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(54) **Multicomponent Aliphatic Polyester Fibers**

(57) The present invention provides multicomponent thermoplastic fibers that are biodegradable and that are capable of forming strong bonds in air bonding processes. In various embodiments, the multicomponent fibers can include a first polymer component that includes a first aliphatic polyester, and a second polymer component

also including an aliphatic polyester, wherein the first polymer component comprises at least a portion of an exposed surface of the multicomponent fiber. The first polymer component can be a fully amorphous polylactic acid and the second polymer component can be a semi-crystalline polylactic acid.

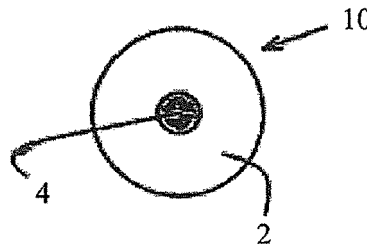


FIG. 1

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DescriptionFIELD OF INVENTION

[0001] The present disclosure relates to a multicomponent thermoplastic fiber. In particular, the fiber can exhibit useful thermal-bonding characteristics, such as during thermal-bonding processes, including thermal bonding processes that do not require application of pressure.

BACKGROUND

[0002] Synthetic fibers are widely used in a number of diverse applications to provide stronger, thinner, and lighter weight products. Synthetic thermoplastic fibers are typically heat adhesive (thermobondable) and thus are particularly attractive for the manufacture of nonwoven fabrics, either alone or in combination with other fibers (such as cotton, wool, and wood pulp). Nonwoven fabrics, in turn, are widely used as components of a variety of articles, including without limitation absorbent personal care products, such as diapers, incontinence pads, feminine hygiene products, and the like; medical products, such as surgical drapes, sterile wraps, and the like; filtration devices; interlinings; wipes; furniture and bedding construction; apparel; insulation; and others.

[0003] Conventional synthetic thermoplastic fibers, however, do not naturally degrade, thus creating problems associated with the disposal of products containing such fibers. In particular, recycling articles containing a blend of natural and conventional synthetic fibers is generally not cost effective, but the disposal of these articles in landfills generates significant amounts of non-degradable waste. As landfills reach their capacity, the demand has increased for the incorporation of more degradable components in disposable products, as well as the design of products that can be disposed of by means other than by incorporation into solid waste disposal facilities.

[0004] To address concern over the issue of solid waste disposal, biodegradable polymers are increasingly used as a replacement for conventional synthetic polymers. Biodegradable polymers of interest include water-soluble polymers such as polyvinyl alcohol; naturally synthesized polymers such as sodium alginate and microbial polyesters; hydrolyzable aliphatic polyester and polyurethane polymers; and the like. Synthetic biodegradable aliphatic polyesters include polyglycolide and polylactic acid polymers. See, for example, U.S. Patent Nos. 5,166,231; 5,506,041; 5,759,569; 5,171,309; 6,177,193; 6,441,267; 6,953,622; and 7,338,877, each of which is herein incorporated by reference in its entirety.

[0005] Of particular interest is the use of lactic acid to manufacture biodegradable resin. Polylactic acid (hereinafter "PLA") was initially introduced as a biodegradable polymer for medical products. U.S. Patent Nos. 5,142,023 and 5,807,973 to Gruber et al., each of which is herein incorporated by reference in its entirety, disclose processes by which a nonmedical grade of polylactic acid

may be produced and utilized in nonwoven fabrics. Examples of biodegradable fibers comprised entirely of polylactic acid polymers and/or copolymers are found in U.S. Patent Nos. 5,010,145 and 5,760,144, each of which is herein incorporated by reference in its entirety. See also U.S. Patent Nos. 5,698,322 and 5,593,778 (directed to bicomponent fibers which include polylactic acid components), each of which is herein incorporated by reference in its entirety.

[0006] The successful inclusion of biodegradable materials in disposable absorbent products provides several avenues by which these products may be discarded once their useful life has ended. Primarily, these articles may be easily and efficiently disposed of by composting. Alternatively, the disposable product may be easily and efficiently disposed of to a liquid sewage system wherein the disposable absorbent product is capable of being degraded.

[0007] Although biodegradable fibers are known, problems have been encountered with their use. For example, the known biodegradable fibers may bond when melted under pressure (calendar-bonding), but such fibers may not form a strong bond in other processes, such as an air-bonding process. Furthermore, many conventional binder fibers exhibit shrinkage at air-bonding temperatures since the fiber cannot be heatset at or above the temperature at which the binder component will soften or flow, yet in bonding, the fiber must be exposed to temperatures high enough to achieve the desired melt flow characteristics of the binder component. Therefore, it is desirable to provide an entirely biodegradable fiber that is capable of forming a strong bond in an air-bonding process.

SUMMARY OF THE INVENTION

[0008] The present invention provides multicomponent thermoplastic fibers that are biodegradable and that are useful in thermal bonding processes, particularly air bonding processes. The multicomponent fiber can be selected from the group consisting of continuous filaments, staple fibers, spunbond filaments, and meltblown fibers. In various embodiments, the multicomponent fibers comprise a first polymer component comprising a first aliphatic polyester, and a second polymer component also comprising an aliphatic polyester, wherein the first polymer component comprises at least a portion of an exposed surface of the multicomponent fiber. In some embodiments, about 5% or greater, about 15% or greater, about 25% or greater, about 50% or greater, or about 75% or greater of the exposed multicomponent fiber surface can be defined by the first polymer component. In a preferred embodiment, the entire exposed surface of the multicomponent fiber can be defined by the first polymer component. Furthermore, the multicomponent fiber can have a cross-sectional area comprising the first polymer component and the second polymer component in a ratio of about 1:9 to about 9:1, or in a ratio of about 1:3 to about

3:1. In some embodiments, the ratio of the cross-sectional area is about 1:1.

[0009] In various embodiments, the first polymer component is polylactic acid. In some embodiments, the first polymer component comprises a fully amorphous polylactic acid, wherein the D-isomer content of the amorphous polylactic acid is about 5% or greater, or about 8% or greater. In addition, in various embodiments, the first polymer component can have a melt flow index of about 30 or greater when evaluated according to melt flow test ASTM D1238 at a temperature of 210°C and using a 2160g basis weight. In various embodiments, the melt flow index of the first polymer component is about 45 or greater, or about 60 or greater. In some embodiments, the first polymer component can further comprise an additive adapted to one or both of increase the melt flow rate of the first polymer component and reduce the viscosity of the first polymer component at a target bonding temperature. Thereby, the additive may reduce the temperature at which satisfactory bonding can occur. The bonding temperature can be defined as the temperature at which the first polymer component softens or flows sufficiently to enable bonding between adjacent fibers, and wherein the second polymer component does not soften, flow or melt, such that the fibrous shape of the multicomponent fiber is maintained. The additive can be present in an amount sufficient to reduce the bonding temperature of multicomponent fiber at which satisfactory bonding occurs by about 10°C or more. This can be advantageous because with conventional air bonding, the temperature required for satisfactory bonding of the sheath component can be above the temperature at which the core component either softens or melts or shrinks to an unacceptable degree. Therefore, reducing the bonding temperature can provide energy savings, increased line speed, and make air bonding a practical option for binder fibers disclosed herein, whereas conventional fibers are limited to use in a pressure bonding process such as calendar bonding or point bonding, for example.

[0010] In various embodiments of the multicomponent fiber, the first polymer component is defined by a first molecular weight, and the second polymer component is defined by a second molecular weight. Furthermore, the first polymer component can comprise an additive in an amount sufficient to reduce the first molecular weight to a first reduced molecular weight. In various embodiments, the first reduced molecular weight is less than the first molecular weight by about 10% or more. For example, the ratio of the first reduced molecular weight to the first molecular weight can be about 0.9 or less, or about 0.85 or less. Additionally, the weight ratio of the first polymer component and the second polymer component can vary. For example, in some embodiments, the first polymer component can have a molecular weight that is about 90% or less, about 85% or less, or about 80% or less of the molecular weight of the second polymer component. In some embodiments, the first polymer compo-

nent can include a molecular weight reducing additive. In various embodiments, the first polymer component comprises about 0.5% to about 8.0% by weight of the molecular weight reducing additive. In further embodiments, exemplary molecular weight reducing additives can be selected from the group consisting of pentaerythritol, water, sodium hydroxide, hydrated alumina trihydrate, ethylene glycol, and combinations thereof.

[0011] In various embodiments, the second polymer component is polylactic acid. In some embodiments, the second polymer component comprises a semicrystalline polylactic acid, wherein the D-isomer content of the semicrystalline polylactic acid is about 2% or less, about 1% or less, or about 0.6% or less. In some embodiments, the second polymer component comprises a blend of a first semicrystalline polylactic acid, wherein the D-isomer content of the first semicrystalline polylactic acid is about 1.2% or less, and a second semicrystalline polylactic acid, wherein the D-isomer content of the second semicrystalline polylactic acid is about 2% or less. Such blend can be at a ratio of about 10:90 to about 90:10 or about 25:75 to about 75:25. In various embodiments, the second polymer component has a melt temperature of about 160°C or greater.

[0012] The present invention also overcomes known problems in the art related to acceptable bonding with a binder fiber in an air-bonding process. In particular, the presently disclosed fibers can be characterized by being resistant to shrinkage during heating. In some embodiments, the fibers can be defined by a desirable heat shrinkage value. Specifically, a fiber according to the present disclosure can be defined by a heat shrinkage value of less than 20%, preferably less than 15%, and most preferably less than about 10% when subjected to thermal air bonding conditions. Particularly, the heat shrinkage values can be evaluated under conditions of being exposed to air at a temperature of about 130°C for a time of approximately 5 minutes. Shrinkage can be evaluated at various temperatures and lengths of time depending on the target bonding temperature of an embodiment of the multicomponent fiber.

[0013] Furthermore, the present disclosure can provide a fabric comprising a plurality of thermally bonded multicomponent fibers as described herein. In certain embodiments, such fabrics can exhibit a tensile strength of about 500 grams force to about 4500 grams force or greater per gram of fabric weight. In further embodiments, a heat bonded nonwoven fabric according to the disclosure can exhibit a tensile strength about 150 grams force or greater for a fabric sample having a length and width of about 1.5 inches and about 2 inches, respectively, and having a weight of about 0.1 to about 0.3 grams.

[0014] In particular, the present multicomponent fiber can be adapted to impart a bonded web strength of about 150 grams force or greater for a bonded nonwoven comprising the multicomponent fiber as the sole bonding agent, wherein the bonded web strength is evaluated in

relation to a carded nonwoven web of 75% PLA 6202D fiber and 25% by weight of the multicomponent fiber, the web having a length of about 1.5 inches, a width of about 2 inches, and a weight of about 0.1 to about 0.3 grams, and the web being air bonded with a 12 second residence time in a bonding oven at a temperature of 130 °C.

[0015] In various embodiments, a method of forming a fabric comprises providing a plurality of multicomponent fibers each with an exposed surface, wherein each multicomponent fiber comprises a first polymer component and a second polymer component, and wherein the first polymer component forms at least a portion of an exposed surface of each multicomponent fiber; and thermal air bonding the plurality of multicomponent fibers. In some embodiments, the bonding can be carried out at a temperature of about 80°C to about 150°C. The second polymer component particularly can have a melting temperature that is greater than the bonding temperature.

[0016] The fibers disclosed herein further can be used in the manufacture of further materials. For example, the present disclosure also encompasses spun yarns comprising the present fibers. In further, non-limiting examples, materials that can comprise the present fibers include plugs, tows, waddings, ropes, cords, and the like.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] Having thus described the invention in general terms, reference will now be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein:

Figure 1 is a transverse cross sectional view of an exemplary sheath/core multicomponent fiber of the invention;

Figure 2 is a transverse cross sectional view of a second exemplary sheath/core multicomponent fiber of the invention;

Figure 3 is a transverse cross sectional view of an exemplary "islands in the sea" multicomponent fiber of the invention;

Figure 4 is a transverse cross sectional view of an exemplary side-by-side multicomponent fiber of the invention;

Figure 5 is a transverse cross sectional view of an exemplary pie-wedge multicomponent fiber of the invention; and

Figure 6 is a transverse cross sectional view of an exemplary multi-lobal multicomponent fiber of the invention.

DETAILED DESCRIPTION

[0018] The present invention now will be described more fully hereinafter. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this dis-

closure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. As used in this specification and the claims, the singular forms "a," "an," and "the" include plural referents unless the context clearly dictates otherwise. Reference to "dry weight percent" or "dry weight basis" refers to weight on the basis of dry ingredients (i.e., all ingredients except water).

[0019] The present disclosure provides a multicomponent thermoplastic fiber that is biodegradable and that forms strong bonds in thermal bonding processes. The multicomponent fiber can comprise a first polymer component comprising a first aliphatic polyester and a second polymer component comprising a second aliphatic polyester, wherein the first polymer component comprises at least a portion of an exposed surface of the multicomponent fiber. In some embodiments as used herein, an exposed surface can refer to at least a portion of a circumference of a cross-sectional area of the multicomponent fiber. In further embodiments, an exposed surface can comprise any area of the fiber surface that is exposed to ambient surroundings.

[0020] The term "fiber" as used herein means both fibers of finite length, such as conventional staple fibers, as well as substantially continuous structures, such as continuous filaments, unless otherwise indicated. The fibers of the invention can be hollow or non-hollow fibers, and further can have a substantially round or circular cross section or non-circular cross sections (for example, oval, rectangular, multi-lobed, and the like).

[0021] As used herein, the term "multicomponent fibers" includes staple and continuous fibers prepared from two or more polymers present in discrete structured domains in the fiber, as opposed to blends where the domains tend to be dispersed, random or unstructured. For purposes of illustration only, the present subject matter is generally described in terms of an exemplary bicomponent fiber comprising two polymer components. However, it should be understood that the scope of the present invention is meant to include fibers with two or more structured components and is not limited to the exemplary bicomponent fibers described below. Although the invention is not limited to two components, the terms first component and second component are used throughout for the ease of describing the invention.

[0022] In general, the polymer components are arranged in substantially constantly positioned distinct zones across the cross section of the multicomponent fiber and extend continuously along the length of the multicomponent fiber. Both the shape of the fiber and the configuration of the components therein will depend upon the equipment that is used in the preparation of the fiber, the process conditions, and the melt viscosities of the various components. A wide variety of fiber configurations are possible in the present invention. The cross section of the multicomponent fiber can particularly be circular, since the equipment typically used in the production of multicomponent synthetic fibers often produc-

es fibers with a substantially circular cross section; however, other cross sections are encompassed. The configuration of the first and second components in a fiber of circular cross section can be either concentric or eccentric, the latter configuration sometimes being known as a "modified side-by-side" or an "eccentric" multicomponent fiber.

[0023] Figure 1 is a cross-sectional view of an exemplary multicomponent fiber of the present invention, designated generally as **10**. Multicomponent fiber **10** is a sheath/core fiber that includes at least two structured polymer components: (i) an outer sheath component comprising a first polymer component **2**; and (ii) an inner core component comprising a second polymer component **2**.

[0024] The core (formed of the second polymer component **4**) can be concentric, as illustrated in Figure 1. Alternatively, the core can be eccentric, as shown in Figure 2, which illustrates an eccentric sheath/core fiber **10**. The eccentric sheath/core fiber **10** is substantially the same as the embodiment of Figure 1, except the core (formed of the second polymer component **4**) is eccentrically located within the outer sheath (formed of the first polymer component **2**).

[0025] A concentric configuration is characterized by the sheath component having a substantially uniform thickness so that the core component lies approximately in the center of the fiber, such as illustrated in Figure 1. This is in contrast to an eccentric configuration, such as illustrated in Figure 2, in which the thickness of the sheath component varies, and the core component therefore does not lie in the center of the fiber. Concentric sheath/core fibers can be defined as fibers in which the center of the core component is biased by no more than about 0 to about 20 percent, preferably no more than about 0 to about 10 percent, based on the diameter of the sheath/core multicomponent fiber, from the center of the sheath component.

[0026] Other structured fiber configurations as known in the art can also be used. For example, Figure 3 illustrates another advantageous embodiment of the invention in which the multicomponent fiber **10** of the invention is a "matrix" or "islands in a sea" type fiber having a plurality of inner, or "island," polymer components surrounded by an outer matrix, or "sea," polymer component. The island components can be substantially uniformly arranged within the matrix of the sea component, such as illustrated in Figure 3. Alternatively, the island components can be randomly distributed within the sea matrix. In various embodiments, the sea polymer component comprises the first polymer component **2**. In various embodiments, the island polymer components comprise the second polymer component **4**.

[0027] Figure 4 illustrates yet another embodiment of the invention; namely, a side-by-side multicomponent fiber **10** wherein the first polymer component **2** and the second polymer component **4** are arranged in a side-by-side relationship. Figure 5 illustrates an embodiment of the invention wherein the multicomponent fiber **10** is config-

ured in a pie-wedge arrangement, wherein the first polymer component **2** and the second polymer component **4** are arranged as alternating wedges.

[0028] The multicomponent fibers of the present invention can also include multilobal fibers having three or more arms or lobes extending outwardly from a central portion thereof. Figure 6 is a cross sectional view of an exemplary multilobal fiber **10** of the invention. Fiber **10** includes a central core formed of the second polymer component **4** and arms or lobes formed of the first polymer component **2** and extending outwardly therefrom.

[0029] Various embodiments of the multicomponent fiber have a cross-sectional area comprising the first polymer component and the second polymer component in about a 1:9 to about a 9:1 ratio; or about a 1:3 to about a 3:1 ratio. In some embodiments, the multicomponent fiber has a cross-sectional area comprising the first polymer component and the second polymer component in about a 1.5:2.5 to about a 2.5:1.5 ratio. In a preferred embodiment, the multicomponent fiber has a cross-sectional area comprising the first polymer component and the second polymer component in about a 1:1 ratio. In various embodiments, the first polymer component and the second polymer component can be present in a mass ratio of about 90:10 to about 10:90.

[0030] In various embodiments of a multicomponent fiber described herein, the first polymer component can form at least a portion of the exposed outer surface of the multicomponent fiber. In some embodiments, about 5% or greater, about 15% or greater, about 25% or greater, about 50% or greater, or about 75% or greater of the exposed multicomponent fiber surface can be defined by the first polymer component. In a preferred embodiment, the entire exposed surface of the multicomponent fiber can be defined by the first polymer component.

[0031] In various embodiments of the multicomponent fiber described herein, the polymer components of the multicomponent fiber can be formed of the same or different polymers. As used herein, the "same" polymer refers to polymer components having an identical or similar chemical formula; however, each polymer component can differ with respect to their ability to flow at a target bonding temperature. The ability of a polymer component to flow at a temperature is related to crystallinity, molecular weight, and the possible presence of plasticizers. The first polymer component and the second polymer component can each be an aliphatic polyester. Examples of aliphatic polyesters which may be useful in the present invention include, without limitation, fiber forming polymers formed from (1) a combination of glycol (e.g., ethylene glycol, propylene glycol, butylene glycol, hexanediol, octanediol or decanediol) or an oligomer of ethylene glycol (e.g., diethylene glycol or triethylene glycol) with an aliphatic dicarboxylic acid (e.g., succinic acid, adipic acid, hexanedicarboxylic acid or decanedicarboxylic acid) or (2) the self condensation of hydroxy carboxylic acids other than polylactic acid, such as polyhydroxy butyrate, polyethylene adipate, polybutylene adipate, poly-

hexane adipate, and copolymers containing them. Examples of aliphatic polyesters include, but are not limited to, polyglycolide or polyglycolic acid (PGA), polylactide or polylactic acid (PLA), polycaprolactone (PCL), polyethylene adipate (PEA), polyhydroxyalkanoate (PHA), polyhydroxybutyrate (PHB), poly(3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV), and polylactide-co-glycolide.

[0032] Aliphatic polyesters can be particularly useful because of the biodegradable nature thereof. In addition to biodegradability, aliphatic polyesters, particularly polylactic acid, can impart other desirable properties to the fibers of the invention. For example, the fibers of the invention which include polylactic acid (or a further aliphatic polyester) as a component can exhibit improved hydrophilic properties, improved flame retardant capabilities, or can be dyed to deeper and brighter shades as compared to fibers including polyethylene terephthalate or polyamides traditionally employed in the core of bi-component binder fibers.

[0033] In various embodiments, the first polymer component comprises a first aliphatic polyester and the second polymer component comprises a second aliphatic polyester. However, in embodiments where the first polymer component and the second polymer component comprise the same type of aliphatic polyester, then the first aliphatic polyester and the second aliphatic polyester can each be defined by at least one distinguishing characteristic. In a preferred embodiment, the first aliphatic polyester and the second aliphatic polyester are both polylactic acid, wherein the first PLA polymer component is defined by at least one distinguishing characteristic related to the ability of the polymer component to flow and form a strong bond at the target bonding temperature.

[0034] Polylactic acid polymers useful according to the present disclosure can be prepared by either the polymerization of lactic acid or lactide. PLA and methods of making thereof are disclosed in U.S. Patent Nos. 5,698,322; 5,142,023; 5,760,144; 5,593,778; 5,807,973; and 5,010,145, and the entire disclosure of each is hereby incorporated by reference.

[0035] Advantageously, PLA polymers useful according to the present disclosure exhibit residual monomer percents effective for the first polymer component and the second polymer to exhibit desirable melt strength, fiber mechanical strength, and fiber spinning properties. As used herein, "residual monomer percent" refers to the amount of lactic acid or lactide monomer that is unreacted yet which remains entrapped within the structure of the entangled PLA polymer chain. In general, if the residual monomer percent of a PLA polymer in a component is too high, the component may be difficult to process due to inconsistent processing properties caused by a large amount of monomer vapor being released during processing that causes variations in extrusion pressures. However, a minor amount of residual monomer in a PLA polymer in a component may be beneficial due to such

residual monomer functioning as a plasticizer during a spinning process. Thus, a PLA polymer component generally exhibits a residual monomer percent that is less than about 15 percent, preferably less than about 10 percent, and more preferably less than about 7 percent.

[0036] Aliphatic polyesters useful in the present disclosure can be defined by different characteristics or properties. For example, with reference to PLA, lactic acid and lactide are known to be asymmetrical molecules, having two optical isomers referred to, respectively as the levorotatory (hereinafter referred to as "L") enantiomer and the dextrorotatory (hereinafter referred to as "D") enantiomer. As a result, by polymerizing a particular enantiomer or by using a mixture of the two enantiomers, it is possible to prepare polymers that are chemically similar yet which have significantly differing properties. In particular, it has been found that by modifying the stereochemistry of a polylactic acid polymer, it is possible to control the melting characteristics of the polymer.

[0037] Crystallinity is another property that can be used to define aliphatic polyesters. The degree of crystallinity of a PLA polymer, for example, is based on the regularity of the polymer backbone and its ability to line up with similarly shaped sections of itself or other chains. If even a relatively small amount of D-enantiomer (of either lactic acid or lactide), such as about 3 to about 4 weight percent, is copolymerized with L-enantiomer (of either lactic acid or lactide), the polymer backbone generally becomes irregularly shaped enough that it cannot line up and orient itself with other backbone segments of pure L-enantiomer polymer, thus reducing the crystallinity of the polymer, which in turn can decrease the bonding temperature at which the polymer forms satisfactory bonds below a defined value. In various embodiments, the inclusion of a nucleating agent can increase the crystallinity of a polymer component.

[0038] In various embodiments, a melt flow index measurement is used to define an aliphatic polyester. Tests known in the art can be used to measure the melt flow index of a polymer component. For example, melt flow test ASTM D1238 can be used to determine the melt flow index of a polymer component.

[0039] Additionally, aliphatic polyesters can be defined by their molecular weight. Molecular weight can refer to the length of each polymer chain. Thus, the first and second polymer components may have the same or different molecular weights. While a difference in molecular weight can be inherent to the polymer grade, in various embodiments, a polymer component can comprise an additive which causes a reduction of the polymer's molecular weight. In various embodiments, the additive causes the reduction in the polymer's molecular weight during extrusion. In various embodiments, extrusion refers only to the fiber extrusion process (i.e., the additive is added immediately prior to fiber extrusion.) In some embodiments, extrusion refers to a first extrusion wherein the additive can be added into the polymer component to form a compound that is later extruded in a second ex-

trusion to form a fiber. Two or more extrusions can cause a larger reduction in molecular weight than a single extrusion. In various embodiments, the additive can cause a reduction in the polymer component's molecular weight of about 5% or greater, about 10% or greater, or about 15% or greater. Accordingly, in some embodiments, the molecular weights of the first and second polymer components can be substantially identical, and the additive can be utilized to reduce the molecular weight of the first polymer component to achieve a desired molecular weight ratio as otherwise described herein. In various embodiments, the molecular weight ratio of the first polymer after extrusion as compared to before extrusion is less than 1.0 or is about 0.95 or less, about 0.9 or less, or about 0.85 or less.

[0040] A non-limiting example of an additive that can be utilized according to the present disclosure is pentaerythritol, which can be added to a polymer component prior to or during extrusion. Pentaerythritol reduces the molecular weight of condensation polymers such as esters by hydrolysis. In preferred embodiments, the first polymer component can be blended with about 0.5% to about 8% by weight or about 1.5% to about 4.5% by weight of pentaerythritol prior to or during extrusion. Other, non-limiting examples of additives that can be included in a polymer component to reduce the molecular weight of the polymer component include water, sodium hydroxide, hydrated alumina trihydrate, ethylene glycol, and the like.

[0041] In some embodiments, an additive can be utilized that improves bonding performance of a multicomponent fiber without necessarily reducing the molecular weight of a polymer component. For example, plasticizers such as an aliphatic diester and/or a polyhydroxyalkanoate ("PHA") can be included in a PLA polymer component. Such additives can be blended with a polymer component prior to or during extrusion, as described above.

[0042] As further described herein, the fibers of the present invention can be particularly useful as a binder fiber or can be adapted for improved bonding, particularly in bonding methods such as air bonding. Accordingly, in various embodiments it is desirable for the second polymer component to have a melting temperature that is greater than a softening temperature of the first polymer component. The second polymer component can be selected to provide strength or rigidity to the fiber and, thus, to nonwoven structures comprising the multicomponent fiber. Strength or rigidity of the fiber is generally achieved by selecting a second polymer component having a thermal melting temperature greater than the softening temperature of the first polymer component. Thus, when the multicomponent fiber is subjected to an appropriate bonding temperature, typically greater than the softening temperature of the first polymer component but less than the melting temperature of the second polymer component, the first polymer component will soften and preferably flow while the second polymer component will gen-

erally maintain its rigid form. This is especially desirable in the preferred sheath/core arrangement described above. Furthermore, by the second polymer component not melting at the target bonding temperature, the fibrous shape of the multicomponent fiber can be maintained.

[0043] A PLA binder fiber undergoing an air-bonding process can suffer from heat shrinkage since the fiber cannot be heatset at or above a temperature at which the binder component will soften or flow, yet in bonding, the fiber must be exposed to temperatures high enough to achieve the desired melt flow characteristics of the binder component. The heat shrinkage mainly occurs due to the thermally-induced chain relaxation of the polymer segments that are present in the amorphous phase. At bonding temperatures then, significant heat shrinkage is typically observed. This is a particular problem with PLA because its shrinkage force is known in the art to be relatively high. Thus, when such fiber is utilized in forming a heat bonded fabric, the shrinking binder fiber is more likely to cause holes or non-uniformities in the fabric as it shrinks. According to the present invention, however, using a PLA with a relatively high L-isomer purity in the core of a multicomponent fiber can significantly lower shrinkage of the fiber.

[0044] Accordingly, a polymer component useful in the present invention can be defined by a D-isomer content, as discussed above. Specifically, the L-isomer purity of a PLA polymer component can affect the melting characteristics of the polymer. The melting characteristics of the respective polymers thus can be defined by the isomeric content of the polymeric components. In various embodiments, the isomeric purity of the second polymer component is higher than the isomeric purity of the first polymer component. For example, a first polymer component of the multicomponent fiber described herein can be a fiber component that softens or flows at a target bonding temperature while a second polymer component does not substantially soften, flow, or melt at the same target bonding temperature. Therefore, the first polymer component can comprise a fully amorphous PLA with a bonding temperature that is at or below a defined value. In various embodiments, the first polymer component can comprise polylactic acid defined by a D-isomer content of about 2% or more, about 3% or more, about 4% or more, or about 5% or more. In a preferred embodiment, the first polymer sheath component is an amorphous PLA that can be modified such that the first polymer sheath component softens or flows more readily at the target bonding temperature. In some embodiments, a semicrystalline PLA (i.e. with a D content below about 5%) can be a useful binder sheath in combination with a PLA core polymer of high L-isomer purity. For example, a non-bonding (second) polymer component comprising a roughly equal blend of relatively pure PLA with relatively pure PDLA (conventionally known as a "stereocomplex") has a sufficiently high melt temperature such that a semicrystalline PLA with a D-content of about 0.1% to about 5% can be used as the first (bonding) polymer compo-

nent.

[0045] In various embodiments the second polymer component comprises a semicrystalline PLA. In some embodiments, the second polymer component comprises a PLA stereocomplex. In some embodiments, the second PLA polymer component preferably comprises only a small amount of D-isomer such that the melting point of the second polymer component is not decreased below a defined value. Moreover, the second polymer component (e.g., a core polymer component) can comprise PLA with a D-isomer content of about 2.0% or less, about 1.2% or less, about 1.0% or less, about 0.8% or less, or about 0.6% or less. As described, D-isomer content of a core component polymer can beneficially reduce heat shrinkage of the fiber. Accordingly, in light of the foregoing, D- and L- isomer content of the first and second polymer components can be combined such that a fiber formed therewith exhibits a heat shrinkage value of less than 20%, preferably less than 15% and most preferably less than about 10% when exposed to air at a temperature of about 130°C for a time of approximately 5 mins. The inclusion of a nucleating agent can also increase the crystallinity of the second polymer component.

[0046] Additionally, a polymer component can be defined by a melting temperature, particularly relative melting temperatures. In some embodiments, the second polymer component has a melt temperature of about 160°C or greater, although further melt temperature points can be utilized depending upon the desired processing conditions. Preferably, the first polymer component has a bonding temperature that is significantly below the melt temperature of the second polymer component such that softening or flowing of the first polymer component occurs at a temperature that does not significantly soften or melt the second polymer component. If desired, additional additives can be added to the polymer components in order to differentiate the melting characteristics of two PLA components. In some embodiments, the first polymer component comprises an additive suitable to reduce the bonding temperature of the first polymer component.

[0047] As discussed above, melt flow index is another property that can be used to distinguish between two PLA polymer components. In various embodiments first polymer component has a melt flow index of about 30 or greater when tested according to melt flow test ASTM D1238 at a temperature of 210°C and using a 2160g basis weight. In an embodiment, the first polymer component has a melt flow index of about 45 or greater under the same test conditions. In a preferred embodiment, the first polymer component has a melt flow index of about 60 or greater under the same test conditions.

[0048] Each of the thermobondable first polymer component and second polymer component can optionally include other components not adversely affecting the desired properties thereof. Exemplary materials which could be used as additional components would include, without limitation, pigments, antioxidants, stabilizers, surfactants, waxes, flow promoters, solid solvents, par-

ticulates, and other materials added to enhance processability of the first and the second components. For example, a stabilizing agent may be added to the biodegradable polymer to reduce thermal degradation which might otherwise occur during the polylactic acid spinning process. The use of such stabilizing agents is disclosed in U.S. Patent No. 5,807,973, hereby incorporated in its entirety by reference. Further, additives which enhance the biodegradability of the polylactic acid may optionally be included, as disclosed in U.S. Patent No. 5,760,144, previously incorporated by reference. These and other additives can be used in conventional amounts.

[0049] If desired, a fiber according to the present disclosure can comprise one or more further polymers selected from any of the types of polymers known in the art that are capable of being formed into fibers, including polyolefins, polyesters, polyamides and the like. Examples of suitable polymers include, without limitation, polyolefins including polypropylene, polyethylene, polybutene, and polymethyl pentene (PMP), polyamides including nylon, such as nylon 6 and nylon 6,6, polyacrylates, polystyrenes, polyurethanes, acetal resins, polyethylene vinyl alcohol, polyesters including aromatic polyesters, such as polyethylene terephthalate, polyethylene naphthalate, polytrimethylene terephthalate, poly(1,4-cyclohexylene dimethylene terephthalate) (PCT), polyphenylene sulfide, thermoplastic elastomers, polyacrylonitrile, cellulose and cellulose derivatives, polyaramids, acetals, fluoropolymers, copolymers and terpolymers thereof and mixtures or blends thereof.

[0050] Further examples of aromatic polyesters include (1) polyesters of alkylene glycols having 2-10 carbon atoms and aromatic diacids; (2) polyalkylene naphthalates, which are polyesters of 2,6-naphthalenedicarboxylic acid and alkylene glycols, as for example polyethylene naphthalate; and (3) polyesters derived from 1,4-cyclohexanedimethanol and terephthalic acid, as for example polycyclohexane terephthalate. Exemplary polyalkylene terephthalates include without limitation, polyethylene terephthalate (also PET) and polybutylene terephthalate.

[0051] In a preferred embodiment, the multicomponent fiber is a concentric sheath/core binder fiber with a core component (the second polymer component) comprising about 50% of the fiber's cross-sectional area. The second polymer component can comprise semicrystalline PLA with a D-isomer content of about 2.0 % or less and a corresponding melt temperature of 160°C or higher. A sheath component (the first polymer component) can comprise about 50% of the fiber's cross-sectional area and can comprise fully amorphous PLA with a D-isomer content of about 8% or more. In some embodiments, the sheath component can be blended with about 0.5% to about 4.5% by weight of pentaerythritol prior to or during extrusion.

[0052] Methods for making multicomponent fibers are well known and need not be described here in detail. Generally, to form a multicomponent fiber, at least two

polymers are extruded separately and fed into a polymer distribution system wherein the polymers are introduced into a segmented spinneret plate. The polymers follow separate paths to the fiber spinneret and are combined in a spinneret hole. The spinneret is configured so that the extrudant has the desired shape.

[0053] Following extrusion through the die, the resulting thin fluid strands, or filaments, remain in the molten state for some distance before they are solidified by cooling in a surrounding fluid medium, which may be chilled air blown through the strands. Once solidified, the filaments are taken up on a godet or another take-up surface. In a continuous filament process, the strands are taken up on a godet which draws down the thin fluid streams in proportion to the speed of the take-up godet. In the jet process, the strands are collected in a jet, such as for example, an air gun, and blown onto a take-up surface such as a roller or a moving belt to form a spunbond web. In the meltblown process, air is ejected at the surface of the spinneret which serves to simultaneously draw down and cool the thin fluid streams as they are deposited on a take-up surface in the path of cooling air, thereby forming a fiber web. Regardless of the type of melt spinning procedure which is used, it is important that the thin fluid streams be melt drawn down in a molten state, i.e. before solidification occurs, to reduce the diameter of the fibers. Typical melt draw down ratios known in the art may be utilized. Where a continuous filament or staple process is employed, it may be desirable to draw the strands in the solid state with conventional drawing equipment, such as, for example, sequential godets operating at differential speeds. See, for example, U.S. Pat. No. 5,082,899, incorporated herein by reference in its entirety.

[0054] Following drawing in the solid state, the continuous filaments may be crimped or texturized and cut into a desirable fiber length, thereby producing staple fiber. The length of the staple fibers generally ranges from about 25 to about 50 millimeters, although the fibers can be longer or shorter as desired. See, for example, U.S. Pat. No. 4,789,592 to Taniguchi et al. and U.S. Pat. No. 5,336,552 to Strack et al., each of which is herein incorporated by reference in its entirety.

[0055] The multicomponent fibers of the invention can be staple fibers, tows, spunbond filaments, continuous filaments, or meltblown fibers. In general, staple, multifilament, and spunbond fibers formed in accordance with the present invention can have a fineness of about 0.5 to about 100 denier. Meltblown filaments can have a fineness of about 0.001 to about 10.0 denier. Monofilament fibers can have a fineness of about 50 to about 10,000 denier.

[0056] As noted above, the multicomponent fibers can be incorporated into a nonwoven fabric. The fibers of the present invention may be formed into nonwoven webs by any means suitable in the art, particularly wherein heat bonding is used. In addition, continuous filament may be spun directly into nonwoven webs by a spunbonding

process. Fibers other than the multicomponent fibers of the invention may be present as well, including any of the various synthetic and/or natural fibers known in the art. Exemplary synthetic fibers include polyolefin, polyester, polyamide, acrylic, rayon, cellulose acetate, thermoplastic multicomponent fibers (such as conventional sheath/core fibers, for example polyethylene sheath/polyester core fibers) and the like and mixtures thereof. Exemplary natural fibers include wool, cotton, wood pulp fibers and the like and mixtures thereof.

[0057] The multicomponent fibers of the invention particularly may be incorporated, alone or in conjunction with other fibers, into a meltblown nonwoven fabric. The technique of meltblowing is known in the art and is discussed in various patents, e.g., Buntin et al., U.S. Patent No. 3,987,185; Buntin, U.S. Patent No. 3,972,759; and McAmish et al., U.S. Patent No. 4,622,259, each of which is herein incorporated by reference in its entirety. Other thermal bonding means known in the art can be used as well.

[0058] Thus, when the multicomponent fiber is subjected to an appropriate bonding temperature, at which the first polymer component is capable of forming suitable bonds, but less than the melting temperature of the second polymer component, the first component will soften or melt while the second component will generally maintain its rigid form. The multicomponent fibers described herein are particularly suited for an air-bonding process wherein heated air (typically in the absence of added pressure) is used to thermally bond the fibers or a fabric formed therewith. This includes through-air bonding and radiant-heat bonding. In various embodiments, a plurality of multicomponent fibers as described herein can be air bonded at a temperature of approximately 80°C to approximately 220°C. In a preferred embodiment, a plurality of multicomponent fibers as described herein can be air bonded at a temperature of approximately 130°C. Other bonding means, such as calendar bonding or other pressure driven bonding processes for example, also can be used to form a fabric from the multicomponent fibers described herein.

[0059] Nonwoven fabrics which include the multicomponent fibers of the invention as a component are particularly suited for use in disposable products. Specific examples include without limitation disposable diapers, adult incontinent products, sanitary napkins, tampons, wipes, bibs, wound dressings, and surgical capes or drapes.

[0060] As discussed above, multicomponent fibers according to the present disclosure can be particularly beneficial in providing improved bonding characteristics, particularly in methods such as through air bonding. The ability to prepare a fiber per the present disclosure that performs suitably in an air bonding process can be evaluated according to multiple different standards. As such, it is expected that one of skill in the art with the knowledge of the present disclosure can utilize polymer components having characteristics as described herein to form mul-

ticomponent fibers that fall within the various standards. The following description is thus provided so that one can clearly evaluate a given fiber in relation to the presently disclosed fibers and should not be construed as limiting the presently disclosed fibers to only specific embodiments.

[0061] One test suitable for evaluating a fiber according to the present invention relates to the tensile strength of a thermally bonded nonwoven web or fabric formed using a multicomponent fiber as disclosed herein as the sole bonding agent. Specifically, tensile strength can be evaluated in relation to a carded nonwoven fabric comprising 75% PLA 6202D fiber (manufactured by Fiber Innovation Technology) and 25% by weight of the present multicomponent bonding fibers, wherein the final fabric is air bonded through a 12 second dwell time in a bonding oven at a temperature of 130 °C. An air bonded, nonwoven formed using multicomponent fibers described herein as the binder fiber preferably exhibits a tensile strength of about 500 grams force to about 4500 grams force per gram of fabric weight when evaluated in the cross direction. In some embodiments of an air bonded, nonwoven formed using multicomponent fibers described herein as the binder fiber, the nonwoven exhibits a tensile strength of about 150-670 grams force for a fabric sample measuring about 1.5 inches in length and about 2 inches in width, and having a weight of about 0.1 to about 0.3 grams, when evaluated in the cross direction. One test method for carrying out such evaluation is described in the Example.

[0062] A further test suitable for evaluating a fiber according to the present invention relates to the melt flow index of one or more components of the fiber. Particularly, the first polymer component has a melt flow index of about 30 or greater when evaluated according to melt flow test ASTM D1238 at a temperature 210°C and using a 2160g basis weight. In various embodiments, the melt flow index of the first polymer component is about 45 or greater, or about 60 or greater.

[0063] Yet another means for evaluating a fiber according to the present invention relates to the specific nature of the material used to form the fiber. Specifically, in various embodiments the multicomponent fiber comprises a first polymer component that is fully amorphous PLA having a first molecular weight. The multicomponent fiber further comprises a second polymer component that is a semicrystalline PLA having a second molecular weight and a melt temperature of at least 150°C. In various embodiments, the first polymer component can further comprise an additive that can cause a reduction in the first polymer component's molecular weight of about 5% or greater, about 10% or greater, or about 15% or greater.

EXAMPLE

[0064] An exemplary, non-limiting PLA binder fiber bonding test is described, such that the sensitivity of bond strength to bonding temperature at a 12 second dwell

time in the bonding oven of a carded nonwoven fabric comprising 75% PLA 6202 fibers (available from NatureWorks, LLC) and 25% experimental binder fibers can be determined. Each test sample (a carded nonwoven fabric measuring 3 inches by 2 inches, with the 2 inch dimension in the direction of carding (i.e., parallel to the fiber direction) can be prepared as follows. First, 1.5 g of crimped PLA staple fiber made using Natureworks grade 6202D, 2 denier per filament, 1.5 inch cut length (the "matrix" fiber) can be prepared. Also, 0.5 g of binder fiber (as disclosed herein) can be weighed. The two fiber samples are placed on a hand card, being careful to distribute both fibers as evenly across the card as possible. Ideally, the matrix fiber goes onto the card first, since the experimental fiber may be uncrimped and thus is prone to falling down between the card teeth. The hand cards are used to create a uniform blend of the two fibers. This can take several minutes of carding, including multiple instances of removing the fiber mass from the card and repositioning it before continuing with carding. Any binder fibers that are left out of the mass from falling through the card teeth ("strays") are retrieved, put back into the fiber mass, and blended smoothly into it. When the fiber web is uniform and thoroughly carded, the fiber mass is removed as a single "fabric," taking care to preserve the uniformity of the "fabric." Using a paper template, 1.5 in. x 2 in. test samples are cut from the "fabric," ensuring that the entire cut out sample has a roughly uniform fabric density and fiber distribution throughout the sample. There can inevitably be feathery, low-density and low-uniformity edges to the fabric, so these edges preferably are avoided and thus not included in the cut-out samples. The samples are oriented such that the 2 inch direction is parallel with the width of the card and the 1.5 inch direction is parallel with the fibers. The weight of each sample is then measured and recorded.

[0065] Once adequate samples have been prepared according to the method above or similar methods, the bond strength of the fibers is tested. An oven is heated to a test temperature of 130 °C, and 10 fabric samples are exposed to the test temperature for approximately 12 seconds. Due to the short exposure time, there can be some reduction in oven temperature as a result of opening and closing the door. Therefore, the oven is allowed to regain the test temperature between sample exposures. After bonding, each sample is cooled to room temperature and then the tensile strength is tested by pulling along a sample's 2 inch axis. This axis can be less than 2 inches after bonding due to shrinkage. Pulling along the fiber direction is avoided since this will typically only test the strength of the fibers and not the actual bond strength. Measured tensile strengths can be plotted against the sample's weight to normalize any varying tenacities.

[0066] Many modifications and other embodiments of the invention will come to mind to one skilled in the art to which this invention pertains having the benefit of the teachings presented in the foregoing description. There-

fore, it is to be understood that the invention is not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

Claims

1. A multicomponent fiber having an exposed surface comprising:

a first polymer component comprising a first aliphatic polyester, wherein the first polymer component forms at least a portion of the exposed surface of the multicomponent fiber; and a second polymer component comprising a second aliphatic polyester; wherein about 5% or greater of the exposed surface of the multicomponent fiber is defined by the first polymer component; and wherein the multicomponent fiber has a cross-sectional area comprising the first polymer component and the second polymer component in a ratio of about 1:9 to about 9:1.

2. The multicomponent fiber of claim 1, wherein the fiber is selected from the group consisting of continuous filaments, staple fibers, spunbond, and meltblown fibers.

3. The multicomponent fiber of claim 1, wherein one or both of the first polymer component and the second polymer component is polylactic acid.

4. The multicomponent fiber of claim 1, wherein one or both of:

the first polymer component comprises a fully amorphous polylactic acid having a D-isomer content of about 5% or greater; the second polymer component comprises a semicrystalline polylactic acid having a D-isomer content of about 2% or less.

5. The multicomponent fiber of claim 1, wherein the first polymer component comprises an additive adapted to reduce the bonding temperature of the first polymer component, wherein the additive is present in an amount sufficient to reduce the bonding temperature of the first polymer component by about 10°C or more.

6. The multicomponent fiber of claim 1, wherein the first polymer component is defined by a first molecular weight, and wherein the first polymer component

comprises an additive in an amount sufficient to reduce the first molecular weight to a first reduced molecular weight.

7. The multicomponent fiber of claim 6, wherein the first reduced molecular weight is less than the first molecular weight by about 10% or more; or wherein the ratio of the first reduced molecular weight to the first molecular weight is about 0.9 or less.

8. The multicomponent fiber of claim 7, wherein the additive is selected from the group consisting of pentaerythritol, water, sodium hydroxide, hydrated alumina trihydrate, ethylene glycol, and combinations thereof; or wherein the first polymer component comprises about 0.5% to about 8.0% by weight of pentaerythritol.

9. The multicomponent fiber of claim 1, wherein the first polymer component has a melt flow index of about 30 or greater when evaluated according to melt flow test ASTM D1238 at a temperature 210°C and using a 2160g basis weight.

10. The multicomponent fiber of claim 1, wherein the second polymer component has a melt temperature of about 160°C or greater.

11. The multicomponent fiber of claim 1, wherein the first polymer component is defined by a first molecular weight, wherein the second polymer component is defined by a second molecular weight, and wherein the ratio of the first molecular weight to the second molecular weight is about 0.9 or less.

12. The multicomponent fiber of claim 1, wherein the fiber exhibits a shrinkage of less than 20% after exposure to a temperature of 130 °C for 5 minutes.

13. The multicomponent fiber of claim 1, wherein the fiber is adapted to impart a bonded web strength of about 150 grams force or greater for a bonded nonwoven comprising the multicomponent fiber as the sole bonding agent, wherein the bonded web strength is evaluated in relation to a carded nonwoven web of 75% PLA 6202D fiber and 25% by weight of the multicomponent fiber, the web having a length of about 1.5 inches, a width of about 2 inches, and a weight of about 0.1 to about 0.3 grams, and the web being air bonded with a 12 second residence time in a bonding oven at a temperature of 130 °C.

14. A fabric comprising a plurality of thermally bonded multicomponent fibers according to claim 1, particularly wherein the fabric exhibits a tensile strength of about 500 grams force or greater per gram of fabric weight, or wherein the fabric exhibits a tensile strength of about 150 grams force or greater for a

fabric sample having a length and width of about 1.5 inches and about 2 inches, respectively, and having a weight of about 0.1 to about 0.3 grams.

15. A method of forming a nonwoven fabric comprising: 5

providing a plurality of multicomponent fibers each with an exposed surface, wherein each multicomponent fiber comprises a first polymer component and a second polymer component, and wherein the first polymer component forms at least a portion of an exposed surface of each multicomponent fiber; and 10
thermal air bonding the plurality of multicomponent fibers, wherein the bonding is carried out at temperature of about 80°C to about 220 °C, and wherein the second polymer component has a melting temperature that is greater than the bonding temperature. 15

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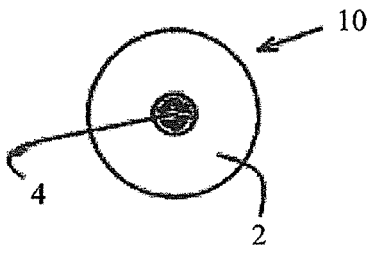


FIG. 1

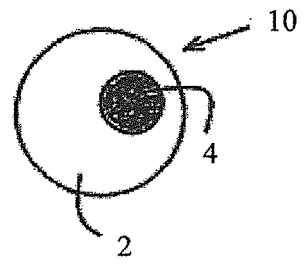


FIG. 2

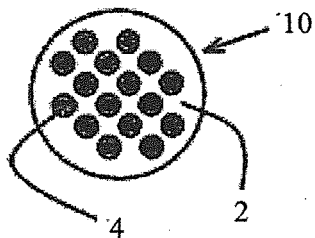


FIG. 3

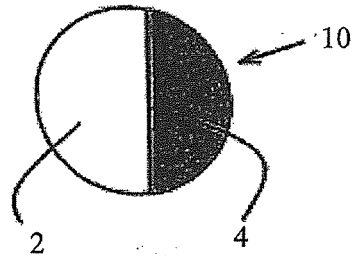


FIG. 4

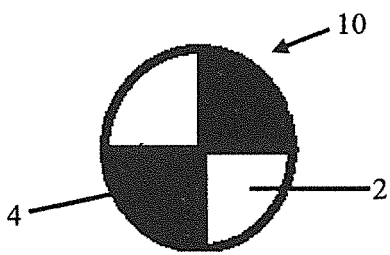


FIG. 5

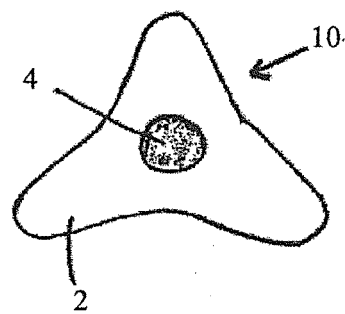


FIG. 6



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Place of search The Hague		Date of completion of the search 3 July 2015	Examiner Malik, Jan
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