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(54) Filament nonwoven fabrics and method of fabricating the same

(57) The invention concerns a nonwoven fabric made up of filaments comprised of a polylactic acid-based polymer, wherein the polylactic acid-based polymer is a polymer selected from copolymers of D-lactic acid and L-lactic acid, copolymers of D-lactic acid and hydroxy-carboxylic acid, and copolymers of L-lactic acid and hydroxy-carboxylic acid, said polymer having a melting point of 100°C or more, or being a blend of such polymers having a melting point of 100°C or more. The constituent filaments of the nonwoven fabric are partially fusion bonded with heat and pressure by embossing or ultrasonic fusion, wherein said fusion bonding is present in spottedly configured individual fusion bonded areas. The invention also concerns a method of fabricating a nonwoven fabric made up of filaments comprised of a polylactic acid-based polymer.

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Description

FIELD OF THE INVENTION

[0001] The present invention relates generally to filament nonwoven fabrics which are degradable due to microorganisms and the like in natural environments and a method of manufacturing the same. More particularly, the invention relates to a degradable filament nonwoven fabric which can be produced from a biodegradable polymer composed principally of a thermoplastic aliphatic polyester under particular conditions, and a method of manufacturing the same.

BACKGROUND OF THE INVENTION

[0002] Hitherto, nonwoven fabrics which are degradable due to microorganisms have been known including, for example, biodegradable nonwoven fabrics made from natural or regenerated filaments, such as cotton, flax, hemp, ramie, wool, rayon, chitin, and alginic acid filaments.

[0003] However, such degradable nonwoven fabrics, which are generally hydrophilic and water absorptive, are not suitable for use in such an application as disposable diaper top sheet, wherein it is required that the fabric be hydrophobic and less water absorptive and should have a dry feel when it gets wet. Another problem is that such nonwoven fabrics are very much liable to deterioration in strength and dimensional stability under wet environmental conditions; and this has limited the possibility of exploiting new uses for such nonwoven fabrics in general industrial material applications. Further, such nonwoven fabrics, because of their non-thermoplastic nature, have no thermoformability and are therefore less processable.

[0004] Recently, therefore, research and development efforts have been positively made for microbially degradable filaments which may be obtainable by the melt spinning technique from a microbially degradable polymer having thermoplastic and hydrophobic characteristics, and microbially degradable nonwoven fabrics made up of such filaments. In particular, a group of polymers generally called aliphatic polyesters are attracting high attention because they have microbial degradation characteristics. Specifically, such polymers include, for example, poly-β-hydroxyalkanoate as represented by microbially degradable polyester, poly-ω-hydroxyalkanoate as represented by polycaprolactone, polyalkylene dicarboxylate composed of a polycondensate of glycol and dicarboxylic acid, such as polybutylene succinate, or copolymers of these polymers. In such situation, and with recent development of a new polymerization process which can efficiently produce polymers of high polymerization degree, various attempts have been made to produce filaments from poly-α-oxyacid, a polymeric product as represented by poly-L-lactic acid, and nonwoven fabrics comprised of such filaments. Of aforesaid aliphatic polyesters, polylactic acid in particular has a relatively high melting point such that, when a nonwoven fabric comprised of that material would prove to be very useful in applications which require heat resistance. As such, much expectation is now entertained for possibilities of polylactic nonwoven fabrics for practical use.

[0005] A polylactic nonwoven fabric is already disclosed in JP-A-7-126970 in which is described a staple filament nonwoven fabric composed principally of polylactic acid. In JP-A-6-212511 there is given a teaching about a polylactic staple filament material useful for the manufacture of polylactic staple filament nonwoven fabrics. However, the manufacture of such a staple filament nonwoven fabric involves many operating stages, from melt spinning and up to nonwoven fabric forming; and this poses a problem from the standpoint of production cost economy.

[0006] Whilst, in a number of publications, including JP-A-7-48769, JP-A-6-264343, International Nonwovens Journal, Vol. 7, No. 2, pp 69 (1995), and EP 0637641 (A1), suggestions are given for fabrication of filament nonwoven fabrics from polylactic acid under the so-called spun bond technique in which filaments are extruded by melt extrusion for being formed into webs deposited on a screen. However, in JP-A-7-48769, a suggestion is simply given that a nonwoven fabric can be produced from polylactic acid-based polymers by employing the spun bond technique, with no particular mention made as to any specific process for fabrication of such a fabric and the properties of the nonwoven fabric to be obtained. In JP-A-6-264343, which pertains to a biodegradable agricultural filament assembly, there is no detailed statement as to such important manufacturing conditions as filament drafting speed, and other necessary particulars, nor is there any teaching on the properties of the nonwoven fabric produced. The teaching of International Nonwovens Journal, Vol. 7, No. 2, pp 69 (1995) is merely such that hard and brittle plate-like, polylactic spun bonded fabrics were obtained. In EP 0637641 (A1), there is no teaching that a polylactic spun bonded fabric having good flexibility and high mechanical strength can be produced.

DISCLOSURE OF THE INVENTION

[0007] The present invention is intended to solve the foregoing problems and has as its primary object the provision of a polylactic filament nonwoven fabric degradable due to microorganisms and the like in natural environments and yet having sufficient mechanical strength for practical use.

[0008] In order to accomplish this object, according to the present invention there is provided a nonwoven fabric made up of filaments comprised of a polylactic acid-based polymer, wherein the polylactic acid-based polymer is a polymer selected from the group consisting of poly(D-lactic acid), poly(L-lactic acid), copolymers of D-lactic acid and L-lactic acid, copolymers of D-lactic acid and hydroxy-carboxylic acid, and copolymers of L-lactic acid and hydroxy-carboxylic acid, said polymer having a melting point of 100°C or more, or a blend of such polymers having a melting point of 100°C or more, characterized in that constituent filaments of the nonwoven fabric are partially fusion bonded with heat and pressure by embossing or ultrasonic fusion, wherein said fusion bonding is present in spottedly configured individual fusion bonded areas.

[0009] In the nonwoven fabric, it is preferable that constituent filaments of the nonwoven fabric are partially bonded with heat and pressure. According to such construction, polylactic acid-based polymer filaments are not joined together at their intersections but are partially bonded with heat and pressure, whereby the nonwoven fabric is allowed to retain its form as such. Therefore, in contrast to known nonwoven fabrics formed with polylactic acid-based polymers, which are characteristically hard and brittle, the nonwoven fabric of the invention has good flexibility while retaining sufficient mechanical strength for practical purposes. Further, being comprised of polylactic acid-based polymer filaments, the nonwoven fabric is well degradable under natural environmental conditions.

[0010] According to the present invention, there is also provided a method of fabricating a nonwoven fabric made up of filaments comprised of a polylactic acid-based polymer, comprising the steps of melting a polymer selected from the group consisting of poly(D-lactic acid), poly(L-lactic acid), copolymers of D-lactic acid and L-lactic acid, copolymers of D-lactic acid and hydroxy-carboxylic acid, and copolymers of L-lactic acid and hydroxy-carboxylic acid, said polymer having a melting point of 100°C or more, or a blend of such polymers having a melting point of 100°C or more, said polymer or polymer blend having a melt flow rate of 10 to 100 g/10 minutes as measured at 190°C according to ASTM-D-1238 (E), in a temperature range of from (Tm + 20)°C to (Tm + 80)°C, where Tm°C is the melting point of the polymer or polymer blend; extruding the melt through a spinneret into filaments; drafting the extruded filaments by means of a suction device at a drafting speed of from 1,000 to 5,000 m/minute, thereby fining them down into finer filaments; depositing such filaments, as they are spread open each other, and are laid up on a travelling collector surface to form a web; and partially fusion bonding the filaments with heat and pressure by embossing or ultrasonic fusion, in which said fusion bonding is present in spottedly configured individual fusion bonded areas, thereby to obtain the nonwoven fabric.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Figs. 1 through 6 are illustrations showing, by way of example, different cross-sectional configurations of constituent filaments of nonwoven fabrics in accordance with the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0012] Filaments employed in the present invention are comprised of a polylactic acid-based polymer.

[0013] For the polylactic acid-based polymer is used a polymer having a melting point of 100°C or more selected from the group consisting of poly(D-lactic acid), poly(L-lactic acid), copolymers of D-lactic acid and L-lactic acid, copolymers of D-lactic acid and hydroxy-carboxylic acid, and copolymers of L-lactic acid and hydroxy-carboxylic acid, the selected polymer having a melting point of 100°C or more, or a blend of such polymers.

[0014] Where a homopolymer such as poly(D-lactic acid) or poly(L-lactic acid) is used as a polylactic acid-based polymer, it is desirable that a plasticizer be added thereto especially for enhancement of spinnability during the process of spinning and flexibility improvement with respect to the resulting filaments and nonwoven fabric. Examples of useful plasticizers for such purposes include triacetin, lactic acid oligomers, and dioctyl phthalate. The amount of addition of such a plasticizer should be from 1 to 30 % by weight, preferably from 5 to 20 % by weight.

[0015] In the present invention, from the view points of heat resistance and related performance of the nonwoven fabric to be obtained, it is preferable that the melting point of constituent filaments of the nonwoven fabric is 100°C or more. Therefore, it is important that the melting point of the polylactic acid-based polymer, a constituent material of the filaments, be 100°C or more. More specifically, whereas the melting point of poly(L-lactic acid) or poly(D-lactic acid) as a polylactic homopolymer is about 180°C, it is important that, where any of aforesaid copolymers is used as a polylactic acid-based polymer, the copolymerization molar ratio of monomer components must be determined so as to enable the copolymer to have a melting point of 100°C or more. If the copolymerization molar ratio of L-lactic acid or D-lactic acid in the copolymer is lower than a specified range, the melting point of the polylactic polymer is and, in turn, the melting point of constituent filaments of the nonwoven fabric is lower than 100°C, or the polymer may become an amorphous polymer. As such, the quenching effect of filaments in the spinning stage is lowered, and this adversely affects nonwoven fabrics formed from such filaments in respect of heat resistance, with the result that the range of applications for such a nonwoven fabric is limited.

[0016] Where the polylactic acid-based polymer is a copolymer of lactic acid and hydroxy-carboxylic acid, examples of hydroxy-carboxylic acid include glycolic acid, hydroxybutanoic acid, hydroxyvaleric acid, hydroxypentanoic acid, hydroxycaproic acid, hydroxyheptanoic acid, and hydroxyoctanoic acid. Of these, hydroxycaproic acid or glycolic acid is particularly preferred from the standpoints of microbial degradation performance and cost economy.

[0017] The above enumerated polylactic acid-based polymers may be used alone or in the form of a blend of two or more kinds. In case that such polymers are used in the form of a blend, conditions such as polymers to be mixed and mixing proportions may be suitably determined in consideration of spinnability and other factors.

[0018] Such polymers each may be added with various additives, such as dulling agent, pigment, and crystallizing agent, as required within the limits in which the advantageous feature of the invention will not be affected.

[0019] The cross section of each constituent filament of the nonwoven fabric may have any cross-sectional configuration, such as solid and otherwise. More specifically, it is preferable that the filament has one of such cross-sectional configurations as hollow section, odd-shaped section, sheath-core type composite section, and slit type composite section.

[0020] Fig. 1 shows a cross sectional view in which filament 1 has a hollow cross section. Reference numeral 2 designates a filament portion, and 3 designates a hollow portion. Where a nonwoven fabric is made up of filaments having such a hollow section, the nonwoven fabric has good degradation capability. The reason is that as microorganisms and moisture erode inward from the outer circumferential portion for entry into the hollow portion 3 through holes formed in the filament portion 2 so that the surface area per unit polymer weight is so enlarged as to enhance the rate of degradation by microorganisms and the like. Further, it is significant to note that a filament having an hollow section exhibits good performance for enhancement of quenching efficiency with respect to filaments spun, because per-unit-time polymer passage through a quenching region during spinning operation is relatively small in weight terms, and because the filament contains therein air bubbles of a small specific heat.

[0021] Where the filament has a polygonal odd-shaped cross section or a planar odd-shaped cross section as shown in Figs. 2 and 3, such sectional configuration can enhance filament quenching and spreading-open efficiency in the spinning stage, and can provide improved degradability with respect to the nonwoven fabric to be obtained. The reason for this is that where a filament has an odd-shaped sectional configuration, the filament provides a larger surface area per unit polymer weight.

[0022] In case that the filament cross section is a sheath-core type composite section, it is important that after at least one of a polylactic acid-based polymer and a blend of plural kinds of polylactic acid-based polymers is chosen as one filament component, filaments of a sheath-core structure be formed of two kinds of components including the one filament component, the two kinds of components being arranged in such a manner that one having a higher melting point (hereinafter referred to as high melting point component) is used to assume a core position, the other of a lower melting point (hereinafter referred to as low melting point component) being used to assume a sheath position. In this case, it is also important that between the two components there must be a melting point difference of at least 5°C or more, preferably 10°C or more, more preferably 20°C or more. It is to be noted, however, that where two or more kinds of polylactic acid-based polymer blends are used as core component(s) and/or sheath component (s), the melting point difference between the core and sheath components is determined in such a manner that for the core component, the melting point of one of the constituent polymers of the blend which has a lowermost melting point is taken as a basis, whereas for the sheath component, the melting point of one of the constituent polymers of the blend which has the highest melting point is taken as a basis. Through this arrangement, for the purpose of bonding a web with heat and pressure, it is possible to carry out such bonding operation at a comparatively low temperature, say at a temperature close to the melting point of the sheath component, without causing fusion to the high melting point component of the core portion. Therefore, the resulting nonwoven fabric can have good flexibility.

[0023] In case that the filament cross section is a split type composite section, a nonwoven fabric formed from filaments of such a cross-sectional configuration can exhibit good degradability and good flexibility. The term "split type composite section" used herein refers to a filament section such that the filament comprises two kinds of filament components arranged in divisions separate from one another in a circumferential direction of the filament section, the two kinds of filament components including at least one of a polylactic acid-based polymer and a blend of plural kinds of polylactic acid-based polymers, chosen as one filament component, wherein both components extend continuously in the longitudinal direction of the filament and are exposed to the exterior of the filament. Specifically, cross-sectional configurations as shown in Figs. 4 to 6 may be exemplified. More particularly, Fig. 4 shows a cross section wherein two components of filament 1, that is, high melting point component 4 and low melting point component 5 have respective radially extending divisions arranged in alternate relation. Fig. 5 shows a cross section wherein low melting point component 5 constitutes a center portion of filament 1 and wherein high melting point component 4 has a plurality of divisions arranged along a circumferential edge of the low melting point component 5 in such a way that they protrude outward of the low melting point component 5. According to these cross sectional filament configurations, division of the filament itself is accelerated as a portion of a component having higher degradability (usually, low melting point component) is degraded. Therefore, a nonwoven fabric formed from filaments of such cross-sectional configuration will have improved degradability. In Fig. 6, there is shown a filament cross section which is similar to the one shown in Fig. 4 but is different in that there is provided an hollow portion 3. Such filament configuration provides for further improvement in degradability, and filament quenching and spreading-open efficiency. Where such split type composite section is used, it is possible as well to carry out fusion bonding in a temperature range near the melting point of low melting point component 5 during the process of web bonding with heat and pressure. In this operation, no fusion is caused to high melting point component 4. Thus, it is possible to obtain a nonwoven fabric having good flexibility.

[0024] In addition to the above described cross-sectional filament configurations, various other odd-shaped composite cross-sectional configurations may be used including, for example, triangular, quadrangular, hexagonal, planar, Y-shaped, and T-shaped.

[0025] In the manufacture of the filament nonwoven fabric of the invention, a web is partially bonded with heat and pressure without individual filaments being joined at intersection points, so that the web can retain a sheet-like configuration of nonwoven structure. Such a nonwoven fabric has good flex properties because the constituent filaments are bonded only in partially formed fusion-bonded areas.

[0026] The single filament fineness of constituent filaments of the nonwoven fabric is preferably in the range of from 1 to 12 denier. If the single filament fineness is less than 1 denier, there may frequently occur single filament breaks in spinning and drafting stages, which results in poor spinning efficiency and lower strength characteristics of nonwoven fabrics obtained. If the fineness is more than 12 denier, quenching effect for filaments spun is insufficient, and the flexibility of filaments obtained is unfavorably affected.

[0027] It is preferable that the nonwoven fabric of the invention be comprised of filaments having a single filament fineness of the above mentioned range, and that weight per unit area of the fabric be within the range of from 10 to 200 g/m^2. If the weight per unit area is less than 10g/m^2, the fabric has poor texture and insufficient mechanical strength and is unsuitable for practical use. If the weight per unit area is more than 200g/m^2, the resulting nonwoven fabric is unfavorably affected in flexibility.

[0028] The nonwoven fabric of the invention preferably has a tensile strength of not less than 5 kg/5cm width as calculated on the basis of weight per unit area 100 g/m^2. The term "tensile strength" used herein means an average value of tensile strength measurements in both machine direction which is parallel to the manufacturing line and crossing direction perpendicular to the machine direction as measured according to JIS-L-1096 as will be described hereinafter, which is proportionally converted on the basis of weight per unit area 100 g/m^2 for evaluation. If the tensile strength of the nonwoven fabric is less than 5 kg/5cm width, the mechanical strength of the fabric is too insufficient and may not serve for practical purposes.

[0029] Next, the method of fabricating a nonwoven fabric of polylactic acid-based polymer filaments in accordance with the present invention will be explained.

[0030] The nonwoven fabric of the invention can be efficiently manufactured by the so-called spun bond process. A polylactic acid-based polymer of the above mentioned type having a melt flow rate of 10-100 g/10 minutes as measured at a temperature of 190°C in accordance with ASTM-D-1238 (E) is melted in a spinning temperature range of from (Tm + 20)°C to (Tm + 80)°C, where Tm°C is the melting point of the polymer, and the melt is spun into filaments through a spinneret which provides a desired filament cross section. The filaments obtained are quenched by means of a conventional quenching device known in the art, such as horizontal blow type or annular blow type, and then the filaments are drafted by a suction device. such as air sucker, in an air stream of from 1,000 to 5,000 m/min. to the desired fineness. Masses of filaments discharged from the suction device are spread open each other and then deposited while being spread open each other on a travelling collector device, such as a screen conveyor, being thus formed into a web. Then, the web formed on the travelling collector device is subjected to heat treatment. A nonwoven fabric is thus obtained.

[0031] It is essential that, as earlier stated, the melt flow rate (hereinafter referred to as MFR value) of the polylactic acid-based polymer composition be within the range of 10-100 g/10 min. when measured at 190°C in accordance with the method described in ASTM-D-1238(E). If the MFR value is less than 10 g/10 min., the melting viscosity is excessively high, which results in poor high-speed spinnability. If the MFR value is more than 100 g/10 min., the melting viscosity is too low, which results in poor drafting ability, it being thus difficult to maintain stable operation.

[0032] In melt spinning operation, as earlier mentioned, the polymer used should be melted within a temperature range of from (Tm + 20) °C to (Tm + 80) °C, where Tm°C is the melting point of the polymer. However, where a blend of two or more kinds of polylactic acid-based polymers is used, Tm °C should be a melting point which is the highest of the melting points of the constituent polymers of the blend. If the spinning temperature is lower than (Tm + 20) °C, drafting operation in high-speed air currents will be of low efficiency. If the spinning temperature is higher than (Tm + 80) °C, some delay will occur in the process of crystallization at the quenching stage, resulting in inter-filament fusion and poor spreading effect, as well as some thermal decomposition of the polymer itself. Therefore, it is difficult to obtain a nonwoven fabric having good flexibility and uniform texture.

[0033] In the process of drafting filaments by means of a suction device to a desired fineness, as already stated, it is important that the drafting speed be within the range of from 1,000 to 5,000 m/min. The drafting speed may be suitably selected according to the MFR value of the polymer. If the drafting speed is less than 1,000 m/min., oriented crystallization of the polymer is retarded, which may result in inter-filament adhesion; and therefore the resulting nonwoven fabric is likely to have hard feel and inferior mechanical strength. If the drafting speed is more than 5,000 m/min., the process of drafting is forced to be carried out in excess of a critical drafting limit, and this results in filament break occurrences, it being thus difficult to maintain stable operation.

[0034] For heat treatment of webs, a partial bonding apparatus with heat and pressure is used to give partial bonding with heat and pressure at a temperature lower than the melting point which is the lowest of the melting points of polymeric components of the filament. The expression "partially bonding with heat and pressure" means formation of fusion bonded areas by embossing or ultrasonic fusion bonding. Specifically, a web is passed through a clearance between a heated embossing roll and a flat surface metal roll for formation of inter-filament fusion bonded areas.

[0035] More particularly, individual bonded areas with heat and pressure, as particular partial areas in a web, each have an area of 0.2 to 15 mm^2 which may be of any configuration, such as circular, elliptic, diamond, triangular, T-shaped, and number sign-shaped. Preferably, the density of distribution of such areas, that is, the density of bonded areas with heat and pressure is within the range of 4 to 100 bonded areas per cm^2. If the density of bonded areas with heat and pressure is less than 4 bonded areas per cm^2, no improvement can be had in the mechanical strength and shape retention capability of the resulting nonwoven fabric. If the density is more than 100 bonded areas per cm^2, the resulting nonwoven fabric is rough and hard and has only poor flexibility. The ratio of total bonded area with heat and pressure to total surface area of the web, that is, pressure bonded area ratio, should be 3 to 50 %, though it depends upon the area of each individual pressure bonded area. If the pressure bonded area ratio is less than 3 %, the resulting nonwoven fabric cannot have improved mechanical strength or improved form retention capability. If the pressure bonded area ratio is more than 50 %, the resulting nonwoven fabric is rough and hard and has only poor flexibility.

[0036] Operating temperature for bonding with heat and pressure, that is, the surface temperature of the embossing roll, as already stated, must be lower than the melting point of the polymer used. However, where the web to be bonded with heat and pressure is formed from filaments comprised of a blend of two or more kinds of polylactic acid-based polymers, or where the web is formed from bicomponent filaments having a composite cross-sectional configuration, for example, such a sheath-core type composite section or a split type composite section as earlier mentioned, the melting point of one polymer whose melting point is the lowest of those of all component polymers of the blend, or the melting point of one component of the bicomponent composite cross section which is lower than that of the other is taken as a reference, and operation must be carried out at an operating temperature lower than such a melting point. If the operating temperature exceeds that temperature limit, there may occur polymer adhesion to the bonding apparatus with heat and pressure, with the result that operating efficiency is adversely affected. In addition, the resulting nonwoven fabric has a very hard hand, it being thus impractical to obtain a reasonably flexible nonwoven fabric.

[0037] For the operation of bonding with heat and pressure, in addition to the earlier mentioned method using heated embossing rolls, it is possible to adopt a method such that an ultrasonic fusion bonding apparatus is employed to ultrasonically apply a high frequency to the web on a pattern roll, thereby to form inter-filament fusion bonded areas in a pattern section. More specifically, the ultrasonic fusion bonding apparatus comprises an ultrasonic oscillator having a frequency of about 20 kHz which is generally called "horn", and a pattern roll having raised projections arranged circumferentially thereon in a area pattern or belt-like pattern. The pattern roll is disposed below the ultrasonic oscillator so that partial hot fusion bonding can be effected by passing a web through a nip between the ultrasonic oscillator and the pattern roll. Raised projections arranged on the pattern roll may be of a single row or plural rows. In the case of plural-row arrangement, the raised projections may be arranged either in parallel rows or in staggered rows.

[0038] Above said operation of partially bonding with heat and pressure using embossing rolls or such an ultrasonic fusion bonding apparatus may be carried out either in a continuous process or in a separate stage. Either way of operation may be suitably selected according to the intended use of the nonwoven fabric.

EXAMPLES

[0039] The invention will be explained more specifically with reference to the following examples. It is understood, however, the invention is in no way limited to these

examples.

[0040] In the following examples and comparative examples, various property values were determined as stated below. MFR (Melt Flow Rate) value (g/10 min.): measured at 190°C in accordance with the method described in ASTM-D-1238 (E).

[0041] Melting point (°C) : In a fusion-endotherm curve based on measurements obtained by means of a differential scanning calorimeter, Model DSC-2 made by Perkin Elmer, with a sample weight of 5 mg, and the rate of temperature rise set at 20°C/min., an intermediate temperature between a shift start temperature at the base line and a shift end temperature was determined to be a glass transition temperature Tg (°C), and a temperature which gives the extreme of enareahermic peaks was determined to be a melting point Tm (°C). Then, after the sample was maintained in melted condition for 10 minutes, quenching was effected at a temperature decreasing rate of 20°C/min. In an exotherm curve obtained, a temperature which gives a maximum value was determined to be a crystallizing temperature Tc (°C).Where two or more maximum values were given, a main peak was adopted as the maximum value.

[0042] Weight per unit area (g/m^2): From each sample in standard condition were prepared 10 specimens, each of 10 cm x 10 cm. After the moisture content of each specimen was brought to equilibrium, each specimen was weighed for determining the weight (g) thereof. The average of the values obtained was converted into a value per unit area, which was defined as weight per unit area (g/m^2).

[0043] KGSM tensile strength (kg/5 cm width) : Measurement was made in accordance with the strip method described in JIS-L-1096. Ten specimens, each being 5 cm wide and 20 cm long, were prepared for each sample, and by using a constant stretch type tensile strength tester ("Tensilon UTM-4-1-100", made by Toyo Baldwin), each specimen was stretched by being clamped at positions 10 cm distanced from each other, at a stretch rate of 10 cm/min in both directions of the nonwoven fabric, i.e., machine direction which is parallel to the manufacturing line and crossing direction perpendicular to the machine direction. The average of breaking load values (kg/5 cm width) obtained was converted on a 100 g/m^2 weight per unit area basis, and the converted value was taken as a KGSM tensile strength (kg/5cm width).

[0044] Biodegradability: Nonwoven fabrics were buried in an aged compost maintained at about 58°C and were taken out three months later. In the case where the nonwoven fabric did not retain its configuration as such, or where even if the fabric retained its configuration, its tensile strength had been lowered to 50 % or less of the initial strength level of the fabric prior to the burial, the degradability of the nonwoven fabric was evaluated to be good, whereas in case that the strength was more than 50 % of the initial strength prior to the burial, the nonwoven fabric was evaluated to be of poor degradability.

Example 1

[0045] An L-lactic acid-hydroxycaproic acid copolymer of L-lactic acid / hydroxycaproic acid = 90 / 10 mol % which has a melting point of 168 °C and an MFR value of 20 g/10 min. was melt spun into filaments through a circular spinneret at a spinning temperature of 195°C and at a mass out flow rate from each orifice of 1.75 g/min. The filaments were quenched by a conventional quenching device, and were then drafted and attenuated at a drafting speed of 4500 m/min. Filaments were spread open each other and deposited on a collecting surface of a travelling conveyor, being thus formed into a web. The web was then passed through a partial bonding apparatus with heat and pressure comprising embossing rolls wherein partial bonding with heat and pressure was carried out under the following conditions: roll temperature of 138°C, or 30°C lower than the melting temperature of the polymer; pressure bonded area ratio of 15.0 %; pressure bond density of 22.0 bonded areas per cm^2; and linear pressure of a roll set of 50 kg/cm. Thus, a filament nonwoven fabric comprised of filaments of 3.5 denier in single filament fineness and having a weight per unit area of 30 g/m^2 was obtained. Manufacturing conditions, spinnability, and properties and biodegradability of the nonwoven fabric in this instance are shown in Table 1.

TABLE 1

			Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	
Polymer	MFR value	g/10min	20	20	20	20	20	20	20
	D-lactic acid copolymerization ratio	mol%	0	0	80	20	0	0	10
	L-lactic acid copolymerization ratio	mol%	90	70	20	80	90	80	90
	Hydroxycapronic acid copolymerization ratio	mol%	10	30	0	0	10	Note 2 20	0
	Melting point	°C	168	139	110	112	168	111	141
Manufacturing conditions	Filament cross section	—	Solid	Solid	Solid	Solid	Solid	Divided type composite(Fig. 5)	
	Spinning temperature	°C	195	165	135	135	195	170	
	Single-hole discharge rate	g/min	1.75	1.35	1.24	1.24	3.00	1.59	
	Drafting speed	m/min	4500	3500	3200	3200	5000	4100	
	Emboss temperature	°C	138	110	80	82	138	81	
Operational performance	Adhesion	—	None	None	None	None	None	None	
	Filament break	—	None	None	None	None	None	None	
	Filament spreading-open efficiency	—	Good	Good	Good	Good	Good	Good	
Nonwoven fabric properties	Single filament fineness	Denier	3.5	3.5	3.5	3.5	5.4	3.5	
	Weight per unit area	g/m²	30	30	30	30	30	30	
	KGSM strength	kg/5cm width	14	11	13	12	13	14	
	Texture	—	Good	Good	Good	Good	Good	Good	
	Biodegradability	—	Good	Good	Good	Good	Good	Good	

Note 1: L-lactic acid polymer was added with 1 wt% talc as crystallizing agent.
Note 2: Glycolic acid was used in place of hydroxycapronic acid.

Example 2

[0046] The copolymerization ratio of L-lactic acid to hydroxycaproic acid in the L-lactic acid-hydroxycaproic acid copolymer, and the spinning temperature, the mass out flow rate, the drafting speed, and the embossing temperature were changed as shown in Table 1. In other respects, operation was carried out in the same way as in Example 1 to obtain a filament nonwoven fabric. The manufacturing conditions, spinnability, and properties and biodegradability of the nonwoven fabric obtained in this Example 2 are shown in Table 1.

Examples 3 and 4

[0047] A filament nonwoven fabric was produced using a copolymer of L-lactic acid and D-lactic acid. The copolymerization ratio of L-lactic acid to D-lactic acid, spinning temperature, mass out flow rate, drafting speed, and embossing temperature used in each respective example were as shown in Table 1. In other respects, operation was carried out in the same way as in Example 1 to obtain the nonwoven fabric. The manufacturing conditions, spinnability, and properties and biodegradability of the nonwoven fabric obtained, in each respective Example 3, 4 are shown in Table 1.

Example 5

[0048] Operation was carried out in the same way as in Example 1, except that a mass out flow rate of 3.00 g/min. and a drafting speed of 5,000 m/min. were used. As a result, a filament nonwoven fabric comprised of filaments having a single filament fineness of 5.4 denier was obtained. The manufacturing conditions, spinnability, and properties and biodegradability of the nonwoven fabric obtained in this Example 5 are shown in Table 1.

Example 6

[0049] A copolymer of L-lactic acid / glycolic acid = 80 / 20 mol % having a melting point of 111°C and an MFR value of 20 g/10 min. was used as a first component, and a poly (D,L-lactic acid) of L-lactic acid / D-lactic acid = 90 / 10 mol % having a melting point of 141°C and an MFR value of 20 g / 10 min. as a second component. The two components were used in the following ratio: the first component / the second component = 1 / 1 (weight ratio). The components were melt spun into filaments through a spinneret having a configuration such that, in a split type composite cross section as shown in Fig. 5, the first and second components could be respectively arranged in the core and leaf portions, the spinning operation being carried out at a spinning temperature of 170°C and at a mass out flow rate of 1.59 g/min. Filaments spun were quenched by a conventional quenching device and were then drafted and attenuated at a drafting speed of 4,100 m/min. Filaments were spread open each other and deposited on a collecting surface of a travelling conveyor, being thus formed into a web. The web was then passed through a partial bonding apparatus with heat and pressure comprising embossing rolls having a circular protrusion of 3.1 mm^2 in area wherein partial bonding with heat and pressure was carried out under the following conditions: roll temperature of 81°C; pressure bonded area ratio of 6.1%; pressure bond density of 6.7 bonded areas per cm^2; and linear roll pressure of 40 kg/cm. As a result, a split type composite filament nonwoven fabric comprised of filaments of 3.5 denier in single filament fineness (fineness of each leaf segment: about 0.3 denier) and having a weight per unit area of 30 g/m^2 was obtained. Manufacturing conditions, spinnability, and properties and biodegradability of the nonwoven fabric in this Example 6 are shown in Table 1.

[0050] As is apparent from Table 1, all the filament nonwoven fabrics obtained in Examples 1 through 6 had sufficient strength to enable the fabric to serve for practical purposes. The nonwoven fabrics also had very good biodegradability such that when removed from a compost in which these nonwoven fabrics had been buried, and all the fabrics were found as having undergone considerable decrease in weight, substantial changes in configuration, and considerable degradation in strength maintenance.

Comparative Examples 1 and 2

[0051] Filament nonwoven fabrics were produced in the same way as in Example 1, except that the drafting speed was changed as shown in Table 2. Manufacturing conditions and spinnability in these comparative examples are shown in Table 2.

TABLE 2

			Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5	Comparative Example 6	Comparative Example 7
Polymer	MFR value	g/10min	20	20	150	0.6	20	20	20
	D-lactic acid copolymerization ratio	mol%	0	0	0	0	0	0	20
	L-lactic acid copolymerization ratio	mol%	90	90	90	90	90	90	80
	Hydroxycapronic acid copolymerization ratio	mol%	10	10	10	10	10	10	0
	Melting point	℃	168	168	168	168	168	168	112
Manufacturing conditions	Filament cross section	–	Solid	Solid	Solid	Solid	Solid	Solid	Solid
	Spinning temperature	℃	195	195	195	195	180	270	135
	Single-hole discharge rate	g/min	1.75	1.75	1.75	1.75	1.75	1.75	1.24
	Drafting speed	m/min	800	6500	4500	4500	4500	4500	3200
	Emboss temperature	℃	–	–	–	–	–	–	113
Operational performance	Adhesion	–	Present	None	None	None	None	Present	None
	Filament break	–	None	Present	Present	Present	Present	Present	None
	Filament Spreading-open efficiency	–	Poor	–	–	–	–	–	Good
Nonwoven fabric properties	Single filament fineness	Denier	–	–	–	–	–	–	3.5
	Weight per unit area	g/m²	–	–	–	–	–	–	30
	KGSM strength	kg/5cm width	–	–	–	–	–	–	17
	Texture	–	–	–	–	–	–	–	Poor
	Biodegradability	–	–	–	–	–	–	–	Good

Comparative Examples 3 and 4

[0052] Filament nonwoven fabrics were produced in the same way as in Example 1, except that the MFR value of the polymer was changed as shown in Table 2. Manufacturing conditions and spinnability in these comparative examples are shown in Table 2.

Comparative Examples 5 and 6

[0053] Filament nonwoven fabrics were produced in the same way as in Example 1, except that the spinning temperature was changed as shown in Table 2. Manufacturing conditions and spinnability in these comparative examples are shown in Table 2.

Comparative Example 7

[0054] A filament nonwoven fabric formed of filaments was produced in the same way as in Example 4, except that an embossing temperature of 113 °C was used for bonding operation with heat and pressure. Manufacturing conditions, spinnability, and properties and biodegradability of the nonwoven fabric produced in this comparative example are shown in Table 2.

[0055] As is apparent from Table 2, interfilament fusions did occur in Comparative Example 1, because the drafting speed was lower than 1000 m/min. This resulted in poor filament spreading-open effect and, therefore, no sheeting of good texture could be obtained.

[0056] In Comparative Example 2, a drafting speed higher than 5,000 m/min. was used and this resulted in poor draft efficiency in a high-speed air current. As such, filament breaks frequently occurred and this prevented sheet formation.

[0057] In Comparative Example 3, the MFR value was higher than 100 g/10 min. and this resulted in poor draft efficiency in a high-speed air current. As such, filament breaks frequently occurred and this prevented sheet formation.

[0058] In Comparative Example 4, the MFR value was less than 10 g/10 min. and this resulted in poor draft efficiency in a high-speed air current, which in turn adversely affected spinnability.

[0059] In Comparative Example 5, the spinning temperature was lower than (Tm + 20)°C, where Tm is the melting point of the polymer, and this resulted in poor draft efficiency in a high-speed air current, which in turn adversely affected spinnability.

[0060] In Comparative Example 6, the spinning temperature was higher than (Tm + 80)°C, where Tm is the melting point of the polymer, and this slowed down the process of crystallization in the quenching stage and, in the meantime, thermal degradation of the polymer proceeded. As a result, interfilament adhesion did occur, which in turn resulted in poor filament spreading-open effect. Therefore, no sheeting of good texture could be obtained.

[0061] In Comparative Example 7, the embossing temperature was higher than the melting point of the polymer and, therefore, the nonwoven fabric obtained was unsatisfactory in respect of flexibility and texture.

Claims

1. A nonwoven fabric made up of filaments comprised of a polylactic acid-based polymer, wherein the polylactic acid-based polymer is a polymer selected from a group consisting of copolymers of D-lactic acid and L-lactic acid, copolymers of D-lactic acid and hydroxy-carboxylic acid, and copolymers of L-lactic acid and hydroxy-carboxylic acid, said polymer having a melting point of 100°C or more, or being a blend of such polymers having a melting point of 100°C or more, **characterized in that** constituent filaments of the nonwoven fabric are partially fusion bonded with heat and pressure by embossing or ultrasonic fusion, wherein said fusion bonding is present in spottedly configured individual fusion bonded areas.

2. A nonwoven fabric as set forth in claim 1, wherein the fusion bonding is present without the constituent filaments being joined at intersection points in other areas than the fusion bonded areas.

3. A nonwoven fabric as set forth in claim 1, wherein each of individual fusion bonded areas is an area of 0.2 to 15mm^2 which is of any configuration such as circular, elliptic, diamond, triangular, T-shaped, and number-sign-shaped, that density of fusion bonded spots with heat and pressure is 4 to 100 areas per cm^2, and that a ratio of total fusion bonded area with heat and pressure to total surface area of a web is 3 to 50 %.

4. A nonwoven fabric as set forth in claim 1, wherein the cross section of each constituent filament is either a solid or open hollow cross section or a polygonal or planar odd-shaped cross section.

5. A nonwoven fabric made up of filaments comprised of a polylactic acid-based polymer as set forth in claim 1, wherein the cross section of each constituent filament is a sheath-core type composite cross section of a bicomponent filament.

6. A nonwoven fabric made up of filaments comprised of a polylactic acid-based polymer as set forth in claim 1, wherein the cross section of each constituent filament is a split type composite cross section such that bicomponents of the filament have their respective geometric forms separate from each other which both continuously extend as such in the direction of filament axis and are exposed on the surface of the filament.

7. A nonwoven fabric as set forth in claim 1, wherein the filaments have a single filament fineness of from 1 to 12 deniers.

8. A nonwoven fabric as set forth in claim 1, wherein the nonwoven fabric has a weight per unit area of from 10 to 500 g/m^2.

9. A method of fabricating a nonwoven fabric made up of filaments comprised of a polylactic acid-based polymer, comprising the steps of melting a polymer selected from the group consisting of poly(D-lactic acid), poly(L-lactic acid), copolymers of D-lactic acid and L-lactic acid, copolymers of D-lactic acid and hydroxy-carboxylic acid, and copolymers of L-lactic acid and hydroxy-carboxylic acid, said polymer having a melting point of 100°C or more, or a blend of such polymers having a melting point of 100°C or more, said polymer or polymer blend having a melt flow rate of from 10 to 100 g/10 minutes as measured at 190°C according to ASTM-D-1238 (E), in a temperature range of from (Tm + 20)°C to (Tm + 80)°C, where Tm°C is the melting point of the polymer or polymer blend; extruding the melt through a spinneret into filaments; drafting the extruded filaments by means of a suction device at a drafting speed of from 1,000 to 5,000 m/minute, thereby fining them down into finer filaments; depositing such filaments, as they are spread open each other, and are laid up on a travelling collector surface to form a web; and partially fusion bonding the filaments with heat and pressure by embossing or ultrasonic fusion, in which said fusion bonding is present in spottedly configured individual fusion bonded areas, thereby to obtain the nonwoven fabric.

10. A fabricating method as set forth in claim 9, wherein constituent filaments of the web are partially bonded with heat and pressure bonded at a temperature lower than the melting point of the polymer or polymer blend.

11. A fabricating method as set forth in claim 10, wherein two or more kinds of components comprising said polymer or polymer blend are melt spun into filaments by means of a spinneret which provides a composite sectional configuration with respect to the fiber cross section of each of the filaments, and wherein said partial bonding with heat and pressure is effected at a temperature lower than the melting point of one of said two or more kinds of components which is lowermost of their melting points.

FIG.1

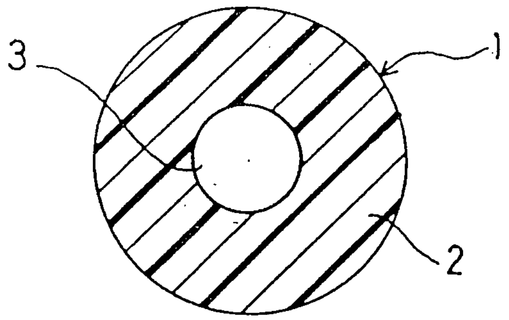

FIG.2

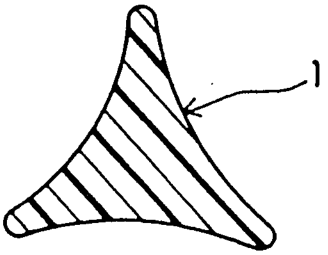

FIG.3

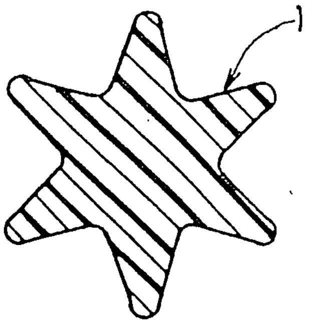

FIG.4

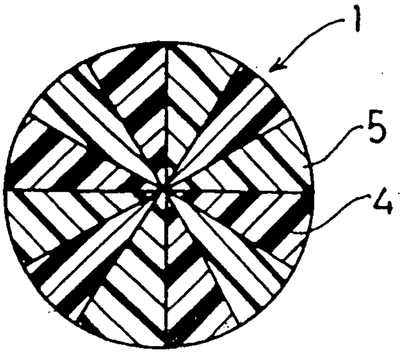

FIG.5

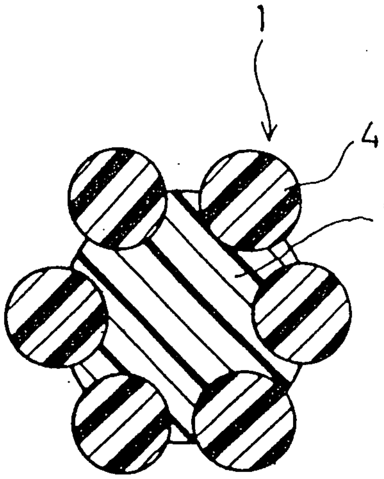

FIG.6