inch divided by the square root of yarn count English) of less than 4.0 and a total denier of less than 400, or even not more than 300. These tenacity and elongation at break values described above are achievable on a spun yarn having a twist multiplier of less than 4.0 or 3.6 or less and a total denier of not more than 300 or not more than 250.

[0090] The spun yarns can have a total denier of at least 100, or at least 125, or at least 150, and up to 1000, or up to 500, or up to 400, or up to 300 or up to 250. Suitable ranges include 100 to 1000, or 125 to 500, or 125 to 400, or 125 to 300, or 100 to 300, or 100 to 250.

[0091] The carded slivers, spun yarn, and textile fabrics can be made with 100% CA staple fibers or be are blends of CA staple fibers with other fibers that are not CA staple fibers. The CA staple fibers may be present in a sliver or spun yarn or in an amount of at least 5, or at least 10, or at least 15, or at least 20, or at least 25, or at least 30, or at least 35, or at least 40, or at least 45 wt.% and up to 100, or up to 90, or up to 80, or up to 70 or up to 60, or up

to 55, or up to 52, or up to 50, or up to 45, or up to 40, or up to 35, or up to 30, or up to 25, or up to 22, or up to 20 wt.%, based on the total weight of the blend. One or more of the other fibers may be present in an amount of at least about 5, or at least 10, or at least 15, or at least 20, or at least 25, or at least 30, or at least 35, or at least 40, or at least 45, or at least 50, or at least 55, or at least 60, or at least 65, or at least 70, or at least 75, or at least 80 weight percent. Compositions of specific blends can be determined according to AATCC TM20A-2014, No. 1. Examples of suitable ranges of the CA staple fibers in the sliver, spun yarn, or textile fabric include from 5 to 70, or 5 to 65, or 5 to 60, or 5 to 55, or 5 to 50, or 5 to 45, or 5 to 40 or 5 to 35, or 5 to 30, or 5 to 25, or 5 to 25, or 5 to 20, or 10 to 70, or 10 to 65, or 10 to 60, or 10 to 55, or 10 to 50, or 10 to 45, or 10 to 40 or 10 to 35, or 10 to 30, or 10 to 25, or 10 to 25, or 10 to 20, or 15 to 70, or 15 to 65, or 15 to 60, or 15 to 55, or 15 to 50, or 15 to 45, or 15 to 40 or 15 to 35, or 15 to 30, or 15 to 25, or 15 to 25, or 15 to 20, or 20 to 70, or 20 to 65, or 20 to 60, or 20 to 55, or 20 to 50, or 20 to 45, or 20 to 40 or 20 to 35, or 20 to 30, or 20 to 25 wt% based on the weight of all fibers in the sliver, spun yarn, or textile fabric.

[0092] Other types of fibers suitable for use in a blend with CA staple fibers can include natural and/or synthetic fibers including, but not limited to, cotton, rayon, viscose) or other types of regenerated cellulose such as Cupro, Tencel, Modal, and Lyocell cellulose, acetates such as polyvinylacetate, wool, glass, polyamides including nylon, polyesters such as polyethylene terephthalate (PET), polycyclohexylenedimethylene terephthalate (PCT) and other copolymers, olefinic polymers such as polypropylene and polyethylene, polycarbonates, poly sulfates, poly sulfones, polyethers, acrylics, acrylonitrile copolymers, polyvinylchloride (PVC), poly lactic acid, poly glycolic acid and combinations thereof.

[0093] In some cases, the fibers may be single-component fibers, while, in other cases, the fibers could be multicomponent fibers including cellulose acetate with one or more other types of materials. Desirably, the fibers are single-component fibers.

[0094] The spun yarn formed from the staple fibers may also exhibit desirable wicking properties. For example, in some embodiments, spun yarn and textile fabrics formed from CA staple fiber may have a wicking height at 5 minutes of not more than 200 mm. In some case, the wicking height of a spun yarn as described herein can be not more than about 175, 150, 125, 100, 90, 80, 70, 60, 50, 40, or 30 mm, measured as described in NWSP 010.1-7.3.

[0095] The textile fabrics made from spun yarns containing the CA staple fibers of the invention also maintain good anti-piling properties in the textile fabric as determined by ASTM 4970 using the Martindale tester. The textile fabrics made with the CA staple fibers described herein can have a Grade 4 or 5.

[0096] The staple fibers and nonwovens formed therefrom can be biodegradable, meaning that such fibers are expected to decompose under certain environmental conditions. The degree of degradation can be characterized by the weight loss of a sample over a given period of exposure to certain environmental conditions. In some cases, the material used to form the staple fibers, the fibers, or the textile fabrics produced from the fibers can exhibit a weight loss of at least about 5, 10, 15, or 20 percent after burial in soil for 60 days and/or a weight loss of at least about 15, 20, 25, 30, or 35 percent after 15 days of exposure to a typical municipal composter. However, the rate of degradation may vary depending on the particular end use of the fibers, as well as the composition of the remaining article, and the specific test. Exemplary test conditions are provided in U.S. Patent No. 5,970,988 and U.S. Patent No. 6,571,802.

[0097] The CA staple fibers as described herein can exhibit enhanced levels of environmental non-persistence, characterized by better-than-expected degradation under various environmental conditions. Fibers and fibrous articles of the present invention meet or exceed passing standards set by international test methods and authorities for industrial compostability, home compostability, and/or soil biodegradability.

[0098] To be considered "compostable," a material must meet the following four criteria: (1) the material must be biodegradable; (2) the material must be disintegrable; (3) the material must not contain more than a maximum amount of heavy metals; and (4) the material must not be ecotoxic. As used herein, the term "biodegradable" generally refers to the tendency of a material to chemically decompose under certain environmental conditions. Biodegradability is an intrinsic property of the material itself, and the material can exhibit different degrees of biodegradability, depending on the specific conditions to which it is exposed. The term "disintegrable" refers to the tendency of a material to physically decompose into smaller fragments when exposed to certain conditions. Disintegration depends both on the material itself, as well as the physical size and configuration of the article being tested. Ecotoxicity measures the impact of the material on plant life, and the heavy metal content of the material is determined according to the procedures laid out in the standard test method.

[0099] The CA staple fibers can exhibit a biodegradation of at least 70 percent in a period of not more than 50 days, when tested under aerobic composting conditions at ambient temperature (28 °C ± 2 °C) according to ISO 14855-1 (2012). In some cases, the CA staple fibers can exhibit a biodegradation of at least 70 percent in a period of not more than 49, 48, 47, 46, 45, 44, 43, 42, 41, 40, 39, 38, or 37 days when tested under these conditions, also called "home composting conditions." These conditions may not be aqueous or anaerobic. In some cases, the CA staple fibers can exhibit a total biodegradation of at least about 71, or at least 72, or at least 73, or at least 74, or at least 75, or at least 76, or at least 77, or at least 78, or at least 79, or at least 80, or at least 81, or at least 82, or at least 83, or at least 84, or at least 85, or at least 86, or at least 87, or or at least 88 percent, when tested under according to ISO 14855-1 (2012) for a period of 50 days under home composting conditions. This may represent a relative biodegradation of at least about 95, or at least 97, or at least 99, or at least 100, or at least 101, or

at least 102, or or at least 103 percent, when compared to cellulose subjected to identical test conditions.

[0100] To be considered "biodegradable," under home composting conditions according to the French norm NF T 51-800 and the Australian standard AS 5810, a material must exhibit a biodegradation of at least 90 percent in total (*e.g.,* as compared to the initial sample), or a biodegradation of at least 90 percent of the maximum degradation of a suitable reference material after a plateau has been reached for both the reference and test item. The maximum test duration for biodegradation under home compositing conditions is 1 year. The CA staple fibers as described herein may exhibit a biodegradation of at least 90 percent within not more than 1 year, measured according 14855-1 (2012) under home composting conditions. In some cases, the CA staple fibers may exhibit a biodegradation of at least about 91, or at least 92, or at least 93, or at least 94, or at least 95, or at least 96, or at least 97, 9 or at least 8, or at least 99, or or at least 99.5 percent within not more than 1 year, or the fibers may exhibit 100 percent biodegradation within not more than 1 year, measured according 14855-1 (2012) under home composting conditions.

[0101] Additionally, or in the alternative, the fibers described herein may exhibit a biodegradation of at least 90 percent within not more than about 350, or not more than 325, or not more than 300, or not more than 275, or not more than 250, or not more than 225, or not more than 220, or not more than 210, or not more than 200, or not more than 190, or not more than 180, or not more than 170, or not more than 160, or not more than or not more than 150, or not more than 140, or not more than 130, or not more than 120, or not more than 110, or not more than 100, or not more than 90, or not more than 80, or not more than 70, or not more than 60, or not more than 50 days, measured according 14855-1 (2012) under home composting conditions. In some cases, the fibers can be at least about 97, or at least 98, or at least 99, or at least 99.5 percent biodegradable within not more than about 70, or not more than 65, or not more than 60, or not more than 50 days of testing

according to ISO 14855-1 (2012) under home composting conditions. As a result, the CA staple fibers may be considered biodegradable according to, for example, French Standard NF T 51-800 and Australian Standard AS 5810 when tested under home composting conditions.

[0102] The CA staple fibers can exhibit a biodegradation of at least 60 percent in a period of not more than 45 days, when tested under aerobic composting conditions at a temperature of 58°C (± 2°C) according to ISO 14855-1 (2012). In some cases, the fibers can exhibit a biodegradation of at least 60 percent in a period of not more than 44, or not more than 43, or not more than 42, or not more than 41, or not more than 40, or not more than 39, or not more than 38, or not more than 37, or not more than 36, or not more than 35, or not more than 34, or not more than 33, or not more than 32, or not more than 31, or not more than 30, or not more than 29, or not more than 28, or not more than 27 days when tested under these conditions, also called "industrial composting conditions." These may not be aqueous or anaerobic conditions. In some cases, the fibers can exhibit a total biodegradation of at least about 65, or at least 70, or at least 75, or at least 80, or at least 85, or at least 87, or at least 88, or at least 89, or at least 90, or at least 91, or at least 92, or at least 93, or at least 94, or at least 95 percent, when tested under according to ISO 14855-1 (2012) for a period of 45 days under industrial composting conditions. This may represent a relative biodegradation of at least about 95, or at least 97, or at least 99, or at least 100, or at least 102, or at least 105, or at least 107, or at least 110, or at least 112, or at least 115, or at least 117, or at least 119 percent, when compared to cellulose fibers subjected to identical test conditions.

[0103] To be considered "biodegradable," under industrial composting conditions according to ASTM D6400 and ISO 17088, at least 90 percent of the organic carbon in the whole item (or for each constituent present in an amount of more than 1% by dry mass) must be converted to carbon dioxide by the end of the test period when compared to the control or in absolute. According to European standard ED 13432 (2000), a material must exhibit a

biodegradation of at least 90 percent in total, or a biodegradation of at least 90 percent of the maximum degradation of a suitable reference material after a plateau has been reached for both the reference and test item. The maximum test duration for biodegradability under industrial compositing conditions is 180 days. The CA staple fibers described herein may exhibit a biodegradation of at least 90 percent within not more than 180 days, measured according 14855-1 (2012) under industrial composting conditions. In some cases, the CA staple fibers may exhibit a biodegradation of at least about 91, or at least 92, or at least 93, or at least 94, or at least 95, or at least 96, or at least 97, or at least 98, or at least 99, or at least 99.5 percent within not more than 180 days, or the fibers may exhibit 100 percent biodegradation within not more than 180 days, measured according 14855-1 (2012) under industrial composting conditions.

[0104] Additionally, or in the alternative, CA staple fibers described herein may exhibit a biodegradation of least 90 percent within not more than about 175, or not more than 170, or not more than 165, or not more than 160, or not more than 155, or not more than 150, or not more than 145, or not more than 140, or not more than 135, or not more than 130, or not more than 125, or not more than 120, or not more than 115, or not more than 110, or not more than 105, or not more than 100, or not more than 95, or not more than 90, or not more than 85, or not more than 80, or not more than 75, or not more than 70, or not more than 65, or not more than 60, or not more than 55, or not more than 50, or not more than 45 days, measured according 14855-1 (2012) under industrial composting conditions. In some cases, the CA staple fibers can be at least about 97, 98, 99, or 99.5 percent biodegradable within not more than about 65, or not more than 60, or not more than 55, or not more than 50, or not more than 45 days of testing according to ISO 14855-1 (2012) under industrial composting conditions. As a result, the CA staple fibers described herein may be considered biodegradable according ASTM D6400 and ISO 17088 when tested under industrial composting conditions.

[0105] The fibers or fibrous articles of the present invention may exhibit a biodegradation in soil of at least 60 percent within not more than 130 days, measured according to ISO 17556 (2012) under aerobic conditions at ambient temperature. In some cases, the fibers can exhibit a biodegradation of at least 60 percent in a period of not more than 130, or not more than 120, or not more than 110, or not more than 100, or not more than 90, or not more than 80, or not more than 75 days when tested under these conditions, also called "soil composting conditions." These may not be aqueous or anaerobic conditions. In some cases, the fibers can exhibit a total biodegradation of at least about 65, or at least 70, or at least 72, or at least 75, or at least 77, or at least 80, or at least 82, or at least 85 percent, when tested under according to ISO 17556 (2012) for a period of 195 days under soil composting conditions. This may represent a relative biodegradation of at least about 70, or at least 75, or at least 80, or at least 85, or at least 90, or at least 95 percent, when compared to cellulose fibers subjected to identical test conditions.

[0106] In order to be considered "biodegradable," under soil composting conditions according the OK biodegradable SOIL conformity mark of Vinçotte and the DIN Geprüft Biodegradable in soil certification scheme of DIN CERTCO, a material must exhibit a biodegradation of at least 90 percent in total (*e.g.,* as compared to the initial sample), or a biodegradation of at least 90 percent of the maximum degradation of a suitable reference material after a plateau has been reached for both the reference and test item. The maximum test duration for biodegradability under soil compositing conditions is 2 years. The CA staple fibers as described herein may exhibit a biodegradation of at least 90 percent within not more than 2 years, 1.75 years, 1 year, 9 months, or 6 months measured according ISO 17556 (2012) under soil composting conditions. In some cases, the CA staple fibers may exhibit a biodegradation of at least about 91, or at least 92, or at least 93, or at least 94, or at least 95, or at least 96, or at least 97, or at least 98, or at least 99, or at least 99.5 percent within not more than 2 years, or the fibers may exhibit

100 percent biodegradation within not more than 2 years, measured according ISO 17556 (2012) under soil composting conditions.

[0107] Additionally, or in the alternative, CA staple fibers described herein may exhibit a biodegradation of at least 90 percent within not more than about 700, 650, 600, 550, 500, 450, 400, 350, 300, 275, 250, 240, 230, 220, 210, 200, or 195 days, measured according 17556 (2012) under soil composting conditions. In some cases, the CA staple fibers can be at least about 97, or at least 98, or at least 99, or at least 99.5 percent biodegradable within not more than about 225, or not more than 220, or not more than 215, or not more than 210, or not more than 205, or not more than 200, or not more than 195 days of testing according to ISO 17556 (2012) under soil composting conditions. As a result, the CA staple fibers described herein may meet the requirements to receive The OK biodegradable SOIL conformity mark of Vinçotte and to meet the standards of the DIN Geprüft Biodegradable in soil certification scheme of DIN CERTCO.

[0108] In some cases, CA staple fibers (or fibrous articles) of the present invention may include less than 1, or not more than 0.75, or not more than 0.50, or not more than 0.25 weight percent of components of unknown biodegradability, based on the weight of the CA staple fiber. In some cases, the fibers or fibrous articles described herein may include no components of unknown biodegradability.

[0109] In addition to being biodegradable under industrial and/or home composting conditions, CA staple fibers or fibrous articles as described herein may also be compostable under home and/or industrial conditions. As described previously, a material is considered compostable if it meets or exceeds the requirements set forth in EN 13432 for biodegradability, ability to disintegrate, heavy metal content, and ecotoxicity. The CA staple fibers or fibrous articles described herein may exhibit sufficient compostability under home and/or industrial composting conditions to meet the requirements to receive the OK compost and OK compost HOME conformity marks from Vinçotte.

[0110] In some cases, the CA staple and fibers and fibrous articles described herein may have a volatile solids concentration, heavy metals and fluorine content that fulfill all of the requirements laid out by EN 13432 (2000). Additionally, the CA staple fibers may not cause a negative effect on compost quality (including chemical parameters and ecotoxicity tests).

[0111] In some cases, the CA staple fibers or fibrous articles can exhibit a disintegration of at least 90 percent within not more than 26 weeks, measured according to ISO 16929 (2013) under industrial composting conditions. In some cases, the fibers or fibrous articles may exhibit a disintegration of at least about 91, or at least 92, or at least 93, or at least 94, or at least 95, or at least 96, or at least 97, or at least 98, or at least 99, or at least 99.5 percent under industrial composting conditions within not more than 26 weeks, or the fibers or articles may be 100 percent disintegrated under industrial composting conditions within not more than 26 weeks. Alternatively, or in addition, the fibers or articles may exhibit a disintegration of at least 90 percent under industrial compositing conditions within not more than about 26, or not more than 25, or not more than 24, or not more than 23, or not more than 22, or not more than 21, or not more than 20, or not more than 19, or not more than 18, or not more than 17, or not more than 16, or not more than 15, or not more than 14, or not more than 13, or not more than 12, or not more than 11, or not more than 10 weeks, measured according to ISO 16929 (2013). In some cases, the CA staple fibers or fibrous articles described herein may be at least 97, or at least 98, or at least 99, or at least 99.5 percent disintegrated within not more than 12, or not more than 11, or not more than 10, or not more than 9, or not more than 8 weeks under industrial composting conditions, measured according to ISO 16929 (2013).

[0112] In some cases, the CA staple fibers or fibrous articles can exhibit a disintegration of at least 90 percent within not more than 26 weeks, measured according to ISO 16929 (2013) under home composting conditions. In some cases, the fibers or fibrous articles may exhibit a disintegration of at least about 91, or at least 92, or at least 93, or at least 94, or at least 95, or at least

96, or at least 97, or at least 98, or at least 99, or at least 99.5 percent under home composting conditions within not more than 26 weeks, or the fibers or articles may be 100 percent disintegrated under home composting conditions within not more than 26 weeks. Alternatively, or in addition, the fibers or articles may exhibit a disintegration of at least 90 percent within not more than about 26, or not more than 25, or not more than 24, or not more than 23, or not more than 22, or not more than 21, or not more than 20, or not more than 19, or not more than 18, or not more than 17, or not more than 16, or not more than 15 weeks under home composting conditions, measured according to ISO 16929 (2013). In some cases, the CA staple fibers or fibrous articles described herein may be at least 97, or at least 98, or at least 99, or at least 99.5 percent disintegrated within not more than 20, or not more than 19, or not more than 18, or not more than 17, or not more than 16, or not more than 15, or not more than 14, or not more than 13, or not more than 12 weeks, measured under home composting conditions according to ISO 16929 (2013).

[0113] CA staple fibers of the present invention can achieve higher levels of biodegradability and/or compostability without use of additives that have traditionally been used to facilitate environmental non-persistence of similar fibers. Such additives can include, for example, photodegradation agents, biodegradation agents, decomposition accelerating agents, and various types of other additives. Despite being substantially free of these types of additives, the CA staple fibers and articles have unexpectedly been found to exhibit enhanced biodegradability and compostability when tested under industrial, home, and/or soil conditions, as discussed previously.

[0114] In some embodiments, the CA staple fibers described herein may be substantially free of photodegradation agents. For example, the fibers may include not more than about 1, or not more than 0.75, or not more than 0.50, or not more than 0.25, or not more than 0.10, or not more than 0.05, or not more than 0.025, or not more than 0.01, or not more than 0.005, or not more than 0.0025, or not more than 0.001 weight percent of photodegradation agent, based on the total weight of the fiber, or the fibers may include no

photodegradation agents. Examples of such photodegradation agents include, but are not limited to, pigments which act as photooxidation catalysts and are optionally augmented by the presence of one or more metal salts, oxidizable promoters, and combinations thereof. Pigments can include coated or uncoated anatase or rutile titanium dioxide, which may be present alone or in combination with one or more of the augmenting components such as, for example, various types of metals. Other examples of photodegradation agents include benzoins, benzoin alkyl ethers, benzophenone and its derivatives, acetophenone and its derivatives, quinones, thioxanthones, phthalocyanine and other photosensitizers, ethylene-carbon monoxide copolymer, aromatic ketone-metal salt sensitizers, and combinations thereof.

[0115] In some embodiments, the CA staple fibers described herein may be substantially free of biodegradation agents and/or decomposition agents. For example, the fibers may include not more than about 1, or not more than 0.75, or not more than 0.50, or not more than 0.25, or not more than 0.10, or not more than 0.05, or not more than 0.025, or not more than 0.01, or not more than 0.005, or not more than 0.0025, or not more than 0.0020, or not more than 0.0015, or not more than 0.001, or not more than 0.0005 weight percent of biodegradation agents and/or decomposition agents, based on the total weight of the fiber, or the fibers may include no biodegradation and/or decomposition agents. Examples of such biodegradation and decomposition agents include, but are not limited to, salts of oxygen acid of phosphorus, esters of oxygen acid of phosphorus or salts thereof, carbonic acids or salts thereof, oxygen acids of phosphorus, oxygen acids of sulfur, oxygen acids of nitrogen, partial esters or hydrogen salts of these oxygen acids, carbonic acid and its hydrogen salt, sulfonic acids, and carboxylic acids.

[0116] Other examples of such biodegradation and decomposition agents include an organic acid selected from the group consisting of oxo acids having 2 to 6 carbon atoms per molecule, saturated dicarboxylic acids having 2 to 6 carbon atoms per molecule, and lower alkyl esters of said oxo acids or said

saturated dicarboxylic acids with alcohols having from 1 to 4 carbon atoms. Biodegradation agents may also comprise enzymes such as, for example, a lipase, a cellulase, an esterase, and combinations thereof. Other types of biodegradation and decomposition agents can include cellulose phosphate, starch phosphate, calcium secondary phosphate, calcium tertiary phosphate, calcium phosphate hydroxide, glycolic acid, lactic acid, citric acid, tartaric acid, malic acid, oxalic acid, malonic acid, succinic acid, succinic anhydride, glutaric acid, acetic acid, and combinations thereof.

[0117] CA staple fibers of the present invention may also be substantially free of several other types of additives that have been added to other fibers to encourage environmental non-persistence. Examples of these additives can include, but are not limited to, polyesters, including aliphatic and low molecular weight (e.g., less than 5000) polyesters, enzymes, microorganisms, water soluble polymers, modified cellulose acetate, water-dispersible additives, nitrogen-containing compounds, hydroxy-functional compounds, oxygen-containing heterocyclic compounds, sulfur-containing heterocyclic compounds, anhydrides, monoepoxides, and combinations thereof. In some cases, the fibers described herein may include not more than about 0.5, or not more than 0.4, or not more than 0.3, or not more than 0.25, or not more than 0.1, or not more than 0.075, or not more than 0.05, or not more than 0.025, or not more than 0.01, or not more than 0.0075, or not more than 0.005, or not more than 0.0025, or not more than 0.001 weight percent of these types of additives, or the CA staple fibers may not include any of these types of additives.

[0118] The following examples are given to illustrate the invention and to enable any person skilled in the art to make and use the invention. It should be understood, however, that the invention is not to be limited to the specific conditions or details described in these examples. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art.

EXAMPLES

Example 1

[0119] The feasibility of successfully making a 100% cellulose acetate spun yarn from low denier, high CPI, round CA staple fibers was explored. A successful trial of making a sliver and spun yarn from 100% CA staple fiber is predictive of the influence such fibers would have in a blended sliver.

[0120] CA staple fiber tow bundles were produced having a round cross section of 1.8 denier fiber, 17CPI, and coated with Pulcra Stantex 2098 finish in an amount of 0.5% FOY. A 100 pound sample of the tow bundle was collected and cut to a 38 mm stretched staple length with 0.5% FOY PM lubricant commercialized by Eastman as PM 30419 added just prior to cutting. The yarn spinning conditions were maintained at ~55% humidity during the experiment. The staple fibers were subjected to carding, drawing, roving, and ring spinning.

[0121] For an initial proof of concept, the staple fibers successfully spun into six 2 pound packages of 20 singles (~250 denier) yarn at 4.2 twist multiple. However, this resulting yarn had a low tenacity of 0.7 g/den and low elongation of about 11% measured according to ASTM D-2256 method. The low tenacity and elongation numbers are a reflection of low cohesion between the staple fibers which causes them to easily slide past each other upon stretching the yarn. Additionally, the higher twist multiple of 4.2 (typical twist multiple for a knitting yarn is 3.5-3.9) had to be employed to overcome the low cohesion between the fibers since the initial target of a 30 singles (~150 denier) with a 3.5 twist multiplier was too weak to successfully spin into yarn.

Example 2

[0122] In this example, the effect of CPI, shape, and finishes on the staple fiber's carding and spinning performance were evaluated. The variables explored were 8, 12 and 18 CPI, while the fiber shapes explored were round and trilobal and the two secondary spin finishes compared were PM 30149 and Pulcra Tow (E8-0.5%), and Stantex H1385 available from Pulcra, as

summarized in Table 1. The primary spin finish was applied to the fibers after extrusion, prior to crimping, and the secondary spin finish was applied to the tow band prior to cutting. The amount of primary and secondary finishes is set forth in Table 1. The staple fibers had a cut length of 38 mm and a denier of 1.8.

Table 1

	Crimp Level (cpi)	Cross Section	Primary Spin Finish	Secondary Spin Finish
Sample 1	8	Trilobal	Tow (E8 – 0.5%)	AY23
Sample 2	12	Trilobal	Tow (E4.7 – 0.5%)	AY23
Sample 3	18	Round	Pulcra (Stantex 2098 0.65%)	AY23
Sample 4	18	Trilobal	Pulcra (Stantex 2098 0.65%))	AY23
Sample 5	18	Trilobal	Pulcra (Stantex 2098 0.65%))	Stantex H1385
Sample 6	18	Round	Pulcra (Stantex 2098 0.65%))	Stantex H1385
Sample 7	12	Trilobal	Tow (E4.7 – 0.5%)	Stantex H1385

[0123] The samples were all subjected to a carding operation, however, only samples 3 and 6 were successfully converted into a carded sliver, drawn and converted into roving and finally spun into a yarn.

[0124] Samples 3 and 4 had the same CPI and finish. Samples 5 and 6 also had the same CPI and finish. However, only the round samples 3 and 6 could be successfully spun into yarns. Surprisingly, none of the samples with a trilobal cross section could be successfully carded to a viable sliver as determined by failure to produce a card sliver with sufficient cohesion and static properties.

Example 3

[0125] This example demonstrates the successful spinning of a yarn using the CA staple fibers of the invention alone and blended with other fiber materials.

[0126] The CA staple fibers and all other synthetic staple fibers had a denier of about 1.5 and cut to a 38 mm staple length. For cotton, upland cotton was used. The synthetic fibers were blended intimately while the acetate/cotton blending was done on a draw frame.

[0127] For the 100% acetate spun yarns, a round 1.65 DPF bright tow (no TiO2), 16 CPI fiber tow band was made with a 0.7% AY23 as the primary spin finish. The fibers from this tow band were used to make the samples set forth in Table 2 to produce 29/1 spun yarns. The tow sample was cut using either AY23 or Lurol 7414K as the secondary spin finish targeting 1.5% each respectively. The cut length of the staple fibers were 38 mm. The break factor was determined by the count strength product as a function of skein strength and yarn count and according to ASTM D1576.

[0128] ASTM 1576 determines the breaking strength of yarn in skein form which is converted to a skein break factor (count strength product) dependent on yarn count, while ASTM 2256 provides the breaking strength and elongation using a single strand method. The skein method is useful for spun yarns because it provides an average across multiple strands in the skein thereby overcoming the inherent non-uniformity of spun yarns. ASTM 1576 is rarely, if ever, used for filament yarns because the uniformity of filament yarns makes it possible to obtain reliable results economically by the single-strand method (ASTM 2256).

[0129] For 100% cellulose acetate containing spun yarns, the skein break factor (count strength product) should be equal to or greater than 1100.

Table 2

Sample	Yarn Composition (%)	Yarn Size	Denier Equivalent	Break Factor[1]
Acetate Filament	100	*35/1*	150	1800
Acetate (AY23)	100	29/1	*183*	1137
Acetate (Lurol 74414K)	100	29/1	*183*	1181
Polyester	100	29/1	*183*	2825
Nylon	100	29/1	*183*	2795
Cotton	100	29/1	*183*	2368
Acetate/Polyester	50/50	29/1	*183*	1767
Acetate/Nylon	50/50	29/1	*183*	1739
Acetate/Cotton	46.5/53.5	29/1	*183*	1447

[1] Break factor measured on skeins and is not typically done for filament yarns but done for illustrative purposes to show the difference in relative strengths of spun yarns relative to 150 denier filament acetate which is accepted as a weak yarn. The relative strengths of the 100% synthetic yarns were consistent with the range expected for industry standards.

[0130] Both samples of CA staple fibers were taken to sliver and successfully spun to a yarn. Both samples were taken to sliver. CA staple fiber samples containing Lurol 7414K finish were used as the CA staple fiber for blending with other fiber materials.

[0131] The synthetic blend yarns (acetate/nylon and acetate/polyester) were made by intimately blending 50/50 weight ratios of both fibers by weight in the hopper prior to the fine opener. No issues were observed during carding, drawing, roving or spinning. The specific density needed to be taken into consideration as the specific densities affected the sliver weights and adjustments needed to be made to hit the targeted sliver weights. The final yarns were targeted at 29/1 based on the best balance obtained using the acetate Lurol 7414K sample as the standard to match. In order to reach a

29/1 of acceptable break factor (1181) a twist multiple of 3.8 was used based on results from a twist curve where the strength to twist multiple were optimized to balance liveliness (knittability and hand in final fabric) with strength. All the yarn properties were determined according to ASTM 2256. Table 3 summarize the yarn properties.

Table 3

Sample	Time to Break(s)	B-Force (gF)	Elongation (%)	Tenacity (gF/den)	B-Work (gF.cm)	Mod 2% (N/tex)
Acetate	0.79	164.0	13.06	0.91	778.6	1.181
Acetate 1	0.81	160.3	13.49	0.89	790.1	1.521
Polyester	1.09	329.7	18.12	1.83	1678	1.089
Nylon	1.34	379.9	22.10	2.11	1935	0.606
Cotton	0.41	312.9	6.89	1.74	538.8	1.463
Acetate/Polyester	1.11	250.1	18.47	1.39	1428	1.612
Acetate/Nylon	1.06	233.6	17.60	1.30	1176	0.849
Acetate/Cotton	0.35	186.6	5.79	1.04	313.6	1.514

Example 4

[0132] This example evaluates the utility of a variety of finishes on the F/F CODF and F/M CODF as well as the effectiveness of static electricity build up on continuous filaments, which would have similar values upon being cut into staple fibers.

[0133] Uncrimped CA continuous fibers were produced on a pilot-scale single tow cabinet and wound on a yarn tube. The yarn total denier was 1600 g/9000 m and the dpf was 1.80. The amount of finish is set forth in Table 4 below, and the finish was applied at an emulsion level of 2%. No other finish lubricant was applied other than the finish described in Table 4. The yarn packages were conditioned at 70°F ±2°F and 65% ±4% relative humidity for 24 hours before testing. F/M CODF was measured according to ASTM D3108/D3108M – 13 at 100 m/min and an input tension of 10 grams on a

Constant Tension Transport with Electronic Drive (CTT-E) instrument set up according Fig. 2 in the ASTM D3412/3412M – 13 procedure. F/F CODF was measured according to ASTM D3412/3412M – 13, with the exception that only 1 twist could be used rather than 3 twists due to the strength of the fiber and that it was performed at 20 m/min rather than 0.2 m/min due to equipment constraints. The yarn was tested on a CTT-E set up according to Fig. 1 in the ASTM procedure and had an input tension of 10 grams.

[0134] Static electricity was measured as follows: for each package, a 2 foot section of yarn was secured at one end, the fiber was then rubbed with a pencil along the full length three times back and forth, and the resulting electric field was measured using a model FMX-003 Simco Electrostatic Fieldmeter. The measurements were taken at ambient conditions.

Table 4

Package #	Finish	Level	%FOY	F/M	F/F	Static (kV)
65	Lurol 6511	HIGH	0.18	0.4816	0.1	0
68	Lurol 6511	HIGH	0.18	0.4718	0.098	0.06
73	Lurol 6511	HIGH	0.18	0.4779	0.1009	-0.02
76	Lurol 6511	HIGH	0.18	0.4658	0.099	0.01
71	Lurol 6511	HIGH	0.18	0.4718	0.0975	0
66	Lurol 6511	LOW	0.13	0.4673	0.0971	-0.01
75	Lurol 6511	LOW	0.13	0.4572	0.0931	0.03
74	Lurol 6511	LOW	0.13	0.4565	0.0979	0.02
80	Lurol 6511	LOW	0.13	0.4549	0.0966	0.01
78	Lurol 6511	LOW	0.13	0.4576	0.0841	0.06
79	Lurol 6511	LOW	0.13	0.4561	0.0895	0.02
70	Lurol 6511	MEDIUM	0.15	0.4665	0.0978	0
77	Lurol 6511	MEDIUM	0.15	0.4808	0.1012	0.03
72	Lurol 6511	MEDIUM	0.15	0.4629	0.103	-0.01
69	Lurol 6511	MEDIUM	0.15	0.4675	0.0988	-0.01
67	Lurol 6511	MEDIUM	0.15	0.4626	0.0986	0
53	Lurol 7414K	LOW	0.04	0.5326	0.2202	1.03
59	Lurol 7414K	LOW	0.04	0.5365	0.2083	0.27
63	Lurol 7414K	LOW	0.04	0.5321	0.2151	1.04
56	Lurol 7414K	LOW	0.04	0.5365	0.2111	0.8

58	Lurol 7414K	LOW	0.04	0.5489	0.2021	1.02
61	Lurol 7414K	LOW	0.04	0.5859	0.2174	1.26
60	Lurol 7414K	HIGH	0.64	0.4512	0.1289	0.97
62	Lurol 7414K	HIGH	0.64	0.451	0.1289	0.49
51	Lurol 7414K	HIGH	0.64	0.4739	0.1637	0.68
54	Lurol 7414K	HIGH	0.64	0.4585	0.1087	1.04
50	Lurol 7414K	HIGH	0.64	0.5038	0.1231	0.31
49	Lurol 7414K	MEDIUM	0.28	0.5207	0.2143	1.2
57	Lurol 7414K	MEDIUM	0.28	0.5145	0.2111	0.53
55	Lurol 7414K	MEDIUM	0.28	0.5236	0.2004	0.96
64	Lurol 7414K	MEDIUM	0.28	0.5072	0.2075	0.78
52	Lurol 7414K	MEDIUM	0.28	0.5363	0.1985	0.63
45	Lurol 912T	LOW	0.26	0.5561	0.224	0.98
35	Lurol 912T	LOW	0.26	0.5484	0.2305	0.9
40	Lurol 912T	LOW	0.26	0.6344	0.2211	1.18
37	Lurol 912T	LOW	0.26	0.6501	0.221	1.14
34	Lurol 912T	LOW	0.26	0.6241	0.2162	0.68
39	Lurol 912T	MEDIUM	0.34	0.5999	0.2069	0.49
47	Lurol 912T	MEDIUM	0.34	0.6025	0.2152	0.62
48	Lurol 912T	MEDIUM	0.34	0.6047	0.1955	0.96
42	Lurol 912T	MEDIUM	0.34	0.6144	0.2067	0.55
36	Lurol 912T	MEDIUM	0.34	0.6377	0.2021	0.73
33	Lurol 912T	MEDIUM	0.34	0.6244	0.2018	0.97
38	Lurol 912T	HIGH	0.29	0.5982	0.2209	0.8
43	Lurol 912T	HIGH	0.29	0.6105	0.1993	0.87
46	Lurol 912T	HIGH	0.29	0.6174	0.1969	0.8
44	Lurol 912T	HIGH	0.29	0.6084	0.205	0.71
41	Lurol 912T	HIGH	0.29	0.6299	0.1955	0.41
17	Stantex 2098	LOW	0.11		0.2116	0.58
24	Stantex 2098	LOW	0.11	0.5991	0.2153	0.56
27	Stantex 2098	LOW	0.11	0.6155	0.2074	0.47
20	Stantex 2098	LOW	0.11	0.574	0.2136	1.08
22	Stantex 2098	LOW	0.11	0.6055	0.2151	0.8
28	Stantex 2098	MEDIUM	0.31	0.5873	0.2135	0.67
18	Stantex 2098	MEDIUM	0.31	0.5164	0.2137	1.3
32	Stantex 2098	MEDIUM	0.31	0.5502	0.2066	0.9
26	Stantex 2098	MEDIUM	0.31	0.5756	0.2164	0.95
19	Stantex 2098	MEDIUM	0.31	0.6093	0.2035	0.89
23	Stantex 2098	HIGH	0.69	0.499	0.1741	0.7
21	Stantex 2098	HIGH	0.69	0.5146	0.1917	1.15
25	Stantex 2098	HIGH	0.69	0.5225	0.1759	0.75

30	Stantex 2098	HIGH	0.69	0.5269	0.1862	0.66
29	Stantex 2098	HIGH	0.69	0.5312	0.2143	1.02
31	Stantex 2098	HIGH	0.69	0.5532	0.1957	0.85
9	Stantex 7638-A	LOW	0.29	0.6672	0.2094	0.62
6	Stantex 7638-A	LOW	0.29	0.5991	0.2095	0.82
5	Stantex 7638-A	LOW	0.29	0.5893	0.2057	0.73
7	Stantex 7638-A	LOW	0.29	0.6264	0.2106	0.48
8	Stantex 7638-A	LOW	0.29	0.6106	0.1994	1.05
1	Stantex 7638-A	MEDIUM	0.25	0.6135	0.2068	0.61
15	Stantex 7638-A	MEDIUM	0.25	0.5959	0.1913	0.82
16	Stantex 7638-A	MEDIUM	0.25	0.6156	0.189	0.49
4	Stantex 7638-A	MEDIUM	0.25	0.6144	0.19	0.2
14	Stantex 7638-A	MEDIUM	0.25	0.6449	0.201	0.82
2	Stantex 7638-A	HIGH	0.39	0.5839	0.1709	0.73
3	Stantex 7638-A	HIGH	0.39	0.595	0.2051	1.8
11	Stantex 7638-A	HIGH	0.39	0.5337	0.1889	0.21
10	Stantex 7638-A	HIGH	0.39	0.6048	0.1868	1.03
13	Stantex 7638-A	HIGH	0.39	0.6281	0.2001	0.65
12	Stantex 7638-A	HIGH	0.39	0.6261	0.1989	1.33
6	Lurol PS-15602	LOW	0.19	0.6136	0.2228	1.08
10	Lurol PS-15602	LOW	0.19	0.6256	0.2254	0.95
12	Lurol PS-15602	LOW	0.19	0.6005	0.2123	0.58
8	Lurol PS-15602	LOW	0.19	0.5881	0.2341	0.68
1	Lurol PS-15602	LOW	0.19	0.573	0.2088	0.35
9	Lurol PS-15602	LOW	0.19	0.6022	0.2174	0.96
5	Lurol PS-15602	MEDIUM	0.29	0.6113	0.2066	0.62
3	Lurol PS-15602	MEDIUM	0.29	0.6009	0.2188	0.89
15	Lurol PS-15602	MEDIUM	0.29	0.5991	0.2163	0.73
2	Lurol PS-15602	MEDIUM	0.29	0.5909	0.2094	0.84
4	Lurol PS-15602	MEDIUM	0.29	0.5985	0.2087	0.61
13	Lurol PS-15602	HIGH	0.47	0.5968	0.2154	0.37
16	Lurol PS-15602	HIGH	0.47	0.5951	0.205	0.68
7	Lurol PS-15602	HIGH	0.47	0.5903	0.191	1.2
11	Lurol PS-15602	HIGH	0.47	0.5914	0.2061	0.7
14	Lurol PS-15602	HIGH	0.47	0.6037	0.21	1.15
22	Tallopol SE 90	LOW	0.18	0.6056	0.2253	0.75
30	Tallopol SE 90	LOW	0.18	0.6003	0.2282	0.68
31	Tallopol SE 90	LOW	0.18	0.594	0.2117	0.84
23	Tallopol SE 90	LOW	0.18	0.5802	0.2339	0.78
17	Tallopol SE 90	LOW	0.18	0.5911	0.2251	0.78
20	Tallopol SE 90	MEDIUM	0.34	0.554	0.2167	0.66

18	Tallopol SE 90	MEDIUM	0.34	0.5652	0.2264	0.62
19	Tallopol SE 90	MEDIUM	0.34	0.5819	0.226	0.83
32	Tallopol SE 90	MEDIUM	0.34	0.6135	0.2314	0.5
24	Tallopol SE 90	MEDIUM	0.34	0.5666	0.226	0.28
21	Tallopol SE 90	MEDIUM	0.34	0.579	0.2232	0.4
28	Tallopol SE 90	HIGH	0.4	0.6551	0.2251	0.47
25	Tallopol SE 90	HIGH	0.4	0.6807	0.2275	0.78
26	Tallopol SE 90	HIGH	0.4	0.61	0.2211	0.89
27	Tallopol SE 90	HIGH	0.4	0.5867	0.2173	0.44
29	Tallopol SE 90	HIGH	0.4	0.5842	0.2317	0.47

[0135] Lurol 6511 had the lowest CODF for both F/M and F/F as well as the lowest static charge—approximately zero. Lurol 7414K had downward trends for both F/M and F/F, but F/F was steeper. Other lubricants were generally flat and comparable to one another, though Stantex 2098 did show slight downward trends. All the spin finishes, aside from Lurol 6511 were not statistically significantly different from one another in regards to controlling static.

[0136] As used herein, the terms “comprising,” “comprises,” and “comprise” are open-ended transition terms used to transition from a subject recited before the term to one or more elements recited after the term, where the element or elements listed after the transition term are not necessarily the only elements that make up the subject.

[0137] As used herein, the terms “including,” “includes,” and “include” have the same open-ended meaning as “comprising,” “comprises,” and “comprise.”

[0138] As used herein, the terms “having,” “has,” and “have” have the same open-ended meaning as “comprising,” “comprises,” and “comprise.”

[0139] As used herein, the terms “containing,” “contains,” and “contain” have the same open-ended meaning as “comprising,” “comprises,” and “comprise.”

[0140] As used herein, the terms “a,” “an,” “the,” and “said” mean one or more.

[0141] As used herein, the term “and/or,” when used in a list of two or more items, means that any one of the listed items can be employed by itself

or any combination of two or more of the listed items can be employed. For example, if a composition is described as containing components A, B, and/or C, the composition can contain A alone; B alone; C alone; A and B in combination; A and C in combination; B and C in combination; or A, B, and C in combination.

[0142] The preferred forms of the invention described above are to be used as illustration only, and should not be used in a limiting sense to interpret the scope of the present invention.

WHAT WE CLAIM IS:

1. A carded sliver comprising cellulose acetate staple fibers (CA staple fibers) having a round shape, a denier of less than 3.0, a crimp frequency per inch (CPI) from 5 to 30, and wherein said sliver has a fiber-to-fiber cohesion energy of at least 10,000 Joules.

2. The carded sliver of claim 1, wherein said CA staple fibers have an uncrimped fiber to fiber coefficient of dynamic friction (F/F CODF) between 0.11 to less than 0.2 as measured according to ASTM D3412/3412M – 13, at one twist, a rate of 20 m/min, and with an input tension of 10 grams on filaments used to make said CA staple fibers

3. The carded sliver of any one of claims 1-2, wherein said CA staple fibers have a static electricity charge of less than 1.0 kV at 65 % relative humidity as measured using an electrostatic fieldmeter on a two foot sample length of filaments used to make said CA staple fibers rubbed with three times back and forth.

4. The carded sliver of any one of claims 1-3, wherein the sliver has a coefficient of variation (CVm) of no more than 4.5% or not more than 4%.

5. The carded sliver of any one of claims 1-4, wherein the sliver has a short fiber content (less than ½ inch) of no more than 15% as determined by the Keisokki Fiber Length Distribution Tester.

6. The carded sliver of any one of claims 1-5, wherein at least 10 wt.% and up to 55% of the staple fibers in the sliver are CA staple fibers, and wherein the CA staple fibers are coated with a finish.

7. The carded sliver of any one of claims 1-6, wherein the CA staple fibers have a denier from 0.5 to 1.9, a CPI from 8 to 19, and wherein the cellulose acetate used to make the fibers has an acetyl degree of substitution of at least 2.2.

8. The carded sliver of any one of claims 1-7, wherein the CA staple fibers have a CPI:DPF ratio from 6:1 to 14:1.

9. The carded sliver of any one of any one of claims 1-8, wherein at least 90% of the CA staple fibers have a shape factor from 1.0 to 1.5.

10. The carded sliver of any one of claims 1-9, wherein at least 90 wt.% of the CA staple fibers have a cut length of 10 mm to 150 mm.

11. The carded sliver of any one of claims 1-10, wherein said CA staple fibers are coated with a finish in an amount of less than 2.0 wt.% FOY on a dry weight basis.

12. The carded sliver of any one of claims 1-11, wherein said the CA staple fibers have a tenacity of at least 0.9 grams-force/denier, as measured according to ASTM D3822, or are made from filaments that have a tenacity of at least 0.9 grams-force/denier, as measured according to ASTM D3822.

13. The carded sliver of any one of claims 1-12, wherein said CA staple fibers have an elongation at break of at least 15%, as measured according to ASTM D3822, or wherein the sliver is obtained from staple fibers made from filaments that have has an elongation at break of at least 15%, as measured according to ASTM D3822.

14. The carded sliver of any one of claims 1-13, having a fiber-to-fiber cohesion energy of at least 15,000 Joules or at least 20,000 Joules.

15. A spun yarn obtained from one or more carded slivers that are drawn, and at least one of said carded staple slivers comprising cellulose acetate staple fibers (CA staple fibers) having a round shape, a denier of less than 3.0, a crimp frequency per inch (CPI) from 5 to 30 wherein said at least one sliver has a fiber-to-fiber cohesion energy of at least 10,000 Joules.

16. The spun yarn of claim 15, wherein said CA staple fibers have an uncrimped fiber to fiber coefficient of dynamic friction (F/F CODF) between 0.11 to less than 0.2 as measured by according to ASTM D3412/3412M – 13, at one twist, a rate of 20 m/min, and with an input tension of 10 grams on filaments used to make said CA staple fibers, and have a have a static electricity charge of less than 1.0 kV at 65% % relative humidity as measured

on a two foot sample length of filaments used to make said CA staple fibers rubbed with three times back and forth.

17. The spun yarn of any one of claims 15-16, wherein said yarn contains from 10 wt.% to 70 wt% CA staple fibers.

18. The spun yarn of any one of claims 15-17, wherein said yarn has at least one of the following characteristics: (i) a breaking force of at least 150 g-N, as measured according to ASTM D2256 on a sample containing 100% of the CA staple fibers, (ii) a tenacity of at least 0.85 gF/denier as measured according to ASTM D2256 on a sample containing 100% of the CA staple fibers, or (iii) an elongation at break of at least 13% as measured according to ASTM D2256 on a sample containing 100% of the CA staple fibers.

19. The spun yarn of any one of claims 15-18, having a total denier of less than 300 and a twist per inch of less than 4.

20. A textile fabric obtained from spun yarn, said yarn obtained from carded slivers comprising CA staple fibers (CA staple fibers) containing a quantity of spin finish, and wherein the textile fabric contains no spin finish or a quantity of spin finish that is less than said quantity on the CA staple fibers, said staple CA staple fibers having round shape, a denier of less than 3.0, a crimp frequency per inch (CPI) from 5 to 30., wherein said one or more carded slivers has a fiber-to-fiber cohesion energy of at least 10,000 Joules.

21. The textile fabric of claim 21, wherein said CA staple fibers have an untwisted fiber to fiber coefficient of dynamic friction (F/F CODF) between 0.1 to less than 0.2 as measured by according to ASTM D3412/3412M – 13, at one twist, a rate of 20 m/min, and with an input tension of 10 grams on filaments used to make said CA staple fibers and a static electricity charge of less than 1.0 at 65 % relative humidity as measured on a two foot sample length of filaments used to make said CA staple fibers rubbed with three times back and forth.

22. A carded sliver comprising cellulose acetate staple fibers (CA staple fibers) having a round shape, a denier of less than 3.0, a crimp

frequency per inch (CPI) from 5 to 30, and wherein said sliver is obtained from CA staple fibers having a scroop value of at least 0.2 and not more than 1.

23. The carded sliver of claim 22, wherein the CA fibers have a fiber-to-fiber staple pad friction coefficient of friction of at least 0.20 and not more than 1, or at least 0.30 and not more than 0.8, or at least 0.35 and not more than 0.65.

24. The carded sliver of any one of claims 22-23, wherein the CA fibers have a fiber-to-metal staple pad friction coefficient of friction of at least 0.10 and not more than 0.4.

25. The carded sliver of any one of claims 22-24, wherein said CA staple fibers have a static electricity charge of less than 1.0 kV at 65 % relative humidity as measured using an electrostatic fieldmeter on a two foot sample length of filaments used to make said CA staple fibers rubbed with three times back and forth.

26. The carded sliver of any one of claims 22-25, wherein said CA staple fibers have an uncrimped fiber to fiber coefficient of dynamic friction (F/F CODF) between 0.11 to less than 0.2 as measured according to ASTM D3412/3412M – 13, at one twist, a rate of 20 m/min, and with an input tension of 10 grams on filaments used to make said CA staple fibers.

27. The carded sliver of any one of claims 22-26, wherein the sliver has a coefficient of variation (CVm) of no more than 4.5% or not more than 4%.

28. The carded sliver of any one of claims 22-27, wherein the sliver has a short fiber content (less than ½ inch) of no more than 15% as determined by the Keisokki Fiber Length Distribution Tester.

29. The carded sliver of any one of claims 22-28, wherein at least 10 wt.% and up to 55% of the staple fibers in the sliver are CA staple fibers, and wherein the CA staple fibers are coated with a finish.

30. The carded sliver of any one of claims 22-29, wherein the CA staple fibers have a denier from 0.5 to 1.9, a CPI from 8 to 19, and wherein

the cellulose acetate used to make the fibers has an acetyl degree of substitution of at least 2.2.

31. The carded sliver of any one of claims 22-30, wherein the CA staple fibers have a CPI:DPF ratio from 6:1 to 14:1.

32. The carded sliver of any one of any one of claims 22-31, wherein at least 90% of the CA staple fibers have a shape factor from 1.0 to 1.5.

33. The carded sliver of any one of claims 22-32, wherein at least 90 wt.% of the CA staple fibers have a cut length of 10 mm to 150 mm.

34. The carded sliver of any one of claims 22-33, wherein said CA staple fibers are coated with a finish in an amount of less than 2.0 wt.% FOY on a dry weight basis.

35. The carded sliver of any one of claims 22-34, wherein said the CA staple fibers have a tenacity of at least 0.9 grams-force/denier, as measured according to ASTM D3822, or are made from filaments that have a tenacity of at least 0.9 grams-force/denier, as measured according to ASTM D3822.

36. The carded sliver of any one of claims 22-35, wherein said CA staple fibers have an elongation at break of at least 15%, as measured according to ASTM D3822, or wherein the sliver is obtained from staple fibers made from filaments that have has an elongation at break of at least 15%, as measured according to ASTM D3822.

37. The carded sliver of any one of claims 22-36, having a fiber-to-fiber cohesion energy of at least 15,000 Joules or at least 20,000 Joules.

38. A spun yarn obtained from one or more carded slivers that are drawn, and at least one of said carded staple slivers comprising cellulose acetate staple fibers (CA staple fibers) having a round shape, a denier of less than 3.0, a crimp frequency per inch (CPI) from 5 to 30, wherein said sliver is obtained from CA staple fibers having a scroop value of at least 0.2 and not more than 1.

39. The spun yarn of claim 38, wherein said yarn has at least one of the following characteristics: (i) a breaking force of at least 150 g-N, as measured according to ASTM D2256 on a sample containing 100% of the CA staple fibers, or (ii) a tenacity of at least 0.85 gF/denier as measured according to ASTM D2256 on a sample containing 100% of the CA staple fibers, or (iii) an elongation at break of at least 13% as measured according to ASTM D2256 on a sample containing 100% of the CA staple fibers.

40. The spun yarn of any one of any one of claims 38-39, having a total denier of less than 300 and a twist per inch of less than 4.

41. A textile fabric obtained from spun yarn, said yarn obtained from carded slivers comprising CA staple fibers (CA staple fibers) containing a quantity of spin finish, and wherein the textile fabric contains no spin finish or a quantity of spin finish that is less than said quantity on the CA staple fibers, said staple CA staple fibers having round shape, a denier of less than 3.0, a crimp frequency per inch (CPI) from 5 to 30., wherein said one or more carded slivers are made from CA staple fibers having a scroop value of at least 0.2 and up to 1.

42. The textile fabric of claim 41, wherein said CA staple fibers have an untwisted fiber to fiber coefficient of dynamic friction (F/F CODF) between 0.1 to less than 0.2 as measured by according to ASTM D3412/3412M – 13, at one twist, a rate of 20 m/min, and with an input tension of 10 grams on filaments used to make said CA staple fibers.

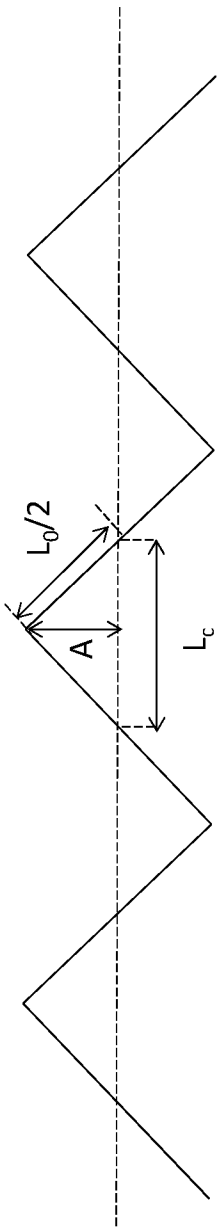


Figure 1

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2019/019580

A. CLASSIFICATION OF SUBJECT MATTER
INV. D02G3/02
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
D02G D01F D01G D01H A24D D06M

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 796 344 A (BRITISH CELANESE) 11 June 1958 (1958-06-11) page 1, line 9 - line 41; claims 10-11; example 1 page 3, line 15 - line 18 -----	1-42
A	GB 748 772 A (BRITISH CELANESE) 9 May 1956 (1956-05-09) page 2, line 5 - line 25 page 4, line 26 - line 65; figures 2,5 -----	1,22
A	WO 93/02247 A1 (EASTMAN KODAK CO [US]) 4 February 1993 (1993-02-04) page 3, line 21 - line 32 page 5, line 5 - line 9; example 6 -----	1,22

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 May 2019	12/06/2019

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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