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(54) **SPUNBOND NONWOVEN FABRIC**

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(57) **ABSTRACT**

Provided is a spunbond nonwoven fabric which is made of a polypropylene fiber and satisfies all of the following conditions A to E: A. the average single fiber diameter of the fiber is 6-17 μm; B. the degree of crystal orientation of the fiber as obtained by wide-angle X-ray diffraction is at least 0.91; C. the crystallite size of the (110) plane of the fiber as obtained by wide angle X-ray diffraction is at least 12 nm; D. the average orientation parameter of the fiber as obtained by Raman spectroscopy is at least 8.0; and E. the complex viscosity of the spunbond nonwoven fabric at a temperature of 230° C. is 20-100 Pa·sec at an angular frequency of 6.3 rad/sec.

SPUNBOND NONWOVEN FABRIC

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This is the U.S. National Phase application of PCT/JP2018/035928, filed Sep. 27, 2018, which claims priority to Japanese Patent Application No. 2017-188004, filed Sep. 28, 2017 and Japanese Patent Application No, 2018-141053, filed Jul. 27, 2018, the disclosures of each of these applications being incorporated herein by reference in their entireties for all purposes.

FIELD OF THE INVENTION

[0002] The present invention relates to a spun-bonded nonwoven fabric which is soft and has excellent mechanical properties and higher-order processability.

BACKGROUND OF THE INVENTION

[0003] Spun-bonded nonwoven fabrics made of polyolefin, particularly polypropylene spun-bonded nonwoven fabrics, are low in cost and have excellent processability, and are hence widely used mainly in hygienic material applications.

[0004] In recent years, as for polypropylene spun-bonded nonwoven fabrics used in hygienic material applications, further improvement in texture, touch, softness and production efficiency is required, and various studies have particularly been made to improve softness.

[0005] It is known that fiber diameter reduction is effective as means for improving softness. However, in diameter-reducing methods in which ejection rates are reduced, production efficiency is lowered. In methods in which spinning speeds are increased to increase the production efficiency, filament breakage occurs frequently, hence stable production is difficult to realize.

[0006] Therefore, a polyolefin-based long fiber nonwoven fabric, in which fiber diameter, fiber adsorption force and friction coefficient of the nonwoven fabric are set in specific ranges to improve softness of the spun-bonded nonwoven fabric, and bending flexibility and slipperiness of the fibers are both achieved, has been proposed (see Patent Literature 1).

[0007] Meanwhile, a spun-bonded nonwoven fabric, in which propylene-based polymers are used as raw materials, and basis weight, melt flow rate, fineness and emboss area ratio of the spun-bonded nonwoven fabric are set in specific ranges, and fuzzing resistance, softness, strength and production efficiency are excellent, has been proposed (see Patent Literature 2).

PATENT LITERATURE

[0008] Patent Literature 1: JP-A-2013-159884

[0009] Patent Literature 2: WO2007/091444

SUMMARY OF THE INVENTION

[0010] According to the method disclosed in Patent Literature 1, the softness of the nonwoven fabric can be reliably improved. However, since a melt flow rate of resin used therein is low, a softness improving effect thereof is not sufficient, and nonwoven fabrics exemplified in examples thereof are nonwoven fabrics containing low melting point polyolefin-based resin, hence the production efficiency may decrease due to occurrence of filament breakage. Further, there is also a problem that the resin used is substantially limited.

[0011] In the method disclosed in Patent Literature 2, although the softness of the nonwoven fabric can be reliably improved, since the melt flow rate of the resin used therein is low, a softness improving effect thereof is not sufficient. Moreover, a hole diameter of a spinneret exemplified in examples thereof is as large as 0.6 mmφ, hence spinneret pressure is difficult to be applied, spinning cannot be performed uniformly, and filament breakage and fiber diameter unevenness are generated, which makes it difficult to stably obtain uniform nonwoven fabrics.

[0012] Therefore, an object of the present invention is to provide a spun-bonded nonwoven fabric which is soft and has excellent mechanical properties and higher-order processability.

[0013] As a result of studies performed by the present inventors, it has been found that the softness of the spun-bonded nonwoven fabric has a high correlation with complex viscosity thereof in a molten state. As the complex viscosity of the spun-bonded nonwoven fabric becomes lower, the softness is improved, while the mechanical properties and the higher-order processability are reduced. Therefore, as a result of intensive studies to solve the above problems, the present inventors have found that a spun-bonded nonwoven fabric, in which softness and excellent mechanical properties and higher-order processability are all achieved, is obtained by setting fineness, crystal orientation degree, crystallite size, and orientation parameter of the spun-bonded nonwoven fabric in specific ranges, and further by setting the complex viscosity of the spun-bonded nonwoven fabric in a specific range, hence the present invention was completed.

[0014] An object of the present invention is to solve the above problems, and a spun-bonded nonwoven fabric according to embodiments of the present invention contains polypropylene fibers, in which all of the following conditions A to E are satisfied:

[0015] A. an average single fiber diameter of the fibers is 6 μm or more and 17 μm or less;

[0016] B. a crystal orientation degree in wide-angle X-ray diffraction of the fibers is 0.91 or more;

[0017] C. a crystallite size of a (110) plane in the wide-angle X-ray diffraction of the fibers is 12 nm or more;

[0018] D. an average orientation parameter in Raman spectroscopy of the fibers is 8.0 or more; and

[0019] E. a complex viscosity of the spun-bonded nonwoven fabric is 20 Pa·sec or more and 100 Pa·sec or less at a temperature of 230° C. at an angular frequency of 6.3 rad/sec.

[0020] According to a preferred mode of the spun-bonded nonwoven fabric according to the present invention, the complex viscosity of the spun-bonded nonwoven fabric is 40 Pa·sec or more and 80 Pa·sec or less at the temperature of 230° C. at the angular frequency of 6.3 rad/sec.

[0021] The fiber diameter of the fibers constituting the spun-bonded nonwoven fabric according to the present invention is low, and the complex viscosity thereof in the molten state is low, hence the spun-bonded nonwoven fabric has high softness. In addition, the crystal orientation thereof is high, the crystallite size thereof is large, and the orientation parameter thereof is high, hence the spun-bonded nonwoven fabric according to the present invention exhibits excellent mechanical properties and higher-order processability.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0022] The spun-bonded nonwoven fabric according to exemplary embodiments of the present invention is a spun-bonded nonwoven fabric containing polypropylene fibers, in which all of the following conditions A to E are satisfied:

[0023] A. the fibers have an average single fiber diameter of 6 μm or more and 17 μm or less;

[0024] B. the fibers have a crystal orientation degree in wide-angle X-ray diffraction of 0.91 or more;

[0025] C. the fibers have a crystallite size of a (110) plane in wide-angle X-ray diffraction of 12 nm or more;

[0026] D. the fibers have an average orientation parameter in Raman spectroscopy of 8.0 or more; and

[0027] E. the spun-bonded nonwoven fabric has a complex viscosity of 20 Pa·sec or more and 100 Pa·sec or less at a temperature of 230° C. at an angular frequency of 6.3 rad/sec.

[0028] The spun-bonded nonwoven fabric according to embodiments of the present invention is explained in detail below.

[0029] [Polypropylene-Based Resin]

[0030] A spun-bonded nonwoven fabric according to embodiments of the present invention is made of fibers of polypropylene-based resin (polypropylene fibers). The polypropylene-based resin means resin containing propylene units serving as main repeating units. By using the polypropylene-based resin, a spun-bonded nonwoven fabric which is low in cost and has excellent softness can be obtained.

[0031] Examples of the polypropylene-based resin used in embodiments of the present invention include propylene homopolymers, copolymers of propylene and various α-olefins, and the like. When a copolymer of propylene and various α-olefins is used as the polypropylene-based resin, a copolymerization ratio of the various α-olefins is preferably 10 mol % or less, more preferably 5 mol % or less, even more preferably 3 mol % or less from the viewpoint of strength improvement.

[0032] The polypropylene-based resin used in the present invention can be blended with other component resin as long as the effects of the present invention are not impaired. Examples of the other component resin include polyolefin-based resin such as polyethylene and poly-4-methyl-1-pentene whose melting points are close to polypropylene, low melting point polyester resin and low melting point polyamide resin. From the viewpoint of imparting softness, low-crystalline olefin-based resin is preferably used. For example, an ethylene-propylene copolymer, low stereoregular polypropylene, or the like is preferably used as the low-crystalline olefin-based resin. A mass ratio of the other component resin is preferably 20% by mass or less, and more preferably 15% by mass or less, so as to sufficiently exhibit characteristics of the polypropylene-based resin.

[0033] Coloring pigments, antioxidants, lubricants such as polyethylene wax, heat-resistant stabilizer, and the like can be added to the polypropylene-based resin used in the present invention as long as the effects of the present invention are not impaired.

[0034] It is preferable not to add additives that decompose the resin and reduce molecular weight, for example, free radical agents such as peroxide, especially dialkylated oxide, to the resin to be used in the polypropylene-based resin used in the present invention. When the above additives are added to the polypropylene-based resin, unevenness of fiber diameter occurs due to partial viscosity unevenness, making it difficult to sufficiently reduce fiber diameter, and in some cases, spinnability is deteriorated by bubbles caused by the viscosity unevenness or decomposition gas. Therefore, by not adding the above additives to the polypropylene-based resin, uniformity of the fiber diameter is improved, and the fiber diameter can be further reduced.

[0035] A melting point of the polypropylene-based resin used in the present invention is preferably 120° C. or more and 180° C. or less. Heat resistance that can withstand practical use can be obtained when the melting point is preferably 120° C. or more, more preferably 130° C. or more. Heat bonding of spun fibers becomes easy when the melting point is preferably 180° C. or less, more preferably 170° C. or less, and hence a spun-bonded nonwoven fabric, which has good mechanical properties and higher-order processability, is obtained.

[0036] About 2 mg of spun-bonded nonwoven fabric is set in a differential scanning calorimeter, differential scanning calorimetry is performed three times in nitrogen at a heating rate of 16° C./min, and an arithmetic average value of a temperature of an endothermic peak is taken as the melting point (° C.) of the spun-bonded nonwoven fabric according to the present invention.

[0037] A weight average molecular weight of the polypropylene-based resin used in the present invention is preferably 100,000 or more and 200,000 or less. The fibers have excellent fiber diameter uniformity when the weight average molecular weight is preferably 100,000 or more, more preferably 110,000 or more, and hence processability of the nonwoven fabric is improved. Flowability of the polypropylene-based resin is improved when the weight average molecular weight is preferably 200,000 or less, more preferably 180,000 or less, hence the spinnability is improved. The weight average molecular weight in the present invention refers to a value calculated in terms of polystyrene and dibenzyl using gel permeation chromatography.

[0038] A melt mass flow rate of the polypropylene-based resin used in the present invention is preferably 155 g/10 min or more and 500 g/10 min or less. Flowability of the polypropylene-based resin is improved when the melt mass flow rate is preferably 155 g/10 min or more, more preferably 160 g/10 min or more, hence the spinnability is improved. Filament breakage caused by low melt viscosity is reduced when the melt mass flow rate is preferably 500 g/10 min or less, more preferably 400 g/10 min or less, and hence the spinnability is improved.

[0039] The melt mass flow rate can be controlled by the weight average molecular weight of the polypropylene-based resin. As the weight average molecular weight of the polypropylene-based resin increases, the melt mass flow rate decreases.

[0040] The melt mass flow rate in the present invention refers to a value measured at a temperature of 230° C. and a load of 2,160 g in accordance with JIS K7210-1: 2014, "Chapter 8, Method A: Mass Measurement".

[0041] The melt mass flow rate of the polypropylene-based resin used in the present invention can also be adjusted by blending two or more types of resin having different melt mass flow rates at any ratio. In this case, the melt mass flow rate of the resin blended with the main polypropylene-based resin is preferably 10 g/10 min or more and 1000 g/10 min or less. Unevenness of fiber diameter and spinnability deterioration caused by partial viscosity unevenness generated in the blended polypropylene-based resin can be inhibited when the melt mass flow rate of the blended resin is preferably 10 g/10 min or more, more preferably 20 g/10 min or more, even more preferably 30 g/10 min or more. A spun-bonded nonwoven fabric which has excellent mechanical properties is obtained when the melt mass flow rate of the blended resin is preferably 1000 g/10 min or less, more preferably 800 g/10 min or less, even more preferably 600 g/10 min or less.

[0042] [Polypropylene Fiber]

[0043] It is important that polypropylene fibers which constitute the spun-bonded nonwoven fabric according to embodiments of the present invention have an average single fiber diameter of 6 μm or more and 17 μm or less. Feel when touching a surface of the spun-bonded nonwoven fabric obtained from the polypropylene fiber becomes smooth when the average single fiber diameter is 17 μm or less, preferably 16 μm or less, and more preferably 15 μm or less. In addition, the average single fiber diameter is reduced, so that a low cross-sectional secondary moment is also exhibited, hence the softness is further improved. Process passability at the time of post processing is improved when the average single fiber diameter is 6 μm or more, preferably 7 μm or more, and more preferably 8 μm or more, hence a spun-bonded nonwoven fabric which has a small number of defects is obtained.

[0044] A small amount is cut out from the spun-bonded nonwoven fabric, and diameters of the polypropylene fibers are acquired from microscopic observation of a side surface of the polypropylene fibers constituting the spun-bonded nonwoven fabric at a portion other than an emboss bonding portion, and the measurement is performed 10 times per level, and an arithmetic average value thereof is referred to as the average single fiber diameter (μm) of the polypropylene fibers in the present invention.

[0045] It is important that a crystal orientation degree in wide-angle X-ray diffraction of the polypropylene fibers which constitute the spun-bonded nonwoven fabric according to embodiments of the present invention is 0.91 or more. A crystal C-axis is arranged along a fiber axis when the crystal orientation degree is 0.91 or more, preferably 0.92 or more, and more preferably 0.93 or more, hence fibers which have excellent strength and higher-order processability are obtained. An upper limit of the crystal orientation degree that can be achieved by the present invention is 1.00.

[0046] The crystal orientation degree can be controlled by melt mass flow rate and spinning speed, and cooling conditions during spinning. As the melt mass flow rate decreases while the spinning speed increases, or as cooling efficiency during spinning increases, the crystal orientation degree is increased.

[0047] It is important that a crystallite size of a (110) plane in the wide-angle X-ray diffraction of the polypropylene fibers which constitute the spun-bonded nonwoven fabric according to embodiments of the present invention is 12 nm or more. Fibers which have excellent strength and higher-order processability are obtained when the crystallite size of the (110) plane is 12 nm or more, preferably 13 nm or more, and more preferably 14 nm or more. An upper limit of the crystallite size that can be achieved by the present invention is about 25 nm.

[0048] The crystallite size can be controlled by melt mass flow rate and spinning speed. As the melt mass flow rate decreases while the spinning speed increases, the crystallite size is increased.

[0049] The crystal orientation degree and the crystallite size (nm) in the wide-angle X-ray diffraction in the present invention respectively refer to values measured and calculated by the following method.

[0050] (1) 20 polypropylene fibers cut from the spun-bonded nonwoven fabric are bundled such that fiber axes thereof are in the same direction.

[0051] (2) The sample bundled in (1) is subjected to wide-angle X-ray diffraction measurement using an X-ray diffraction device.

[0052] (3) An X-ray diffraction profile in a circumferential direction and an X-ray diffraction profile in an equatorial line direction of a peak corresponding to the (110) plane are obtained.

[0053] (4) Based on a peak half-value width H (°) of the X-ray diffraction profile in the circumferential direction and a peak half-value width β_e (°) of the X-ray diffraction profile in the equatorial line direction, values are calculated using the following equations, respectively.

$$\text{Crystal orientation degree } \pi=(180-H)/180$$

$$\text{Crystallite size } L\text{ (nm)}=0.9\lambda/(((\beta_e^2-\beta_0^2)^{0.5}\times\cos\theta)$$

[0054] (In the equation, λ represents an incident X-ray wavelength (0.15418 nm in the present device), β_0 represents a half-value width correction value (0.46° in the present device), and θ represents a peak top Bragg angle (°).)

[0055] It is important that an average orientation parameter in Raman spectroscopy of the polypropylene fibers which constitute the spun-bonded nonwoven fabric according to embodiments of the present invention is 8.0 or more. Molecular chains in amorphous portions and crystal portions are oriented in a fiber axis direction when the average orientation parameter is 8.0 or more, preferably 8.5 or more, more preferably 8.8 or more, hence fibers which have excellent strength and higher-order processability are obtained. An upper limit of the average orientation parameter that can be achieved by the present invention is about 13.0.

[0056] The average orientation parameter can be controlled by melt mass flow rate and spinning speed, and cooling conditions during spinning. As the melt mass flow rate decreases while the spinning speed increases, or as cooling efficiency during spinning increases, the orientation parameter is increased.

[0057] The average orientation parameter in the present invention refers to a value measured and calculated by the following method.

[0058] (1) A single fiber is cut out from the spun-bonded nonwoven fabric and set in a holder.

[0059] (2) A laser Raman spectroscopy is used to obtain polarized Raman spectra under a parallel condition when a polarization direction coincides with the fiber axis and under a perpendicular condition when the polarization direction is perpendicular to the fiber axis.

[0060] (3) Raman band intensity around 810 cm^{-1} attributed to coupling modes of CH_2 bending vibration and C—C stretching vibration is defined as I_{810}, while Raman band intensity of 840 cm^{-1} attributed to the CH_2 bending vibration mode is defined as I_{840}, and the orientation parameter is calculated using the following equation.

$$\text{Orientation parameter}=(I_{810}/I_{840})_{parallel}/(I_{810}/I_{840})_{perpendicular}$$

[0061] (In the equation, parallel represents an intensity ratio under the parallel condition, and perpendicular represents an intensity ratio under the perpendicular condition.)

[0062] (4) The measurement is performed six times per level, and an arithmetic average value thereof is taken as the average orientation parameter.

[0063] A density of the polypropylene fibers which constitute the spun-bonded nonwoven fabric according to the present invention is preferably 0.88 g/cm^3 or more and 0.93 g/cm^3 or less. Fibers which have high crystallinity and excellent strength and higher-order processability are obtained when the density is preferably 0.88 g/cm^3 or more, more preferably 0.89 g/cm^3 or more. Heat bonding performance and processability during embossing or calendering are improved when the density is preferably 0.93 g/cm^3 or less, more preferably 0.92 g/cm^3 or less.

[0064] The density in the present invention refers to a value measured by the following method.

[0065] (1) Water and ethanol are mixed in a room whose temperature is controlled to 15° C. A mass fraction of the ethanol is 40% to 70%, and 31 levels of aqueous ethanol solutions having different concentrations at 1% intervals are prepared.

[0066] (2) A small amount of spun-bonded nonwoven fabric, from which impurities are removed by ultrasonic cleaning, is cut out, the cut-out spun-bonded nonwoven fabric is immersed in the aqueous ethanol solution so as to prevent air bubbles and is left for 6 hours or more.

[0067] (3) The density is calculated by using the following equation based on a mass fraction X_E of an aqueous ethanol solution having the lowest ethanol mass fraction among aqueous ethanol solutions in which the spun-bonded nonwoven fabric did not sink to the bottom.

$$\text{Density of polypropylene fibers (g/cm}^3\text{)}=-0.000005\times X_E^2-0.0017\times X_E+1.0153$$

[0068] A cross-sectional shape of the polypropylene fibers which constitute the spun-bonded nonwoven fabric according to the present invention is preferably circular. When the cross-sectional shape is flat or irregular, there is a bending direction in which cross-sectional secondary moment of the same cross-sectional area is larger than that in the case of the circular cross-section, hence rigidity of the spun-bonded nonwoven fabric is increased, and the softness may be impaired.

[0069] [Spun-Bonded Nonwoven Fabric]

[0070] It is important that complex viscosity of the spun-bonded nonwoven fabric according to embodiments of the present invention is 20 Pa·sec or more and 100 Pa·sec or less at a temperature of 230° C. at an angular frequency of 6.3 rad/sec. Softness of the fibers which constitute the spun-bonded nonwoven fabric is improved when the complex viscosity is 100 Pa·sec or less, preferably 90 Pa·sec or less, and more preferably 80 Pa·sec or less, hence a spun-bonded nonwoven fabric having excellent softness is obtained. Strength reduction and deterioration of higher-order processability of the obtained nonwoven fabric can be inhibited when the complex viscosity is 20 Pa·sec or more, preferably 30 Pa·sec or more, and more preferably 40 Pa·sec or more.

[0071] The complex viscosity of the spun-bonded nonwoven fabric can be controlled by the weight average molecular weight of the polypropylene-based resin. As the weight average molecular weight of the polypropylene-based resin increases, the complex viscosity of the spun-bonded nonwoven fabric decreases.

[0072] A cut-out spun-bonded nonwoven fabric is set in a measuring jig, a measurement using a rotary rheometer is performed three times per level at a temperature of 230° C. at an angular frequency of 6.3 rad/sec, and an arithmetic average value thereof is referred to as the complex viscosity (Pa·sec) in the present invention.

[0073] A melting point of the spun-bonded nonwoven fabric according to the present invention is preferably 120° C. or more and 190° C. or less. Troubles, such as reduction in strength and higher-order processability caused by holes opened during emboss bonding, can be prevented when the melting point is preferably 120° C. or more, more preferably 130° C. or more, and even more preferably 140° C. or more. Heat bonding performance during embossing or calendering is improved when the melting point is preferably 190° C. or lower, more preferably 180° C. or lower, and even more preferably 175° C. or lower, hence the strength and higher-order processability of the spun-bonded nonwoven fabric are improved.

[0074] The melting point (° C.) in the present invention is obtained from a peak temperature of an endothermic peak obtained by performing differential scanning calorimetry with a differential scanning calorimeter at a heating rate of 16° C./min in nitrogen.

[0075] A heat of crystal melting of the spun-bonded nonwoven fabric according to the present invention is preferably 70 J/g or more and 105 J/g or less. The fibers which constitute the spun-bonded nonwoven fabric have appropriate crystallinity when the heat of crystal melting is preferably 70 J/g or more, more preferably 80 J/g or more, hence a spun-bonded nonwoven fabric having high strength and higher-order processability is obtained. The heat bonding performance during embossing or calendering is improved when the heat of crystal melting is preferably 105 J/g or lower, and more preferably 100 J/g or lower, hence the strength and higher-order processability of the spun-bonded nonwoven fabric are improved. The heat of crystal melting (J/g) in the present invention refers to a value obtained based on a peak area of the endothermic peak obtained by performing the differential scanning calorimetry with the differential scanning calorimeter at the heating rate of 16° C./min in the nitrogen.

[0076] A basis weight of the spun-bonded nonwoven fabric according to the present invention is preferably 5 g/m^2 or more and 50 g/m^2 or less. A spun-bonded nonwoven fabric, which has less breakage in succeeding processes and has excellent processability, is obtained when the basis weight is preferably 5 g/m^2 or more, more preferably 10 g/m^2 or more. The softness of the spun-bonded nonwoven fabric can be appropriately exhibited when the basis weight is preferably 50 g/m^2 or less, more preferably 30 g/m^2 or less.

[0077] A stress per basis weight at 5% elongation of the spun-bonded nonwoven fabric according to the present invention (hereinafter, may also be referred to as 5% modulus per basis weight) is preferably 0.06 (N/25 mm)/(g/m^2) or more and 0.33 (N/25 mm)/(g/m^2) or less. A spun-bonded nonwoven fabric which has practically usable strength is obtained when the 5% modulus per basis weight is preferably 0.06 (N/25 mm)/(g/m^2) or more, more preferably 0.13 (N/25 mm)/(g/m^2) or more, and even more preferably 0.20 (N/25 mm)/(g/m^2) or more. A spun-bonded nonwoven fabric which has excellent softness is obtained when the 5% modulus per basis weight is preferably 0.33 (N/25 mm)/(g/m^2) or less, more preferably 0.30 (N/25 mm)/(g/m^2) or less, and even more preferably 0.27 (N/25 mm)/(g/m^2) or less.

[0078] In the present invention, the 5% modulus per basis weight of the spun-bonded nonwoven fabric adopts a value measured by the following procedures in accordance with "6.3 Tensile Strength and Elongation Ratio (ISO method)" of JIS L1913: 2010.

[0079] (1) Three test pieces of 25 mm×300 mm are taken for each width of 1 m in a lengthwise direction (a longitudinal direction of the nonwoven fabric) and a widthwise direction (a transverse direction of the nonwoven fabric) of the nonwoven fabric.

[0080] (2) The test pieces are set in a tensile tester at grip intervals of 200 mm.

[0081] (3) A tensile test is conducted at a tensile speed of 100 mm/min, and a stress at 5% elongation (5% modulus) is measured.

[0082] (4) An average value of the 5% modulus in the lengthwise direction and the transverse direction measured for each test piece is calculated, the 5% modulus per basis weight is calculated based on the following equation, and the calculated value is rounded off to the nearest hundredth.

$$\text{5\% modulus per basis weight } ((N/25\text{ mm})/(\text{g/m}^2)) = [\text{average value of 5\% modulus } (N/25\text{ mm})]/\text{basis weight } (\text{g/m}^2).$$

[0083] The spun-bonded nonwoven fabric according to embodiments of the present invention has excellent softness since the average single fiber diameter of the polypropylene fibers constituting the spun-bonded nonwoven fabric is as thin as 6 μm or more and 17 μm or less while the complex viscosity of the spun-bonded nonwoven fabric is low. As a result of intensive studies, the present inventors have found that when the complex viscosity is 20 Pa·sec or more and 100 Pa·sec or less under the above conditions, production stability is improved, which is one of the problems to be solved for obtaining fibers with small average single fiber diameters, and in addition, that the heat bonding performance is improved, hence the strength and processability of the spun-bonded nonwoven fabric are improved. Meanwhile, there is a concern that the strength may be reduced when the average single fiber diameter is reduced. However, it has been surprisingly found that a nonwoven fabric which has excellent processability without reducing strength thereof is obtained when the crystal orientation degree in the wide-angle X-ray of the polypropylene fibers constituting the spun-bonded nonwoven fabric is 0.91 or more, the crystallite size of the (110) plane is 12 nm or more and the average orientation parameter in Raman spectroscopy is 8.0 or more.

[0084] [Method for Preparing Spun-Bonded Nonwoven Fabric]

[0085] Next, a method for preparing the spun-bonded nonwoven fabric according to exemplary embodiments of the present invention will be described in specific examples.

[0086] A raw material used in the present invention is the polypropylene-based resin whose copolymers other than propylene, melting point, melt mass flow rate, and the like are as described above.

[0087] The polypropylene-based resin is used for melt spinning without performing drying or the like.

[0088] In the melt spinning, a melt spinning method using an extruder, such as a single-screw or twin-screw extruder, can be applied. The extruded polypropylene-based resin is passed through piping, metered by a metering device such as a gear pump, passed through a filter for removing foreign substances, and guided to a spinneret. At this time, a temperature from the resin piping to the spinning spinneret (spinning temperature) is preferably 180° C. or more and 280° C. or less, so as to increase flowability.

[0089] A hole diameter D of a spinneret hole of the spinning spinneret used for ejection is preferably 0.1 mm or more and 0.6 mm or less. L/D defined by a quotient obtained by dividing a land length L of the spinneret hole (length of a straight pipe portion having diameter equal to the hole diameter of the spinneret hole) by the hole diameter D is preferably 1 or more and 10 or less.

[0090] Filaments ejected from the spinneret hole are cooled and solidified by blowing air. A temperature of the cooling air can be determined from the viewpoint of cooling efficiency based on a balance between the temperature of the cooling air and a speed of the cooling air, and is preferably 0° C. or more and 20° C. or less from the viewpoint of uniformity of fineness. Dew condensation and freezing at air piping and cooling air discharge portions can be prevented by setting the temperature of the cooling air to preferably 0° C. or more, more preferably 2° C. or more, hence the cooling air can be supplied stably. The crystal orientation degree and orientation parameter of the polypropylene fibers are improved when the temperature of the cooling air is preferably 20° C. or less, more preferably 16° C. or less, and even more preferably 12° C. or less, hence a spun-bonded nonwoven fabric having excellent mechanical properties and higher-order processability is obtained.

[0091] Cooling gas is flowed in a substantially vertical direction relative to the filaments to cool the filaments. At that time, the speed of the cooling air is preferably 10 m/min or more and 100 m/min or less. The crystal orientation degree and orientation parameter of the polypropylene fibers are improved when the speed of the cooling air is preferably 10 m/min or more, more preferably 20 m/min or more, and even more preferably 25 m/min or more, hence a spun-bonded nonwoven fabric having excellent mechanical properties and higher-order processability is obtained. Filament vibration caused by the cooling air can be reduced by setting the speed of the cooling air to preferably 100 m/min or less, more preferably 80 m/min or less, and even more preferably 70 m/min or less, hence the filament breakage during spinning is reduced.

[0092] A distance from the spinning spinneret to the start of the cooling is preferably 20 mm or more and 500 mm or less. When the distance from the spinning spinneret to the start of the cooling is preferably 20 mm or more, more preferably 25 mm or more, and even more preferably 30 mm or more, a surface temperature of the spinneret is not excessively decreased, and the ejection is stabilized, so that the filament breakage during spinning is reduced. The crystal orientation degree and orientation parameter of the polypropylene fibers are improved when the distance from the spinning spinneret to the start of the cooling is preferably 500 mm or less, more preferably 300 mm or less, and even more preferably 200 mm or less, hence a spun-bonded nonwoven fabric having excellent mechanical properties and higher-order processability is obtained.

[0093] The filaments ejected from the spinneret hole are drawn by an air flow that is accelerated at a position preferably within a range of 400 mm or more and 7000 mm or less from the spinning spinneret. Although the accelerated air flow can be obtained by sealing a region where the cooling air is blown and accelerating air flow velocity by gradually reducing a cross-sectional area of the sealed region toward downstream of a spinning line, it is preferable to use an ejector to obtain a higher air flow velocity. The filaments are accelerated by this air flow velocity, and a spinning speed, which is a traveling speed of the fibers, also reaches a speed that is close to the air flow velocity.

[0094] The spinning speed is preferably 3 km/min or more, and is more preferably 4 km/min so as to reduce the average single fiber diameter. Similarly, the air flow velocity is preferably 3 km/min or more. An upper limit of the spinning speed is about 12 km/min.

[0095] The spinning speed refers to a value calculated by the following equation.

$$\text{Spinning speed (km/min)} = Q \cdot 1000/((W/2)^2 \times \pi \times \rho)$$

[0096] (In the equation, Q represents a single-hole ejection rate (g/min), W represents an average single fiber diameter (μm), and ρ represents a density (g/cm^3).)

[0097] The filaments drawn by the air are spread by being passed through a spreading unit which reduces surrounding air flow velocity, then land on a net conveyor which suctions air from a back surface thereof, and are collected as a fiber web. The collected fiber web is conveyed by a conveyor at a speed of 10 m/min or more and 1000 m/min or less, and heat bonding processing is performed to obtain the spun-bonded nonwoven fabric.

[0098] Examples of methods for uniting the fiber web by heat bonding include methods of heat bonding performed by various rolls such as: hot embossing rolls which are a pair of upper and lower rolls that have an engraved surface (have recesses and protrusions) respectively; hot embossing rolls which include a combination of a roll having a flat (smooth) surface and a roll having an engraved surface (has recesses and protrusions); and hot calendar rolls which include a pair of upper and lower flat (smooth) rolls.

[0099] A proportion of embossed bonding area during the heat bonding is preferably 5% or more and 30% or less. Practically usable strength and higher-order processability can be imparted to the spun-bonded nonwoven fabric when the bonding area is preferably 5% or more, more preferably 10% or more. Meanwhile, sufficient softness can be imparted to the spun-bonded nonwoven fabric, especially for use as hygienic materials, when the bonding area is preferably 30% or less, more preferably 20% or less.

[0100] The term "bonding area" in the present invention has the following meanings. In the case of heat bonding with a pair of rolls having recesses and protrusions, that term means a proportion of portions of the fiber web, with which both protrusions of the upper roll and protrusions of the lower roll have come into contact, to the whole nonwoven fabric. In the case of heat bonding with a roll having recesses and protrusions and a flat roll, that term means a proportion of portions of the fiber web, with which protrusions of the roll having recesses and protrusions have come into contact, to the whole nonwoven fabric.

[0101] The shape of the engraving applied to the hot embossing rolls can be circular, elliptic, square, rectangular, parallelogrammic, rhombic, regularly hexagonal, and regularly octagonal shapes and the like.

[0102] A linear pressure of the hot embossing roll during the heat bonding is preferably 5 kgf/cm or more and 50 kgf/cm or less. The heat bonding can be sufficiently performed when the linear pressure is 5 kgf/cm or more, more preferably 10 kgf/cm or more, and even more preferably 15 kgf/cm or more. Meanwhile, roll stress is not excessively applied when the linear pressure is 50 kgf/cm or less, more preferably 40 kgf/cm or less, and still more preferably 30 kgf/cm or less, hence texture hardening of the spun-bonded nonwoven fabric can be prevented.

[0103] An important point in the process of producing the spun-bonded nonwoven fabric according to the present invention is that the average single fiber diameter can be reduced by high-speed spinning while stable production thereof can be made possible. Although this mechanism is not clear, the spun-bonded nonwoven fabric according to the present invention inevitably uses the polypropylene-based resin having low viscosity as the raw material, hence deformation followability of the polypropylene-based resin is improved in thinning behavior during the spinning process, so that filament breakage defects are significantly reduced.

[0104] Meanwhile, when only the above point is considered, the strength and higher-order processability of the obtained spun-bonded nonwoven fabric may be reduced due to the low viscosity. Therefore, another important point in the process of producing the spun-bonded nonwoven fabric according to the present invention is to sufficiently cool and solidify the filaments ejected from the spinneret within a range that does not affect application of high-speed spinning and spinnability, so as to form a specific fiber structure. When such a process is applied, since high spinning stress is applied to the filaments from the spinning spinneret to an entrance of the ejector, the crystal orientation degree and the orientation parameter of the polypropylene fibers constituting the spun-bonded nonwoven fabric can be improved.

[0105] In addition to excellent softness, the spun-bonded nonwoven fabric obtained in this manner has sufficient mechanical properties and higher-order processability to be used as a spun-bonded nonwoven fabric for hygienic materials.

[0106] The spun-bonded nonwoven fabric according to the present invention can be widely used in medical hygienic materials, living materials, industrial materials, and the like, and can be suitably used particularly for hygienic materials, since the spun-bonded nonwoven fabric according to the present invention has excellent softness and good touch feeling, and has few product defects, hence processability thereof is also excellent. Specific examples thereof include base fabrics of disposable diapers, sanitary articles, and poultice materials.

EXAMPLES

[0107] Next, the spun-bonded nonwoven fabric according to the present invention will be described more specifically with reference to examples. Characteristic values in the examples were obtained by the following methods. Unless otherwise specified, it is assumed that the measurement was performed by the methods described above.

[0108] A. Melting Point of Polypropylene-Based Resin:

[0109] About 2 mg of spun-bonded nonwoven fabric was set in a differential scanning calorimeter (DSCQ2000, manufactured by TA Instruments), differential scanning calorimetry was performed in nitrogen at a heating rate of 16° C./min, and a temperature of an endothermic peak was taken as the melting point (° C.).

[0110] B. Average Single-Fiber Diameter and Spinning Speed:

[0111] The average single fiber diameter of the polypropylene fibers used for measurement was measured by cutting a small amount from the spun-bonded nonwoven fabric and observing a portion other than an emboss bonding portion with a microscope. An optical microscope BH2 manufactured by Olympus Corporation was used for the measurement. The spinning speed (km/min) was obtained from the obtained average single fiber diameter.

[0112] C. Crystal Orientation Degree:

[0113] The crystal orientation degree was measured and calculated using the following devices under the following conditions.

[0114] Device: SmartLab manufactured by Rigaku Corporation (sealed tube type)

[0115] X-ray Source: CuK_{α} ray (Ni filter used)

[0116] Output: 40 kV 50 mA

[0117] Detector: D/teX one-dimensional detector

[0118] Entrance Slit: 2 mmh×2.2 mmw

[0119] Light-Receiving Slit: 5 mm-5 mm.

[0120] D. Crystallite Size:

[0121] The crystallite size was measured and calculated using the following devices under the following conditions.

[0122] Device: SmartLab manufactured by Rigaku Corporation (sealed tube type)

[0123] X-ray Source: CuKα ray (Ni filter used)

[0124] Output: 40 kV 50 mA

[0125] Detector: D/teX one-dimensional detector

[0126] Entrance Slit: 2 mmh×2.2 mmw

[0127] Light-Receiving Slit: 15 mm-20 mm.

[0128] E. Average Orientation Parameter:

[0129] The orientation parameter was measured and calculated using the following devices under the following conditions.

[0130] Device: inVia manufactured by Renishaw

[0131] Measurement Mode: Microscopic Raman (beam diameter 1 μm)

[0132] Light Source: YAG 2nd 532 nm

[0133] Laser Power: 10 mW

[0134] Diffraction Grating: Single–3000 gr/mm

[0135] Slit: 65 μm

[0136] Detector: CCD 1024×256 pixels.

[0137] F. Complex Viscosity:

[0138] The complex viscosity was measured and calculated using the following devices under the following conditions.

[0139] Device: Rheosol-G3000 manufactured by UBM Co., Ltd

[0140] Plate: 20 mm parallel plate

[0141] Gap: 0.5 mm

[0142] Strain: 34.9%

[0143] Angular Frequency: 6.3 rad/sec

[0144] Temperature: 230° C.

[0145] G. Defects of Spun-Bonded Nonwoven Fabric:

[0146] A region of 10 cm square at a center in a width (CD) direction of the spun-bonded nonwoven fabric was visually observed with a loupe, fibers whose fiber diameter is at least three times larger than an average fiber diameter due to filament breakage, and fibers whose cut ends are round and appear to be at least three times larger than the average fiber diameter are defined as defects, and the number of the defects is counted. This observation was repeated five times in a longitudinal (MD) direction of the nonwoven fabric, and a total number thereof was taken as the number of defects (pieces) of the spun-bonded nonwoven fabric.

[0147] H. Softness of Spun-Bonded Nonwoven Fabric:

[0148] Sensory evaluation of touch feeling of the spun-bonded nonwoven fabric was performed, and scores were given in an absolute evaluation based on the following criteria, in which 5 points represents excellent softness while 1 point represents poor softness.

[0149] 5 points: There is no stiffness when the spun-bonded nonwoven fabric is gripped, the surface of the spun-bonded nonwoven fabric is smooth and has excellent softness.

[0150] 4 points: Although there is slight stiffness when the spun-bonded nonwoven fabric is gripped, the surface of the spun-bonded nonwoven fabric is smooth.

[0151] 3 points: There is slight stiffness when the spun-bonded nonwoven fabric is gripped, and a sense of resistance is shown when the spun-bonded nonwoven fabrics are rubbed against each other.

[0152] 2 points: There is apparent stiffness when the spun-bonded nonwoven fabric is gripped, and a sense of resistance is shown when the spun-bonded nonwoven fabrics are rubbed against each other.

[0153] 1 point: There is apparent stiffness when the spun-bonded nonwoven fabric is gripped, and there is apparent unevenness when the spun-bonded nonwoven fabrics are rubbed against each other, so the softness thereof is poor.

[0154] This evaluation was performed by 10 participants, and an average score is taken as the softness (point). A spun-bonded nonwoven fabric having an average score of 4.0 or more was judged as a spun-bonded nonwoven fabric having excellent softness.

[0155] I. Processability of Spun-Bonded Nonwoven Fabric:

[0156] The spun-bonded nonwoven fabric was run at 20 m/min for 5 minutes using a rubber nip roller. At this time, matter adhered to the roll and the state of the spun-bonded nonwoven fabric were observed, and scores were given as the processability (point) based on the following criteria. A spun-bonded nonwoven fabric having a score of 4 or more was judged as a spun-bonded nonwoven fabric having excellent processability.

[0157] 5 points: There is no fiber adhered to the roll, and no nonwoven fabric fluff and tear was observed.

[0158] 4 points: Although there are fibers adhered to the roll, no nonwoven fabric fluff and tear was observed.

[0159] 3 points: Although there are fibers adhered to the roll and nonwoven fabric fluff, no tear was observed.

[0160] 2 points: There are fibers adhered to the roll, nonwoven fabric fluff, and tears.

[0161] 1 point: Sheet tearing causes the nonwoven fabric to wrap around the roll.

Example 1

[0162] A polypropylene-based resin, which is a propylene homopolymer and has a melt mass flow rate of 200 g/10 min and a melting point of 160° C., was melt-extruded by a single-screw extruder, and the polypropylene-based resin was supplied to a spinning spinneret while being measured by a gear pump. A spinning temperature (spinneret temperature) was set to 230° C., and the polypropylene-based resin was ejected from a spinneret hole having a hole diameter D of 0.30 mm and a land length L of 0.75 mm at a single-hole ejection rate of 0.6 g/min. The used spinning spinneret included an introduction hole which was a straight hole located directly above the spinneret hole, and a connecting portion between the introduction hole and the spinneret hole had a tapered shape. Ejected fibrous resin was cooled and solidified by applying an air flow of 12° C. from an outer side of the filaments (fibrous resin) at a speed of 30 m/min, the air flow being started from a distance of 40 mm from the spinning spinneret. Then the fibrous resin was drawn by a rectangular ejector at a speed of 4.4 km/min, and collected on a moving net to obtain a fiber web composed of polypropylene fibers.

[0163] Subsequently, a pair of hot embossing rolls composed of an upper roll, which was a metallic embossing roll having dots formed by engraving and having a proportion of bonding area of 16%, and a lower roll, which was a metallic flat roll, was used to heat-bond the fiber web composed of polypropylene fibers obtained as described above, at a temperature of 130° C. Thus, a spun-bonded nonwoven fabric having a basis weight of 18 g/m^2 was obtained. Evaluation results of the obtained spun-bonded nonwoven fabric are shown in Table 1. It can be seen from Table 1 that the obtained spun-bonded nonwoven fabric has an average single fiber diameter of 13.8 μm, a crystal orientation degree thereof is 0.921, a crystallite size of a (110) plane is 16.2 nm, an orientation parameter thereof is 8.37, and complex viscosity thereof is 55 Pa·sec, and that the spun-bonded nonwoven fabric has few defects, and is excellent in softness and processability.

Examples 2, 3, Comparative Example 1

[0164] Spun-bonded nonwoven fabrics were obtained by the same method as Example 1 except that inflow air pressure of the ejector was changed and the spinning speed was changed to 6.9 km/min in Example 2, 3.1 km/min in Example 3, and 2.6 km/min in Comparative Example 1.

[0165] Results thereof are shown in Table 1. It can be seen from Table 1 that the spun-bonded nonwoven fabric obtained in Example 2 has an average single fiber diameter of 11.0 μm, the crystal orientation degree thereof is 0.942, the crystallite size of the (110) plane is 19.4 nm, the orientation parameter thereof is 8.83, and the complex viscosity thereof is 53 Pa·sec, that the spun-bonded nonwoven fabric obtained in Example 3 has an average single fiber diameter of 16.5 μm, the crystal orientation degree thereof is 0.913, the crystallite size of the (110) plane is 14.5 nm, the orientation parameter thereof is 8.05, and the complex viscosity thereof is 57 Pa·sec, and that both of the spun-bonded nonwoven fabrics have few defects, and are excellent in softness and processability.

[0166] On the other hand, it can be seen that the complex viscosity of the spun-bonded nonwoven fabric obtained in Comparative Example 1 is 57 Pa·sec, and the nonwoven fabric has few defects. However, the average single fiber diameter thereof is as large as 18.0 μm, hence softness thereof is poor. The crystal orientation degree thereof is as low as 0.902, the crystallite size of the (110) plane is as low as 10.8 nm, and the orientation parameter thereof is as low as 7.43, hence processability thereof is poor.

Comparative Example 2

[0167] A spun-bonded nonwoven fabric was obtained by the same method as Example 1 except that the temperature of the cooling air flow at the time of spinning was 25° C., and the air flow velocity was 8 m/min.

[0168] Results thereof are shown in Table 1. It can be seen from Table 1 that the spun-bonded nonwoven fabric obtained in Comparative Example 2 has an average single fiber diameter of 14.1 μm and complex viscosity of 55 Pa·sec, hence the nonwoven fabric has few defects and is soft. However, the crystal orientation degree thereof is as low as 0.906, the crystallite size of the (110) plane is as low as 11.8 nm, and the orientation parameter thereof is as low as 6.98, hence processability thereof is poor.

Examples 4, 5, Comparative Example 3

[0169] Spun-bonded nonwoven fabrics were obtained by the same method as Example 1 except that the melt mass flow rate of the used polypropylene-based resin was changed to 170 g/10 min in Example 4, 450 g/10 min in Example 5, and 60 g/10 min in Comparative Example 3.

[0170] Results thereof are shown in Table 1. It can be seen from Table 1 that the spun-bonded nonwoven fabric obtained in Example 4 has an average single fiber diameter of 13.8 μm, the crystal orientation degree thereof is 0.922, the crystallite size of the (110) plane is 16.5 nm, the orientation parameter thereof is 9.37, and the complex viscosity thereof is 83 Pa·sec, and that the spun-bonded nonwoven fabric has few defects, and is excellent in softness and processability. It can be seen that the spun-bonded nonwoven fabric obtained in Example 5 has an average single fiber diameter of 13.6 μm, the crystal orientation degree thereof is 0.912, the crystallite size of the (110) plane is 12.9 nm, the orientation parameter thereof is 8.21, and the complex viscosity thereof is 31 Pa·sec, and that the spun-bonded nonwoven fabric has few defects, and is excellent in softness and processability.

[0171] On the other hand, it can be seen that the spun-bonded nonwoven fabric obtained in Comparative Example 3 has an average single fiber diameter of 13.9 μm, the crystal orientation degree thereof is 0.922, the crystallite size of the (110) plane is 17.3 nm, the orientation parameter thereof is 9.95. However, the complex viscosity thereof is as large as 206 Pa·sec, hence the softness thereof is poor. The spun-bonded nonwoven fabric has a large number of defects, hence processability thereof is also poor.

TABLE 1

		Example 1	Example 2	Example 3	Comparative Example 1	Comparative Example 2	Example 4	Example 5	Comparative Example 3
Resin	Resin	Propylene Homopolymer							
	Melt Mass Flow Rate (g/10 min)	200	200	200	200	200	170	450	60
Spinning Speed (km/min)		4.4	6.9	3.1	2.6	4.2	4.4	4.5	4.3
Characteristics of Fiber/Nonwoven Fabric	Average Single Fiber Diameter (μm)	13.8	11.0	16.5	18.0	14.1	13.8	13.6	13.9
	Crystal Orientation Degree	0.921	0.942	0.913	0.902	0.906	0.922	0.912	0.922
	Crystallite Size of (110) Plane (nm)	16.2	19.4	14.5	10.8	11.8	16.5	12.9	17.3
	Orientation Parameter	8.37	8.83	8.05	7.43	6.98	9.37	8.21	9.95
	Complex Viscosity (Pa · sec)	55	53	57	57	55	83	31	206
	Nonwoven Fabric Defects (Piece)	0	0	0	0	0	1	1	12
Evaluation	Nonwoven Fabric Softness (Point)	4.6	4.7	4.3	3.5	4.6	4.2	4.3	2.2
	Nonwoven Fabric Processability (Point)	5	5	4	2	2	4	4	1

Example 6

[0172] A spun-bonded nonwoven fabric was obtained by the same method as Example 1 except that a resin obtained from kneading resin A having a mass ratio of 88% and resin B having a mass ratio of 12% was used, in which a propylene homopolymer having a melt mass flow rate of 200 g/10 min was used as the resin A while an ethylene-propylene copolymer having a melt mass flow rate of 20 g/10 min ("Vistamaxx6202" manufactured by ExxonMobil) was used as the resin B.

[0173] Results thereof are shown in Table 2. It can be seen from Table 2 that the spun-bonded nonwoven fabric obtained in Example 6 has an average single fiber diameter of 13.8 μm, the crystal orientation degree thereof is 0.927, the crystallite size of the (110) plane is 15.7 nm, the orientation parameter thereof is 9.32, and the complex viscosity thereof is 68 Pa·sec, and that the spun-bonded nonwoven fabric has few defects, and is excellent in softness and processability.

Comparative Example 4

[0174] A spun-bonded nonwoven fabric was obtained by the same method as Example 6, except that the resin A was changed to a propylene homopolymer having a melt mass flow rate of 60 g/10 min.

[0175] Results thereof are shown in Table 2. It can be seen from Table 2 that the spun-bonded nonwoven fabric obtained in Comparative Example 4 has an average single fiber diameter of 13.9 μm, the crystal orientation degree thereof is 0.932, the crystallite size of the (110) plane is 15.9 nm, the orientation parameter thereof is 10.48. However, the complex viscosity thereof is as large as 228 Pa·sec, hence the softness thereof is poor. The spun-bonded nonwoven fabric has a large number of defects, hence processability thereof is also poor.

			Example 6	Comparative Example 4
Resin	Resin A		Propylene Homopolymer	
		Melt Mass Flow Rate (g/10 min)	200	60
		Mass Ratio (%)	88	88
	Resin B		Ethylene-Propylene Copolymer	
		Melt Mass Flow Rate (g/10 min)	20	20
		Mass Ratio (%)	12	12
Spinning Speed (km/min)			4.4	4.3
Characteristics of Fiber/Nonwoven Fabric	Average Single Fiber Diameter (μm)		13.8	13.9
	Crystal Orientation Degree		0.927	0.932
	Crystallite Size of (110) Plane (nm)		15.7	15.9
	Orientation Parameter		9.32	10.48
	Complex Viscosity (Pa · sec)		68	228
	Nonwoven Fabric Defects (Piece)		0	6
Evaluation	Nonwoven Fabric Softness (Point)		4.7	2.9
	Nonwoven Fabric Processability (Point)		5	2

[0176] Examples 1 to 6 have excellent softness since the average single fiber diameter of the fibers constituting the spun-bonded nonwoven fabrics is small while the complex viscosity is low. In addition, the spun-bonded nonwoven fabrics have excellent processability since the fibers constituting the spun-bonded nonwoven fabrics have high crystal orientation degree, high crystallite size of the (110) plane and high orientation parameter while there are few defects in the spun-bonded nonwoven fabric.

[0177] On the other hand, as shown in Comparative Example 1, in a case where the average single fiber diameter of the fibers constituting the spun-bonded nonwoven fabric is large, the softness of the spun-bonded nonwoven fabric is poor. As shown in Comparative Examples 1 and 2, in cases where the crystal orientation degree, the crystallite size of the (110) plane, and the orientation parameter are low, the processability of the spun-bonded nonwoven fabric is poor. As shown in Comparative Examples 3 and 4, in cases where the complex viscosity of the spun-bonded nonwoven fabric is high, the softness of the spun-bonded nonwoven fabric is poor, and the processability is also deteriorated due to an increase in the defects of the nonwoven fabric.

[0178] Although the present invention has been described in detail with reference to specific examples, it will be apparent to those skilled in the art that various changes and modifications can be made without departing from the spirit and scope of the present invention. This application is based on a Japanese patent application filed on Sep. 28, 2017 (patent application No. 2017-188004), and a Japanese patent application filed on Jul. 27, 2018 (patent application No. 2018-141053), the contents of which are incorporated herein by reference.

obtained by wide angle X-ray diffraction is at least 12 nm; D. the average orientation parameter of the fiber as obtained by Raman spectroscopy is at least 8.0; and E. the complex viscosity of the spunbond nonwoven fabric at a temperature of 230° C. is 20-100 Pa·sec at an angular frequency of 6.3 rad/sec.

1. A spun-bonded nonwoven fabric comprising polypropylene fibers wherein all of the following conditions A to E are satisfied:

A. the fibers have an average single fiber diameter of 6 μm or more and 17 μm or less;

B. the fibers have a crystal orientation degree in wide-angle X-ray diffraction of 0.91 or more;

C. the fibers have a crystallite size of a (110) plane in wide-angle X-ray diffraction of 12 nm or more;

D. the fibers have an average orientation parameter in Raman spectroscopy of 8.0 or more; and

E. the spun-bonded nonwoven fabric has a complex viscosity of 20 Pa·sec or more and 100 Pa·sec or less at a temperature of 230° C. at an angular frequency of 6.3 rad/sec.

2. The spun-bonded nonwoven fabric according to claim **1**, wherein the spun-bonded nonwoven fabric has the complex viscosity of 40 Pa·sec or more and 80 Pa·sec or less at the temperature of 230° C. at the angular frequency of 6.3 rad/sec.

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