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(71) Applicant: **Mitsui Chemicals Asahi Life Materials Co., Ltd.**
Tokyo 104-0028 (JP)

(72) Inventors:
- **ODOI, Masaaki**
  Sodegaura-shi, Chiba 299-0265 (JP)
- **IIBA, Kouzou**
  Sodegaura-shi, Chiba 299-0265 (JP)
- **NAKANISHI, Yohei**
  Sodegaura-shi, Chiba 299-0265 (JP)

(74) Representative: **Hoffmann Eitle**
Patent- und Rechtsanwälte PartmbB
Arabellastraße 30
81925 München (DE)

(54) **NON-WOVEN FABRIC, SANITARY MATERIAL, AND NON-WOVEN FABRIC MANUFACTURING METHOD**

(57) A nonwoven fabric comprising a fiber, and a ratio of daughter lamellae is 0.10 or less.

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Description

Technical Field

[0001] The present invention relates to a nonwoven fabric, a sanitary material, and a method of manufacturing a nonwoven fabric.

Background Art

[0002] In recent years, nonwoven fabrics made of fibers containing thermoplastic resins have been widely used for various purposes due to their excellent breathability, flexibility, and lightness. As methods for manufacturing nonwoven fabrics, a melt blowing method and spunbond method, which are suitable for mass production, are widely used.

[0003] Among them, a nonwoven fabric manufactured by a spunbond method (hereinafter also referred to as "spunbond nonwoven fabric") have excellent mechanical properties such as tensile strength, bending resistance, and air permeability, as well as continuous spinnability and productivity. Because of its excellent properties, it is used in many fields.

[0004] Thermoplastic resins used for spunbond nonwoven fabrics or the like include polyamide resins, polyester resins, and polyolefin resins from the viewpoint of melt spinnability, fiber properties, or the like. Particularly in absorbent articles, polyolefin resins are often used because they are inexpensive and have excellent processability.

[0005] For example, it is disclosed in Patent Document 1 that a spunbond nonwoven fabric which is composed of a fiber containing a polyolefin resin has an average single fiber diameter of from 6.5 to 11.9 μm, a fiber dispersion degree of 10 or less based on reflected light brightness, and has a surface roughness SMD on at least one side measured by the KES method of from 1.0 to 2.6 μm.

[Patent Document 1] International Publication No. 2019/167851

SUMMARY OF INVENTION

Technical Problem

[0006] The nonwoven fabric described in Patent Document 1 has room for improvement in terms of achieving both tensile strength and thinning a fiber of the nonwoven fabric.

[0007] The present disclosure has been made in view of the above and provides a nonwoven fabric excellent in tensile strength and having a small fiber diameter, a sanitary material including the nonwoven fabric and a method of manufacturing the nonwoven fabric.

Solution to Problem

[0008] The specific means to solve the above problems include the following aspects.

<1> A nonwoven fabric comprising a fiber,
in which a ratio of daughter lamellae is 0.10 or less.
<2> The nonwoven fabric according to <1>, in which the ratio of daughter lamellae is 0.09 or less.
<3> The nonwoven fabric according to <1> or <2>, in which a fineness of the fiber is 0.8 d or less.
<4> The nonwoven fabric according to <3>, in which the fineness of the fiber is 0.6 d or less.
<5> The nonwoven fabric according to any one of <1> to <4>, in which the fiber contains a thermoplastic resin.
<6> The nonwoven fabric according to <5>, in which the thermoplastic resin contains a propylene homopolymer.
<7> The nonwoven fabric according to <6>, in which a melt flow rate (MFR) of the propylene homopolymer is from 10 g/10 min to 100 g/10 min.
<8> The nonwoven fabric according to any one of <1> to <7>, comprising a spunbond nonwoven fabric.
<9> A sanitary material, comprising the nonwoven fabric according to any one of <1> to <8>.
<10> A method of manufacturing a nonwoven fabric comprising discharging a thermoplastic resin or a resin composition containing the thermoplastic resin from a nozzle, supplying a cooling air to filaments made of the discharged thermoplastic resin or resin composition, and melt-spinning the filaments,

in which the thermoplastic resin has a mesophase ratio of 22% or more, and
in which a ratio of cooling air volume per 1 m width (m^3/h/m) with respect to discharge volume per nozzle hole (g/min) is from 10,000 to 40,000.

<11> The method of manufacturing a nonwoven fabric according to <10>, in which the ratio of cooling air volume per 1 m width (m^3/h/m) with respect to discharge volume per nozzle hole (g/min) is from 15,000 to 40,000.
<12> The method of manufacturing a nonwoven fabric according to <11>, in which the ratio of cooling air volume per 1 m width (m^3/h/m) with respect to discharge volume per nozzle hole (g/min) is from 30,000 to 40,000.
<13> The method of manufacturing a nonwoven fabric according to any one of <10> to <12>, in which the nonwoven fabric includes a spunbond nonwoven fabric.
<14> The method of manufacturing a nonwoven fabric according to any one of <10> to <13>, in which a temperature of the cooling air is from 15°C to 30°C.

Advantageous Effects of Invention

[0009] According to the present disclosure, it is possible to provide a nonwoven fabric having excellent tensile strength and a small fiber diameter, a sanitary material including the nonwoven fabric, and a method of manufacturing the nonwoven fabric.

BRIEF DESCRIPTION OF DRAWINGS

[0010] FIG. 1 is a schematic diagram of a spunbond nonwoven fabric manufacturing apparatus in one embodiment of the present disclosure.

DESCRIPTION OF EMBODIMENTS

[0011] In the present disclosure, those numerical ranges that are expressed with "to" each denote a range that includes the numerical values stated before and after "to" as the minimum value and the maximum value, respectively. In a set of numerical ranges that are stated stepwise in the present disclosure, the upper limit value or the lower limit value of a numerical range may be replaced with the upper limit value or the lower limit value of other numerical range. Further, in a numerical range stated in the present disclosure the upper limit value or the lower limit value of the numerical range may be replaced with a value indicated in Examples.
[0012] In the present disclosure, plural kinds of substances that correspond to a component may be included. When there are plural kinds of substances that correspond to a component in a composition or the like, the indicated content of the component means, unless otherwise specified, the total content of the plural kinds of substances included in the composition or the like.
[0013] In the present disclosure, a nonwoven fabric means a product that is intertwined without being woven.
[0014] In the present disclosure, "mainly include" and "mainly consist of" mean that the target substance is included in the most amount relative to the whole. For example, each of these indicates that the content of the target substance as a percentage of the whole is 50% by mass or more.
[0015] In the present disclosure, a combination of two or more preferred embodiment is a more preferred embodiment.

<Nonwoven fabric>

[0016] The nonwoven fabric of the present disclosure includes fibers, and the ratio of daughter lamellae in the fiber is 0.10 or less or 0.09 or less. Thereby, a nonwoven fabric having excellent tensile strength and a small fiber diameter can be obtained. The reason is not clear, but it can be presumed as follows.
[0017] The ratio of daughter lamellae in the fiber means the ratio of the daughter lamellae with respect to the total of the parent lamellae oriented in the fiber axis direction and the daughter lamellae newly epitaxial grown on the parent lamellae. A small proportion of daughter lamellas means that the growth of daughter lamellae is suppressed. Since the growth of daughter lamellas is suppressed, fiber strength is excellent, especially in the direction of stretching during manufacturing. Because of the excellent fiber strength, it is possible to suppress fiber breakage even if the traction force of the fiber is increased during nonwoven fabric production, and the fiber diameter can be reduced.
[0018] The ratio of daughter lamellae in the fiber is within a specific range, for example, by adjusting the physical properties, composition, or the like of the raw material of the fiber (for example, thermoplastic resin, resin composition containing thermoplastic resins), or by adjusting the manufacturing conditions of the nonwoven fabric (for example, discharge amount of raw material from nozzle, fiber cooling conditions, or the like).
[0019] As the physical properties of the raw material, for example, the ratio of daughter lamellae in the fiber can be suitably adjusted by adjusting the mesophase ratio of the thermoplastic resin. The mesophase ratio can be within a specific range by, for example, adjusting the molecular weight distribution, stereoregularity, amount of low molecular weight components, and the like of the thermoplastic resin.
[0020] Examples of the manufacturing conditions for the nonwoven fabric include adjusting the balance between the

discharge amount from the nozzle of raw material and the cooling air volume. By adjusting the above balance, the increase in the crystallization rate of the raw material in the cooling process can be suppressed, the growth of daughter lamellae can be suppressed, and the ratio of daughter lamellae in the fiber can be suitably adjusted.

[0021] The ratio of daughter lamellae in the fiber is 0.10 or less or 0.09 or less, preferably 0.08 or less, and preferably 0.07 or less, from the viewpoint of the tensile strength of the nonwoven fabric.

[0022] Since the ratio of the daughter lamellae in the fiber is 0.10 or less, the fiber strength is excellent. Therefore, even if the traction force of the fiber is increased during nonwoven fabric production, fiber breakage can be suppressed, and it becomes a nonwoven fabric with a small fiber diameter. Furthermore, since the ratio of the daughter lamellae in the fiber is 0.09 or less, the fiber strength is further increased, and the fiber breaking is suppressed while becoming a nonwoven fabric having a smaller fiber diameter.

[0023] The lower limit of the daughter lamellar ratio in the fiber is not particularly limited, and may be, for example, 0.005 or more, or 0.01 or more.

[0024] The ratio of daughter lamellae in the fiber can be obtained as follows using a synchrotron radiation equipment.

[0025] For example, at the BL03XU beamline dedicated to the Frontier Soft Matter Development Industry-Academia Alliance in the large synchrotron radiation facility SPring-8, X-rays with a wavelength of 0.11 nm are collected so that the total width at half maximum of the irradiation diameter on the sample is approximately 1 μm. Wide-angle X-ray diffraction measurement is performed with an exposure time of 10 seconds at each point, while scanning at a pitch of 1 μm in the direction perpendicular to the fiber axis of the fiber to be measured. The detector resolution, detection range, and camera length of the detector are not particularly limited if the object can be observed. For example, a charge integration type SOI two-dimensional detector (SOPHIAS) with a pixel resolution of 30 μm × 30 μm and a detection range of 2160 × 891 pixels may be set by adjusting the camera length of 56.8 mm.

[0026] The measurement data is corrected by the equation (1) using the blank measurement results and the values of the ion chamber installed downstream of the sample. In the measurement using the above device, since Ieb=0, the corrected intensity I is as shown in equation (2). Herein, C is the value of the ion chamber, and subscripts 1 and 2 are sample and blank data.

[Equation 1]

$$I = \frac{I_{1,sample} - I_{eb}}{C_{1,sample}} - \frac{I_{2,air} - I_{eb}}{C_{2,air}} \quad (1)$$

$$I = \frac{I_{1,sample}}{C_{1,sample}} - \frac{I_{2,air}}{C_{2,air}} \quad (2)$$

[0027] Herein, C is the value of the ion chamber, and subscripts 1 and 2 are sample and blank data. More details regarding formula (1) and formula (2) are as follows.

I: Intensity (arb. u.)
Ci: Value of upstream ion chamber
C_2: Value of downstream ion chamber
sample: Data of the sample to be measured
eb: Electrical background (dark data)
air: Air data

[0028] Using the two-dimensional pattern obtained by the correction, the diffraction peak intensity from the (110) plane of the α crystal is plotted against an azimuth angle φ. Herein, the azimuth angle φ=90° is the direction perpendicular to a fiber axis (X-ray scanning direction), and the azimuth angle φ=180° is the fiber axis direction. The peak seen in the azimuth angle φ=90° is due to the parent lamellae in which the molecular chain axis is oriented in the fiber axis direction. On the other hand, the peak seen in the azimuth angle φ=170° is due to the newly epitaxial daughter lamellae grown on the parent lamellae. Fan-shaped averaging is performed in the azimuth angles φ=90° and φ=170°, and the horizontal axis is the scattering vector q, and the vertical axis is the scattering intensity. The parent lamellar ratio r_d can be defined by the following formula (3). In the formula (3), I_m and I_d, respectively, are the intensities of the parent lamellae and the daughter lamellae obtained by peak fitting with a Gaussian function in the range of q from 8 nm-1 to 11 nm-1.

$$r_d = I_d / (I_m + I_d) \quad (3)$$

[0029] The fibers included in the nonwoven fabric of the present disclosure preferably contain a thermoplastic resin. The fiber containing a thermoplastic resin may be a fiber formed from a thermoplastic resin or a resin composition containing a thermoplastic resin.

[0030] The mesophase ratio of the thermoplastic resin is preferably 22% or more, and more preferably 24% or more. By using the thermoplastic resin having a mesophase ratio of 22% or more, it is easy to obtain a nonwoven fabric having a small daughter lamellae ratio in the fiber, and for example, the ratio of the daughter lamellae is 0.10 or less or 0.09 or less.

[0031] The upper limit of the mesophase ratio of the thermoplastic resin is not particularly limited, and may be, for example, 30% or less, or 29% or less.

[0032] The mesophase ratio of the thermoplastic resin can be measured by the method described in Examples below.

[0033] A molecular weight distribution (Mw/Mn) of the thermoplastic resin may be from 3.0 to 5.5, from 3.5 to 5.0, from 3.8 to 4.8, or from 4.0 to 4.5 from the viewpoint of suitably adjusting the mesophase ratio of the thermoplastic resin.

[0034] The molecular weight distribution, the below mentioned average mass molecular weight, and number average molecular weight can be determined based on monodisperse polystyrene using gel permeation chromatography (GPC).

[0035] The columns and solvents used in GPC measurement are as follows.

Solvent: 1,2,4-trichlorobenzene
Column: TSKgel GMH_{HR}-H (20) HT × 3
Flow rate: 1.0ml/min
Detector: Ri
Measuring temperature: 140°C

[0036] The mass average molecular weight (Mw) of the thermoplastic resin may be from 100,000 to 500,000, from 120,000 to 300,000, from 130,000 to 200,000, or from 140,000 to 155,000.

[0037] The number average molecular weight (Mn) of the thermoplastic resin may be from 20,000 to 100,000, from 25,000 to 80,000, from 30,000 to 50,000, or from 30,000 to 40,000.

[0038] The stereoregularity of the thermoplastic resin is preferably from 90.0 mol% to 94.5 mol%, more preferably from 91.0 mol% to 94.0 mol%, and further more preferably from 92.0 mol% to 94.0 mol%, from the viewpoint of suitably adjusting the mesophase ratio of the thermoplastic resin.

[0039] In the present disclosure, the stereoregularity means mesopentad fraction [mmmm], and the mesopentad fraction [mmmm] can be measured by the method described in the Examples below.

[0040] Examples of the thermoplastic resin is not particularly limited, and examples thereof include olefin polymers, polyester polymers, polyamide polymers, and the like. The thermoplastic resin may be composed of one or mixture of two or more.

[0041] The olefin polymer is a polymer mainly including a structural unit derived from an olefin, the polyester polymer is a polymer that mainly includes a structural unit including an ester bond, and the polyamide polymer is a polymer that mainly includes a structural unit including an ester bond.

[0042] Specific examples of the olefin polymer include homopolymers or copolymers of α-olefins such as ethylene, propylene, 1-butene, 1-pentene, 1-hexene, 1-octene, 1-decene, 3-methyl-1-butene, 3-methyl-1-pentene, 3-ethyl-1-pentene, 4-methyl-1-pentene, and 4-methyl-1-hexene.

[0043] Specific examples of the polyester polymer include polyethylene terephthalate, polybutylene terephthalate, and polyethylene naphthalate and the like.

[0044] Specific examples of the polyamide polymer include nylon-6, nylon-66, and polymethaxylene adipamide and the like.

[0045] The thermoplastic resin preferably includes an olefin polymer, and more preferably includes an olefin polymer as the main body, from the viewpoint of reducing the fineness while maintaining the strength of the nonwoven fabric. The olefin polymer preferably includes at least one selected from the group consisting of a propylene polymer and an ethylene polymer. The olefin polymer may be a homopolymer of an α-olefin or a copolymer of two or more α-olefins.

[0046] The content of the olefin polymer included in the thermoplastic resin may be 60% by mass or more, may be 80% by mass or more, or further more preferably 100% by mass, with respect to the total amount of the thermoplastic resin. "Content of olefin polymer included in thermoplastic resin" may be referred to as "content of propylene polymer included in thermoplastic resin" or "content of ethylene polymer included in thermoplastic resin".

[0047] Propylene polymer is a polymer mainly including a structural unit derived from propylene, and includes a propylene homopolymer and a copolymer of propylene and an α-olefin other than propylene (propylene/α-olefin copolymers). For example, it may be either a propylene homopolymer or a copolymer of propylene and an α-olefin other than propylene, or it may include both. The propylene/α-olefin copolymer is, for example, preferably a copolymer of propylene and one or more α-olefins having 2 to 10 carbon atoms other than propylene, and more preferably a copolymer of propylene and one or more α-olefins having 2 to 8 carbon atoms.

[0048] From the viewpoint of excellent flexibility, preferred examples of the α-olefins to be copolymerized with propylene include ethylene, 1-butene, 1-pentene, 1-hexene, 1-octene, 1-decene, 3-methyl-1-butene, 3-methyl-1-pentene, 3-ethyl-1-pentene, 4-methyl-1-pentene, and 4-methyl-1-hexene and the like.

[0049] Examples of the propylene/α-olefin copolymer include propylene/ethylene copolymer, and propylene/ethylene/1-butene copolymer. The content of a structural unit derived from α-olefin in the propylene/α-olefin copolymer is not particularly limited, for example, preferably from 1 mol% to 10 mol%, and more preferably from 1 mol% to 5 mol%. The propylene polymer may be a one of propylene polymer or a combination of two or more of propylene polymers.

[0050] In the present disclosure, for a copolymer of propylene and an α-olefin other than propylene, if the content of a structural unit derived from propylene and the content of a structural unit derived from ethylene are equal, such a copolymer is classified as a propylene polymer.

[0051] The propylene polymer such as propylene homopolymer or propylene/α-olefin copolymer may be a biomass-derived propylene polymer.

[0052] "Biomass-derived propylene polymer" means a propylene polymer produced from a raw material monomer including biomass-derived propylene. By using a biomass-derived propylene polymer, it is possible to reduce the environmental load in the production of nonwoven fabrics.

[0053] A monomer including biomass-derived propylene as a raw material for a biomass-derived propylene polymer, can be obtained by cracking biomass-derived naphtha, by synthesizing the monomer from biomass-derived ethylene, or the like. The biomass-derived propylene polymer can be obtained by using the biomass-derived propylene-containing monomer thus synthesized by the same method as when using conventionally known petroleum-derived propylene.

[0054] A propylene polymer synthesized using a bio-derived propylene-containing monomer as a raw material becomes a biomass-derived propylene polymer. The content of the bio-derived propylene polymer in the raw material monomer is more than 0% by mass, may be 100% by mass, or less than 100% by mass, with respect to the total amount of the raw material monomer.

[0055] The monomer that is the raw material for the biomass-derived propylene polymer may further include propylene derived from fossil fuels such as petroleum, and/or an α-olefin other than ethylene and propylene (1-butene, 1-hexene, or the like), in addition to bio-derived propylene.

[0056] Biomass-derived propylene polymer can also be obtained by polymerizing propylene obtained by synthesis of methanol-to-olefins (MTO) or methanol-to-propylene (MTP) using gas generated by pyrolysis of empty fruit bunches (EFB) such as coconut shells.

[0057] Biomass-derived propylene polymer can also be obtained by polymerizing propylene obtained by dehydrating isopropanol produced by fermentation from a biomass raw material mainly consisted of inedible plants such as sorghum.

[0058] When the content of radioactive carbon (C14) in a monomer such as propylene used as a raw material is PC14, the content of biomass-derived carbon in the raw material Pbio (%) can be calculated by the following formula.

$$\text{Formula (2): Pbio (\%)} = \text{PC14}/105.5 \times 100$$

[0059] That is, if all the raw materials for the propylene polymer are derived from biomass, the content of biomass-derived carbon is theoretically 100%. Therefore, the biomass degree of the biomass-derived propylene polymer is 100%. Since fossil fuel-derived raw materials contain almost no C14, the content of biomass-derived carbon in propylene polymer produced only from fossil fuel-derived raw material is 0%, and the content of biomass-derived carbon is 0%.

[0060] "Biomass degree" indicates the content of carbon derived from biomass and is calculated by measuring radioactive carbon (C14). Carbon dioxide in the atmosphere contains C14 at a constant rate (approximately 105.5 pMC). Therefore, it is known that the C14 content in plants (for example, corn) that grow by taking in carbon dioxide from the atmosphere is about 105.5 pMC. It is also known that fossil fuels contain almost no C14. Therefore, by measuring the proportion of C14 contained in all carbon atoms in the propylene polymer, the content of biomass-derived carbon in the raw material can be calculated.

[0061] The biomass degree of the propylene polymer that can be used as a raw material for the nonwoven fabric of the present disclosure is preferably 10% or more.

[0062] The biomass content of the propylene polymer that can be used in the nonwoven fabric of the present disclosure may be from 5% by mass to 99% by mass, from 10% by mass to 75% by mass, or from 20% by mass to 50% by mass of the fossil fuel-derived polypropylene resin and the biomass-derived polypropylene resin.

[0063] The propylene polymer that can be used as a raw material for the nonwoven fabric of the present disclosure may include a propylene polymer obtained by recycling, a so-called recycled polymer.

[0064] "Recycled polymer" includes a polymer obtained by recycling a waste polymer product, and can be produced, for example, by the method described in DE102019127827 (A1). The recycled polymer may include a marker that can be identified as obtained through recycling.

[0065] The ethylene polymer is a polymer mainly consisting of structural unit derived from ethylene, and it is a concept that includes an ethylene homopolymer and copolymer of ethylene and an α-olefin other than ethylene (an ethylene/α-olefin copolymer). For example, it may be either an ethylene homopolymer or a copolymer of ethylene and an α-olefin other than ethylene, or may contain both. The ethylene/α-olefin copolymer is preferably a copolymer of ethylene and one or more α-olefins having 2 to 10 carbon atoms other than ethylene.

[0066] From the viewpoint of excellent flexibility, specific examples of preferredα-olefin copolymerized with ethylene include propylene, 1-butene, 1-pentene, 1-hexene, 1-octene, 1-decene, 3-methyl-1-butene, 3-methyl-1-pentene, 3-ethyl-1-pentene, 4-methyl-1-pentene, 4-methyl-1-hexene, and the like.

[0067] Examples of the ethylene/α-olefin copolymer include ethylene/propylene copolymer, ethylene/1-butene copolymer, and the like. The content of a structural unit derived from the α-olefin in the ethylene/α-olefin copolymer is not particularly limited, for example, preferably from 1 mol% to 10 mol%, and more preferably from 1 mol% to 5 mol%. The ethylene polymer may be one ethylene polymer or a combination of two or more ethylene polymers.

[0068] From the viewpoint of reducing the fineness while maintaining the strength of the nonwoven fabric, the thermoplastic resin preferably includes a propylene polymer, and more preferably includes a propylene homopolymer. When the thermoplastic resin includes a propylene homopolymer, the content of the propylene homopolymer included in the thermoplastic resin may be 60% by mass or more, may be 80% by mass or more, or may be 100% by mass, with respect to the total amount of the thermoplastic resin.

[0069] The melting point of the thermoplastic resin (preferably melting point of the olefin polymer, more preferably melting point of the propylene polymer) is not particularly limited, and may be, for example, 100°C or more, may be 130°C or more, or may be 150°C or more. The upper limit of the melting point of the thermoplastic resin is not particularly limited, and may be, for example, 165° C or lower.

[0070] In the present disclosure, the melting point can be measured using differential scanning calorimetry (DSC) as follows.

[0071] The measurement is made by using DSC Pyris1 manufactured by PerkinElmer or DSC7020 manufactured by SII NanoTechnology Inc. as a differential scanning calorimeter (DSC), in a nitrogen atmosphere (20 ml/min). The sample (approximately 5 mg) is heated to the target temperature set for each thermoplastic resin (230°C for propylene polymer), and held at that temperature for 3 minutes, then cooled to 30°C at 10°C/min, held at 30°C for 1 minute, and raised to the above target temperature at 10°C/min. The melting point (Tm) is calculated from the peak apex of the crystal melting peak during the heating process. In addition, when a plurality of crystal melting peaks is observed, the high temperature side peak is taken as the melting point (Tm).

[0072] When a propylene/α-olefin copolymer is used as the propylene polymer, its melting point (Tm) is preferably 153°C or lower, and more preferably from 125°C to 150°C.

[0073] When a propylene homopolymer is used as the propylene polymer, the melting point (Tm) is preferably 155°C or more, and more preferably from 157°C to 165°C.

[0074] The melt flow rate (MFR) (ASTM D-1238, 230° C, load 2160 g) of the propylene polymer (preferably propylene homopolymer) is not particularly limited if it can produce a nonwoven fabric. The MFR of the propylene polymer (preferably propylene homopolymer) is preferably from 10 g/10 min to 100 g/10 min, and more preferably from 15 g/10 min to 60 g/10 min, and further more preferably from 20 g/10 min to 50 g/10 min, from the viewpoint of reducing the fineness while maintaining the strength of the nonwoven fabric.

[0075] The density of the propylene polymer (preferably propylene homopolymer) is not particularly limited if it can be melt-spun and may be from 0.900 g/cm^3 to 0.945 g/cm^3 or may be from 0.910 g/cm^3 to 0.940 g/cm^3.

[0076] The density of the propylene polymer can be measured in accordance with JIS K7112 (density gradient tube method).

[0077] The propylene polymer (preferably the propylene homopolymer) can be obtained by polymerizing the raw material propylene using a known catalyst such as a Ziegler-Natta catalyst or a metallocene catalyst. Among these, it is preferable to use a Ziegler-Natta catalyst to eliminate heterogeneous bonds, and a catalyst capable of polymerization with high stereoregularity.

[0078] As the method of polymerizing propylene, a known method may be adopted, and examples thereof include a method of polymerizing in an inert solvent such as hexane, heptane, toluene, or xylene, a method of polymerizing in a liquid monomer, a method of polymerizing a monomer in the gas phase while adding a catalyst to the gaseous monomer, or a method of polymerizing in combination thereof.

[0079] The nonwoven fabric of the present disclosure may include additives commonly used such as an antioxidant, a weathering stabilizer, a light stabilizer, an antistatic agent, a slip agent, a hydrophilic agent, an antifogging agent, an anti-blocking agent, a lubricant, a nucleating agent, a dye, a pigment, a natural oil, a synthetic oil, a wax, or an amide compound. When producing the nonwoven fabric of the present disclosure, a resin composition may be used in which one or more of the above-mentioned additives are blended as necessary.

[0080] The content of the thermoplastic resin included in the fiber may be 50% by mass or more, may be 60% by mass or more, may be 70% by mass or more, may be 80% by mass or more, may be 90% by mass or more, or may be 95% by mass or more, with respect to the total amount of the fiber.

[0081] The content of the thermoplastic resin contained in the fiber may be 100% by mass or less, may be 99.5% by mass or less, or may be 99% by mass or less.

[0082] The content of the additive contained in the fiber (if two or more additives are contained, total content of additives) may be from 0.1% by mass to 50% by mass, may be from 0.5% by mass to 20% by mass, may be from 0.5% by mass to 10% by mass, or may be from 1% by mass to 5% by mass, with respect to the total amount of the fiber.

[0083] For example, the nonwoven fabric of the present disclosure may contain an amide compound. The amide compound can function as a lubricant. Examples of the amide compound include fatty acid amides, such as fatty acid amides having 15 to 22 carbon atoms. It is considered that, by adsorbing fatty acid amide having 15 to 22 carbon atoms on the fiber surface of the nonwoven fabric, the fiber surface can be modified to further improve flexibility, tactile feeling, blocking resistance, or the like, and for the other merit, the adhesion of fibers against a rotating equipment in an embossing process or the like can be more effectively suppressed.

[0084] The number of carbon atoms in a fatty acid amide in the present disclosure refers to the number of carbon atoms included in the molecule, and the carbon atoms constituting the amide bond are also included in the above number of carbon atoms.

[0085] The number of carbon atoms in the fatty acid amide may be from 18 to 22.

[0086] Examples of the fatty acid amides include fatty acid monoamide compounds, fatty acid diamide compounds, saturated fatty acid monoamide compounds, and unsaturated fatty acid diamide compounds. Specific examples include palmitic acid amide (carbon number 16), stearic acid amide (carbon number 18), oleic acid amide (carbon number 18), erucic acid amide (carbon number 22), and the like.

[0087] When the nonwoven fabric of the present disclosure contains the amide compound, the content of the amide compound is preferably from 0.1% by mass to 5.0% by mass, preferably from 0.1% by mass to 3.0% by mass and further more preferably from 0.1% by mass to 1.0% by mass, with respect to the total amount of the nonwoven fabric.

[0088] The nonwoven fabric may contain one type of amide compound or may contain two or more types of amide compounds.

[0089] The fineness of the fiber included in the nonwoven fabric may be 1.4 d (denier) or less, may be 1.3 d or less, or may be 1.0 d or less. The fineness of the fiber included in the nonwoven fabric is preferably 0.8 d or less, more preferably 0.6 d or less, and further more preferably 0.5 d or less, from the viewpoints of high strength, low air permeability, high water resistance, good tactile feeling, or the like.

[0090] The lower limit of the fineness of the fiber is not particularly limited, and may be, for example, 0.05 d or more.

[0091] The basis weight of the nonwoven fabric is not particularly limited. From the viewpoint of obtaining a nonwoven fabric that has practical mechanical strength and appropriate flexibility, it is preferably from 5 g/m^2 to 100 g/m^2, and more preferably from 5 g/m^2 to 50 g/m^2.

[0092] In the present disclosure, the basis weight of the nonwoven fabric may be read as "the basis weight of the nonwoven fabric laminate".

[0093] Types of nonwoven fabrics are not particularly limited, and examples thereof include spunbond nonwoven fabrics, melt blown nonwoven fabrics, carded air-through nonwoven fabrics, airlaid nonwoven fabrics, needle punched spunbond nonwoven fabrics, wet processed nonwoven fabrics, dry pulp nonwoven fabrics, flash spun nonwoven fabrics, spread nonwoven fabrics, or the like. Preferably, the nonwoven fabric of the present disclosure includes a spunbond nonwoven fabric. Spunbond nonwoven fabrics have a smaller fiber diameter, making them denser and more uniform when compared with other nonwoven fabrics with the same pattern. Therefore, the spunbond nonwoven fabric is suitably used for applications requiring performance such as low air permeability and high-water resistance.

[0094] The nonwoven fabric of the present disclosure may be made of one type of nonwoven fabric or may be made of two or more types of nonwoven fabric.

[0095] The fibers included in the nonwoven fabric of the present disclosure may be either solid fibers or hollow fibers. From the viewpoint of reducing fineness while maintaining nonwoven fabric strength, the nonwoven fabric of the present disclosure is preferably a nonwoven fabric made of solid fibers. As a method of manufacturing hollow fibers, methods described in known literature may be appropriately referenced.

[0096] The form of the fiber included in the nonwoven fabric of the present disclosure is not particularly limited, may be a composite fiber, or may be a monocomponent fiber. The composite fiber preferably contains two or more thermoplastic resins as constituent components.

[0097] Examples of the type of the composite fiber include a core-sheath type, a side-by-side type, and a sea-island type. The core-sheath type composite fiber has a core portion and a sheath portion and may be either a concentric core-sheath type or an eccentric core-sheath type. In the eccentric core-sheath type composite fiber, the core portion may be exposed on the surface, or the core portion may not be exposed on the surface.

[0098] The fiber included in the nonwoven fabric of the present disclosure may be a crimped fiber or non-crimped fiber. The non-crimped fiber may be, for example, an eccentric core-sheath type crimped composite fiber.

[0099] The nonwoven fabric of the present disclosure may be a nonwoven fabric consisting of one layer, may be a nonwoven fabric laminate consisting of two or more layers of nonwoven fabric, or may be a nonwoven fabric laminate including the nonwoven fabric of the present disclosure and another layer other than the nonwoven fabric of the present disclosure. Another layer other than the nonwoven fabric of the present disclosure may be one layer, or two or more layers.

[0100] Examples of another layer other than the nonwoven fabric of the present disclosure include a knitted fabric, a woven fabric, a nonwoven fabric other than the nonwoven fabric of the present disclosure (hereinafter also referred to as "another nonwoven fabric"), a film, and the like. Examples of another nonwoven fabric include the various nonwoven fabrics mentioned above.

[0101] The method for forming the nonwoven fabric laminate is not particularly limited, and various methods can be used. Examples thereof include a heat fusing method such as heat embossing or ultrasonic welding, needle punching, a mechanical entangling method such as water jet, a method using a chemical adhesive such as a hot melt adhesive or a urethane adhesive, or extrusion lamination etc.

[0102] The nonwoven fabric of the present disclosure or the nonwoven fabric laminate including the nonwoven fabric of the present disclosure (hereinafter also referred to as "nonwoven fabric or the like") is preferably embossed or compacted (preferably heat fused) in a portion.

[0103] Examples of compacting a part method of the nonwoven fabric include methods using means such as an ultrasonic wave, hot embossing using an embossing roll, hot air through, and the like.

[0104] The nonwoven fabric or the like may have a compacted portion and a non-compacted portion. The area ratio of the compacted portion is preferably from 5% to 30%, more preferably from 5% to 20%, and further more preferably from 8% to 14%. This allows for a good balance between flexibility and strength of the nonwoven fabric or the like.

[0105] As for the area ratio of the compacted portion, a 10 mm $\times$ 10 mm test piece is collected from the nonwoven fabric. The contact surface of the test piece with the embossing roll (hereinafter also referred to as "convex portion") is observed by using an electron microscope (magnification: 100x). The area ratio of the embossed or compacted portion is calculated from the area ratio of the convex portion with respect to the total area of the nonwoven fabric test piece. Further, the area ratio of the convex portion formed on the embossing roll that can form the compacted portion is also referred to as "embossed area ratio". The preferred range of the embossed area ratio is the same as the preferred range of the area ratio of the compacted portion described above.

[0106] Examples of the shape of the compacted portion include a circle, an ellipse, an oval, a square, a rhombus, a rectangle, a square, and continuous shapes based on these shapes.

[0107] The uses of the nonwoven fabric of the present disclosure are not particularly limited, and the nonwoven fabric can be used in a wide range of applications for which nonwoven fabrics are normally used. Examples of uses for nonwoven fabrics include filters, sanitary materials, medical components, packaging materials (oxygen absorbers, body warmers, heating pads, food packaging materials, or the like), battery separators, thermal reserving materials, thermal insulation materials, protective clothing, clothing components, electronic materials, and sound absorbing materials. Among these, the nonwoven fabrics are suitably used as sanitary materials.

<Sanitary materials>

[0108] A sanitary material of the present disclosure includes the above-mentioned nonwoven fabric of the present disclosure. Examples of the sanitary material include absorbent articles such as disposable diapers, disposable pants, sanitary products, urine absorbing pads, and pet sheets; medical sanitary materials such as bandages, medical gauze, towels, sheets, and poultice materials; industrial masks, and sanitary masks.

[0109] The sanitary material of the present disclosure is not limited to these and can be suitably used for other sanitary material applications. The sanitary material may include a nonwoven fabric laminate consisting of two or more layers of the nonwoven fabric of the present disclosure or may include a nonwoven fabric laminate including the nonwoven fabric of the present disclosure and another layer other than the nonwoven fabric of the present disclosure.

<Method of manufacturing nonwoven fabric>

[0110] A method of manufacturing a nonwoven fabric is a method including discharging a thermoplastic resin or a resin composition containing the thermoplastic resin from a nozzle, supplying a cooling air to filaments made of the discharged thermoplastic resin or resin composition, and melt-spinning the filaments. The thermoplastic resin used in the method of manufacturing a nonwoven fabric has a mesophase ratio of 22% or more, and in the condition of manufacturing a nonwoven fabric, a ratio of cooling air volume per 1 m width (m^3/h/m) with respect to discharge volume per nozzle hole (g/min) is from 10,000 to 40,000 or from 15,000 to 40,000. By using the above-mentioned thermoplastic resin or resin composition containing the thermoplastic resin and producing a nonwoven fabric under the above-mentioned conditions, the nonwoven fabric of the present disclosure having excellent tensile strength and having a small fiber diameter can be obtained. Furthermore, this manufacturing method has excellent spinning stability and tends to suppress fiber breakage during melt-spinning.

[0111] The preferred conditions for the thermoplastic resin or resin composition used in the method of manufacturing the nonwoven fabric of the present disclosure are the same as the preferred conditions for the thermoplastic resin or resin composition of the nonwoven fabric of the present disclosure explained in the above-mentioned section.

[0112] The nonwoven fabric obtained by the manufacturing method of the present disclosure is not particularly limited, and examples thereof include the nonwoven fabrics exemplified above. Among these, the nonwoven fabric obtained by the method of manufacturing the nonwoven fabric of the present disclosure is preferably a spunbond nonwoven fabric.

[0113] The thermoplastic resin or the resin composition containing the thermoplastic resin may be melt-kneaded in an extruder, and the molten thermoplastic resin or resin composition may be discharged from a nozzle. Filaments of the thermoplastic resin or resin composition is obtained by discharging the molten thermoplastic resin or resin composition from the nozzle. The melting temperature of the thermoplastic resin or resin composition is not particularly limited, and may be adjusted as appropriate depending on the type of thermoplastic resin, and for example, it may be from 200°C to 300°C, or may be from 220°C to 290°C.

[0114] The molten thermoplastic resin or resin composition may be discharged into the cooling section from a plurality of nozzles. From the viewpoint of maintaining spinning stability, the discharge volume per nozzle hole (fr) may be 0.60 g/min or less or may be 0.55 g/min or less. The discharge volume per nozzle hole (fr) is preferably 0.40 g/min or less, more preferably 0.35 g/min or less, further more preferably 0.30 g/min or less, particularly preferably 0.25 g/min or less, and extremely preferably 0.20 g/min or less, from the viewpoint of maintaining spinning stability and obtaining a thin fiber. The lower limit of the discharge volume per nozzle hole (fr) is not particularly limited, and for example, may be 0.10 g/min or more, or may be 0.15 g/min.

[0115] Regarding the cooling air supplied to the filaments of the discharged thermoplastic resin or resin composition, the cooling air volume per 1 m width (fa) is preferably from 4,000 m^3/h/m to 7,300 m^3/h/m, more preferably from 4,500 m^3/h/m to 7,000 m^3/h/m, further more preferably from 5,000 m^3/h/m to 7,000 m^3/h/m, and particularly from 5,500 m^3/h/m to 7,000 m^3/h/m, from the viewpoint of maintaining spinning stability and obtaining a thin fiber.

[0116] The cooling air volume per 1 m width refers to the cooling air volume per 1 m width of the means (cooling air supply section) that supplies cooling air to the filaments of the discharged thermoplastic resin or resin composition.

[0117] fa/fr, which is a ratio of cooling air volume per 1 m width (m^3/h/m) with respect to discharge volume per nozzle hole (g/min) is from 10,000 to 40,000 or from 15,000 to 40,000, from the viewpoint of maintaining spinning stability and enabling a thin fiber, the ratio is preferably from 30,000 to 40,000, more preferably from 31,000 to 39,000, and further more preferably from 34,000 to 39,000. fa/fr affects the cooling rate of the filaments, when fa/fr is large, the cooling rate tends to be large, and when fa/fr is small, the cooling rate tends to be small.

[0118] By using a thermoplastic resin with the mesophase ratio of 22% or more and setting fa/fr to 40,000 or less, the increase in the crystallization rate due to the increase in the cooling rate is suppressed. This can lead to suppress the increase in the ratio of daughter lamellae in the fiber by suppressing the growth rate of the daughter lamellae in the fiber and promoting the growth rate of the parent lamellae. This also can lead to suppress the occurrence of fiber breakage by suppressing an excessive increase in the traction force of the filaments.

[0119] By using a thermoplastic resin with the mesophase ratio of 22% or more and setting fa/fr to 10,000 or more or 15,000 or more, the lack of traction force of the filaments is suppressed while maintaining spinning stability. As a result, the fine fiber can be produced.

[0120] By setting fa/fr to 15,000 or more, sufficient traction force of the filaments is obtained, so that further fine fiber formation is possible.

[0121] The temperature of the cooling air is preferably from 15°C to 30°C, more preferably from 20°C to 30°C, and further more preferably from 22°C to 28°C, from the viewpoint of making it possible to form enabling fine fibers while maintaining spinning stability.

[0122] When supplying cooling air to the filaments, the cooling air may be supplied from a cooling air supply section to the filaments of the thermoplastic resin or resin composition discharged into the cooling section. The cooling air supply section may supply cooling air from a direction intersecting (preferably perpendicular to) the vertically downward direction to the filaments of the thermoplastic resin or resin composition discharged in the vertically downward direction. The cooling air supply section may be divided into a plurality of parts, for example, it may be divided into two or more stages in the vertical direction through a partition, or it may be divided into two stages in the vertical direction through a partition. Regarding the cooling air supplied by the divided cooling air supply sections, conditions such as temperature, air volume, and air speed may be the same or different. By dividing the cooling air supply section into multiple parts, it is possible to adjust the temperature, air volume, air speed, or the like of the cooling air in each divided cooling air supply section, which makes it easy to adjust the ratio of daughter lamellae.

[0123] The cooling air supply section may include a first cooling air supply section on the vertically upper side and a second cooling air supply section on the vertically lower side, which are divided into two stages in the vertical direction through a partition.

[0124] From the viewpoint of more preferably suppressing fiber breakage, it is preferable that the temperature of cooling air supplied to the first cooling air supply section is from 10°C to 40°C, and the temperature of cooling air supplied to the second cooling air supply section is higher than the temperature of cooling air supplied to the first cooling air supply section by 10°C or more and is preferably from 30°C to 70°C.

[0125] From the viewpoint of preferably suppressing fiber breakage, the average air speed (V_2) of cooling air supplied to the second cooling air supply section is preferably more than the average air speed (Vi) of cooling air supplied to the first cooling air supply section. In view of more preferably suppressing fiber breakage, the ratio of V_1 to V_2 (V_1/V_2) is preferably from more than 0 to 0.8, more preferably from more than 0 to 0.7, furthermore preferably $0.01 \leq V_1/V_2 \leq 0.5$, and particularly preferably $0.05 \leq V_1/V_2 \leq 0.4$.

[0126] From the viewpoint of being able to appropriately adjust the cooling speed while maintaining the traction force, the upper and lower cooling air volume ratio (first cooling air supply section: second cooling air supply section), which is the ratio between the air volume of cooling air supplied to the first cooling air supply section and the air volume of cooling air supplied to the second cooling air supply section, is preferably from 1: 1.2 to 1:5, and more preferably from 1:1.5 to 1:4.

[0127] From the viewpoint of more preferably suppressing fiber breakage, the upper and lower cooling air volume ratio (first cooling air supply section: second cooling air supply section) may be from 1:1 to 1:5.

[0128] As described above, the method of manufacturing the nonwoven fabric of the present disclosure may include a step of discharging a thermoplastic resin or resin composition from a nozzle, a step of cooling filaments of the discharged thermoplastic resin or resin composition by supplying cooling air to the filaments. Further, the method may include a step of drawing the cooled filaments, and a step of forming a nonwoven web by collecting the drawn filaments. Furthermore, the method of manufacturing the nonwoven fabric of the present disclosure may include a step of subjecting the nonwoven web to heat and pressure treatment.

[0129] When the nonwoven web is subjected to heat and pressure treatment by hot embossing, the embossing temperature may be adjusted as appropriate depending on the line speed during embossing, the pressing pressure, or the like. For example, the embossing temperature may be from 85°C to 150°C.

[0130] Hereinafter, one embodiment of the method of manufacturing the nonwoven fabric of the present disclosure will be described using FIG. 1. In the following embodiment, a method of manufacturing a spunbond nonwoven fabric will be described. Note that the method of manufacturing the nonwoven fabric of the present disclosure is not limited to the following embodiment.

[0131] In the method of manufacturing a nonwoven fabric in one embodiment, a spunbond nonwoven fabric is manufactured using a spunbond nonwoven fabric manufacturing apparatus 100 shown in FIG. 1, for example. The spunbond nonwoven fabric manufacturing apparatus 100 shown in FIG. 1 includes an extruder 1, a spinneret 2, a cooling chamber 3, a cooling air supply section 4, an air-permeable partition 5, a diffuser 7, a mesh belt 8, and a suction device 9. The cooling air supply section 4 is divided into two stages via a non-air-permeable partition 11.

[0132] The filaments 6 of the thermoplastic resin or resin composition discharged into the cooling chamber 3 from the plurality of nozzles of the spinneret 2 are quenched by cooling air supplied into the cooling chamber 3 from the cooling air supply section 4. The cooling air supply section 4 is divided into two stages via the non-air-permeable partition 11, and cooling air is supplied to the cooling chamber 3 from a first cooling air supply section 4A and a second cooling air supply section 4B which are divided into two stages. The preferable conditions for the cooling air supplied from the first cooling air supply section 4A and the second cooling air supply section 4B are as described above.

[0133] The air-permeable partition 5 is not particularly limited if the air-permeable partition 5 is a partition having permeability. In view of the regulation of cooling air, the air-permeable partition 5 preferably has a lattice shape such as a quadrangular shape, or a honeycomb shape such as a hexagonal shape or an octagonal shape, and more preferably has a honeycomb shape.

[0134] In view of strength and the regulation of cooling air, the thickness of the air-permeable partition 5 is preferably from 10 mm to 50 mm, and more preferably from 20 mm to 40 mm.

[0135] The filaments 6 of the discharged thermoplastic resin or resin composition is quenched with cooling air supplied from the cooling air supply section 4 in the cooling chamber 3. After the filaments 6 is quenched, the continuous fibers are drawn (attenuated) with drawing air through a drawing section located on the downstream side of the cooling chamber 3. The drawing comes from the cooling air. The drawn fibers are dispersed by the diffuser 7 disposed on the downstream side of the drawing section. The dispersed fibers are sucked by the suction device 9, so that a nonwoven fabric web 10 is deposited on the collecting surface, the mesh belt 8. The nonwoven web 10 may be heated and pressurized by an interlaced section. Through the above steps, a spunbond nonwoven fabric is obtained.

[0136] In the spunbond nonwoven fabric manufacturing apparatus 100, a gap is provided between the partition 11 and the air-permeable partition 5. As a result, the wind speed difference of the cooling air at the boundary between the first cooling air supply section 4A on the vertically upper side and the second cooling air section 4B on the vertically lower side can be reduced, thereby fiber breakage and fiber shaking can be suppressed.

[0137] The distance d of the gap may be 55 mm or less, 50 mm or less, 45 mm or less, or 40 mm or less, in the view of more preferably suppressing fiber breakage. The distance d of the gap may be 5 mm or more, or 10 mm or more, in the view of more preferably suppressing fiber fluctuation. The above-mentioned gap is not an essential component, and d may be 0 mm.

[0138] The width L of the cooling air supply section 4 is not particularly limited. The width L may be from 3 m to 7 m, or from 4 m to 6 m. The height of the cooling air supply section 4 is not particularly limited. The height may be from 0.4 m to 1.0 m, or from 0.6 m to 0.8 m.

[0139] It is preferable condition that $(L \times h)/d$ satisfies 0.056 or more, when the width of the cooling air supply section 4 is L (m), the height of the cooling air supply section 4 is h (m), and the distance of the gap is d (mm). In such a case, the height h of the cooling air supply section 4 corresponds to hi + h_2 + the thickness of the partition 11 in Fig. 1, and the width L of the cooling air supply section 4 is the length of the inner side of the cooling air supply section 4, excluding an outer wall, in the direction orthogonal to the direction of cooling air supply and the height of the cooling air supply section 4 in Fig. 1.

[0140] The width L of the cooling air supply section 4 and the height h of the cooling air supply section 4 mean the width and height of the cooling air outlet of the cooling air supply section 4. Accordingly, $(L \times h)$ means the area of a surface, through which the cooling air passes, outlet of the cooling air supply section 4, and $(L \times h)/d$ means the ratio of the area to the distance d of the gap.

[0141] $(L \times h)/d$ may be from 0.056 to 0.614, or from 0.112 to 0.448. Fiber breakage can be more preferably suppressed in a case in which $(L \times h)/d$ is 0.056 or more, and fiber fluctuation can be more preferably suppressed in a case in which $(L \times h)/d$ is 0.614 or less.

[0142] The ratio of a distance (distance B) from the nozzle face to the partition 11 with respect to the distance d of the gap (distance B/distance d) may be from 5 to 50.

[0143] The ratio of the height (h_2) of the second cooling air supply section 4B to the height (h_1) of the first cooling air supply section 4A may be from 0.5 to 1.5, or from 0.7 to 1.2.

[0144] The ratio of the thickness of the air-permeable partition to the distance d (thickness of air-permeable partition/distance d) is preferably from 0.5 to 5.0, more preferably from 0.5 to 1.5, and furthermore preferably from 0.8 to 1.2.

[0145] The ratio of the distance (distance B) from the nozzle face to the partition 11 with respect to a distance (distance C) from the nozzle face to the inlet of the drawing section (distance B/distance C) is preferably from 0.2 to 0.8, and more preferably from 0.2 to 0.6.

EXAMPLES

[0146] Hereinafter, embodiments of the present invention will be described in more detail based on Experimental Examples, but the present invention is not limited to these Experimental Examples, which are embodiments of the present invention.

[0147] Physical property values, or the like in the Experimental Examples were measured by the following methods. The results are shown in Table 1.

[0148] Note that in Table 1, "-" means that it has not been measured.

(1) Mesophase ratio [%]

[0149] The mesophase ratio of the raw resin was measured using FLASH DSC1 (METTLER manufactured by TOLEDO). The raw resin pellet was heated from 0°C to 200°C at a rate of 100°C/second, held at 200°C for 0.5 seconds, and then cooled to 0°C at a rate of 100°C/second to determine the exothermic peak position during the cooling process, and measured the calorific value. The peak derived from the α-crystal around 80°C and the mesophase peak around 40°C that appeared in the cooling curve were fitted with a Gauss function, and the peak integral values of the α-crystal and mesophase were compared to obtain the mesophase ratio.

(2) MFR [g/10 min]

[0150] According to ASTM D-1238, the melt flow rate (MFR) of the raw resin was measured at 230°C and a load of 2160 g.

(3) Melting point [°C]

[0151] The melting point (Tm) of the raw resin was measured using a differential scanning calorimeter (Model DSC220C, manufactured by Seiko Instruments Inc.) as a measuring device. Approximately 5 mg of the raw resin was sealed in an aluminum pan for measurement and heated from room temperature to 200°C at a rate of 10°C/min. It was held at 200°C for 5 minutes and then cooled to -50°C at a rate of 10°C/min. After being held at - 50°C for 5 minutes, it was heated a second time to 200°C at a rate of 10°C/min, and the melting point (Tm) was calculated from the peak apex of the crystal melting peak of the calorific value curve at this second heating.

(4) Stereoregularity [mol%]

[0152] The mesopentad fraction [mmmm], which is an index indicating stereoregularity, was determined as follows. The mesopentad fraction [mmmm] is based on the method proposed by A. Zambelli et al. in "Macromolecules, 6, 925 (1973)", and it is the meso fraction in pentad units in a polypropylene molecular chain measured by the methyl group signal in the ^{13}C-NMR spectrum. As the mesopentad fraction [mmmm] increases, stereoregularity increases.

[0153] The ^{13}C-NMR spectrum can be measured using the following equipment and conditions in accordance with the peak assignment proposed by A. Zambelli et al. in "Macromolecules, 8, 687 (1975)".

Device: JNM-EX400 type 13C-NMR device manufactured by Japan Electronics Co., Ltd.
Method: Proton complete decoupling method
Concentration: 220mg/ml
Solvent: 90:10 (volume ratio) mixed solvent of 1,2,4-trichlorobenzene and heavy benzene
Temperature: 130°C
Pulse width: 45°
Pulse repetition time: 4 seconds
Accumulation: 10,000 times

[Calculation formula]

$$M([mmmm]) = m/S \times 100$$

$$S = P\beta\beta + P\alpha\beta + P\alpha\gamma$$

S: Signal intensity of side chain methyl carbon atoms in all propylene units
$P\beta\beta$: 19.8ppm~22.5ppm
$P\alpha\beta$:18.0ppm~17.5ppm
$P\alpha\gamma$:17.5ppm~17.1ppm
m: Meso pentad chain: 21.7ppm to 22.5ppm

(5) Fineness [d: number of grams of fiber per 9000 m]

[0154] Ten test pieces with a machine direction (MD) of 10 mm and a transverse direction (CD) of 10 mm (10 mm (MD) × 10 mm (CD)) were collected from the nonwoven fabric. The sampling locations were arbitrary in the MD direction, and 10 locations in the CD direction were uniformly spaced along a straight line, excluding 20 cm from both ends of the nonwoven fabric. Using a Nikon ECLIPSE E400 microscope, the diameter of the fiber was read in μm to the first decimal place at 20x magnification. The diameter was measured at 20 arbitrary locations for each test piece, for a total of 200 locations. The number of grams of fiber per 9000 m was obtained for each measurement point. In this Experimental Example, the density of the polypropylene polymer was regarded as 0.91 g/cm. The average value of the grams of fiber per 9000 m at each measurement point was calculated, and the average value was rounded off to the second decimal place to obtain the fineness of the nonwoven fabric.

(6) Ratio of daughter lamellae

[0155] X-rays with a wavelength of 0.11 nm were collected at the BL03XU beamline dedicated to the Frontier Soft Matter Development Industry-Academia Alliance in the large synchrotron radiation facility SPring-8 so that the total width at half maximum of the irradiation diameter on the sample was approximately 1 μm. Wide-angle X-ray diffraction measurements were performed while scanning at a pitch of 1 μm in the direction perpendicular to the fiber axis of the fiber to be measured, with an exposure time of 10 seconds at each point.

[0156] A charge integrating type SOI two-dimensional detector (SOPHIAS) with a pixel resolution of 30 μm × 30 μm and a detection range of 2160×891 pixels was installed so that the camera length was 56.8 mm.

[0157] By the method described above, the ratio of daughter lamellae was obtained from the diffraction peak intensity from the (110) plane of the α crystal.

(7) Basis weight [g/m^2]

[0158] Ten test pieces measuring 100 mm (MD) × 100 mm (CD) were collected from the nonwoven fabric. The collection locations were 10 in the CD direction. Next, the mass (g) of each sample was measured using an electronic balance (manufactured by Kensei Kogyo Co., Ltd.) at 23°C and 50% relative humidity. The average mass of each test piece was obtained. The average value thus obtained was converted into the mass (g) per m^2 and rounded off to the first decimal place to obtain the basis weight [g/m^2] of the nonwoven fabric.

(8) Strength per unit basis weight INDEX [N/25mm/(g/m^2)]

[0159] The tensile load was measured in accordance with JIS L 1906. First, in a constant temperature room with a temperature of 20 ± 2°C and a humidity of 65 ± 2% as specified in JIS Z 8703 (standard conditions at the test site), five test pieces each of which had 25 cm in the machine direction (MD) and 2.5 cm in the transverse direction (CD) were taken from the nonwoven fabric.
[0160] The obtained test pieces were subjected to a tensile test using a tensile tester (Instron 5564 model manufactured by Instron Japan Company Limited) with a chuck distance of 100 mm and a tensile speed of 300 mm/min, and the tensile loads on five test pieces were measured, and the average value of those maximum values was taken as the maximum strength (N/25 mm).
[0161] The strength per unit basis weight INDEX expressed by the formula shown below was determined.

Strength per unit basis weight INDEX = (((MD maximum strength)^2+ (CD maximum intensity)^2))/2)$^{0.5}$/Basis weight

(9) Surface roughness of nonwoven fabric by KES method (SMD: unit μm)

[0162] For the measurement of SMD, an automated surface testing machine "KES-FB4-AUTO-A" manufactured by Kato Tech was used. SMD was measured on both sides of the nonwoven fabric, and the smaller value is listed in Table 1. The specific measurement method is as follows.

(a) Three test pieces of 200 mm (MD) × 200 mm (CD) were taken from the nonwoven fabric at equal intervals in the width direction of the nonwoven fabric.
(b) The test piece was set on the sample stand.
(c) The surface of the test piece was scanned with a surface roughness measuring probe (material: φ0.5 mm piano wire, contact length: 5 mm) to which a load of 10 gf was applied, and the average deviation of the surface irregularities was measured.
(d) The above measurements were performed on all test pieces in the longitudinal direction (the length direction of the nonwoven fabric) and the transverse direction (the width direction of the nonwoven fabric), and the average deviations of a total of six points were averaged and rounded off to one decimal place to obtain the SMD (μm).

(10) Average coefficient of friction (MIU) of nonwoven fabric determined by KES method and variation in average coefficient of friction (MMD) determined by KES method of nonwoven fabric

[0163] For the measurement of MIU, an automated surface testing machine "KES-FB4-AUTO-A" manufactured by Kato Tech was used. The average coefficient of friction MIU was measured on both sides of the spunbond nonwoven fabric, and the smaller value is listed in Table 1. A specific method for measuring MIU and calculating method for MMD is as follows.

(a) Three test pieces of 200 mm (MD) × 200 mm (CD) were taken from the nonwoven fabric at equal intervals in the width direction of the nonwoven fabric.
(b) The test piece was set on the sample stand.
(c) The surface of the test piece was scanned with a contact friction probe (material: φ0.5 mm piano wire (20 parallel wires), contact area: 1 cm^2) loaded with 50 gf to measure the average friction coefficient.
(d) The above measurements were performed on all test pieces in the longitudinal direction (longitudinal direction of the nonwoven fabric) and transverse direction (width direction of the nonwoven fabric), and the average deviations of these six points were averaged and rounded to the nearest tenth to obtain MIU. The fluctuations in the average friction coefficients of the six points were further averaged and rounded to the nearest tenth to obtain MMD.

(11) Air permeability [$cm^3/cm^2/s$]

[0164] A test piece of 150 mm (MD) × 150 mm (CD) was taken from the nonwoven fabric, and its air permeability was measured using a Frazier air permeability measuring machine according to JIS L 1096. The average value of n=5 was taken as the measured value.

(12) Water pressure resistance [mmH_2O]

[0165] The water pressure resistance of the nonwoven fabric was measured in accordance with method A (low water pressure method) specified in JIS L 1096.

(13) Spinning stability

[0166] The number of fiber breakages per minute during continuous spinning was randomly observed three times, and the case where no fiber breakage occurred was graded A, and the case where fiber breakage occurred even once out of three times was graded B.

[Preparation of raw resin]

[0167] In each Experimental Example, the propylene polymers (PP1 and PP2) shown below were used as raw resins. PP1 and PP2 were produced according to the method described in International Publication No. 2019/065306 by adjusting synthesis conditions such as reaction temperature and reaction time.

PP1: Propylene homopolymer (A) (mesophase ratio:25%, MFR:35 g/10 min, melting point:160°C, stereoregularity:92.7 mol%, Mw:152,000, Mn:36,000, Mw/Mn:4.2)
PP2: Propylene homopolymer (B) (mesophase ratio:20%, MFR:35 g/10 min, melting point:161°C, stereoregularity:94.9 mol%, Mw:157,000, Mn:42,000, Mw/Mn:3.7)

[Experimental Example 1]

[0168] A spunbond nonwoven fabric was manufactured by the spunbond method using a spunbond nonwoven fabric manufacturing apparatus provided with one extruder shown in FIG. 1. A nozzle for monocomponent fibers was used. The propylene homopolymer (A) was melted using an extruder at a molding temperature of 240°C.

[0169] The molten propylene homopolymer (A) was discharged from the spinneret at the discharge volume per nozzle hole (fr) of 0.18 g/min, and the cooling air was sent to the cooling section at the cooling air volume per 1 m width (fa) of 6720 $m.^3/h/m$, and melt spinning was performed by spunbond method.

[0170] The temperature of the upper cooling air and the lower cooling air were 23°C. The ratio of the height of the lower cooling air supply section (second cooling air supply section) (h_2) to the height of the upper cooling air supply section (first cooling air supply section) (hi), h_2/h_1, was 0.75. The average air speed V_1 of the cooling air supplied from the upper cooling air supply section to the cooling section and the average air speed V_2 of the cooling air supplied from the lower cooling air supply section to the cooling section are shown in Table 1. Anemomaster anemometer (Model 6114) manufactured by KANOMAX was used for air speed measurements. Furthermore, the upper and lower cooling air volume ratio (upper stage: lower stage), which is the ratio between the air volume of cooling air supplied to the cooling section from the upper cooling air supply section and the air volume of cooling air supplied to the cooling section from the lower cooling air supply section, are shown in Table 1. The cooling air volume per 1 m width (fa) satisfies the following formula. fa/fr in Table 1 is a value rounded to the tenth place.

$$\text{Cooling air volume per 1m width (fa)} = V_1[m/s] \times h_1[m] \times 3600[h/sec] + V_2[m/s] \times h_2[m] \times 3600[h/sec]$$

[0171] After depositing the stretched fibers on the collecting surface, heat embossing with the area ratio of 10% was performed to produce a spunbond nonwoven fabric with the basis weight of 17 g/m^2.

[Experimental Example 2]

[0172] A spunbond nonwoven fabric was produced in the same manner as in Experimental Example 1, except that the cooling air volume (fa) was changed to 5,880 $m^3/hr/m$ by changing the average air speeds V_1 and V_2 of the cooling air in Experimental Example 1.

[Experimental Example 3]

[0173] A spunbond nonwoven fabric was produced in the same manner as in Experimental Example 2, except that the basic weight was changed to 34 g/m^2 in Experimental Example 2.

[Experimental Example 4]

[0174] It was attempted to produce a spunbond nonwoven fabric in the same manner as in Experimental Example 1, except that the cooling air volume (fa) was changed to 7,560 m^3/hr/m by changing the average air speeds V_1 and V_2 of the cooling air in Experimental Example 1. However, fiber breakage occurred frequently during melt spinning, and a spunbond nonwoven fabric could not be obtained.

[Experimental Example 5]

[0175] A spunbond nonwoven fabric was produced in the same manner as in Experimental Example 1, except that the discharge volume per nozzle hole (fr) was changed to 0.52 g/min, the cooling air volume (fa) was changed to 5,880 m^3/hr/m by changing the average air speeds V_1 and V_2 of the cooling air, and the basic weight was changed to 34 g/m^2 in Experimental Example 1.

[Experimental Example 6]

[0176] It was attempted to produce a spunbond nonwoven fabric in the same manner as in Experimental Example 1, except that a propylene homopolymer (B) was used and the manufacturing conditions for the spunbonded nonwoven fabric were changed as shown in Table 1. However, fiber breakage occurred frequently during melt spinning, and a spunbond nonwoven fabric could not be obtained.

[Table 1]

			Experimental Example					
			1	2	3	4	5	6
Raw resin			PP1	PP1	PP1	PP1	PP1	PP2
Raw material properties	Mesophase ratio	[%]	25	25	25	25	25	20
	MFR	[g/10 min]	35	35	35	35	35	35
	Melting point	[°C]	160	160	160	160	160	161
	Stereoregular ity	[mol%]	92.7	92.7	92.7	92.7	92.7	94.9
Manufact uring Condition	Discharge volume per nozzle	[g/min]	0.18	0.18	0.18	0.18	0.52	0.42
s	hole fr							
	cooling air volume per 1 m width fa	[m^3/h/m]	6720	5880	5880	7560	5880	3960
	fa/fr	[-]	3730 0	3270 0	32700	42000	11300	9400
	Average air speed of cooling air V_1	[m/s]	1.17	1.02	1.02	1.31	2.04	1.38
	Average air speed of cooling air V_2	[m/s]	4.67	4.08	4.08	5.25	2.72	1.83
	Upper and lower cooling air volume ratio	[-]	1:3	1:3	1:3	1:3	1:1	1:1
	h_2/h_1	[-]	0.75	0.75	0.75	0.75	0.75	0.75

(continued)

			Experimental Example					
			1	2	3	4	5	6
Raw resin			PP1	PP1	PP1	PP1	PP1	PP2
Fiber properties	Fineness	[d]	0.3	0.3	0.3	0.2	1.2	1.5
	Ratio of daughter lamellae	[-]	0.06	0.08	0.08	0.12	0.10	0.11
Nonwove n fabric properties	Basis Weight	[g/m^2]	17	17	34	-	34	-
	Emboss area ratio	[%]	10	10	10	-	10	-
	Strength per unit basis weight INDEX	[N/25mm/(g/m^2)]	1.32	1.20	1.21	-	0.53	-
	SMD	[μm]	2.7	2.8	2.6	-	4.0	-
	MIU	[-]	0.43	0.278	0.322	-	0.213	-
			5					
	MMD	[-]	0.00 68	0.006 1	0.005 4	-	0.007 3	-
	Air permeability	[cm^3/cm^2/s]	140	118	50	-	159	-
	Water pressure resistance	[mmH$_2$O]	229	249	388	-	171	-
Spinning stability		[-]	A	A	A	B	A	B

[0177] From the results in Table 1, in Experimental Examples 1 to 3 and 5, spunbond nonwoven fabrics having excellent strength per unit basis weight INDEX and small fiber diameter were obtained. Furthermore, the spunbond nonwoven fabrics obtained in Experimental Examples 1 to 3 were superior in strength per unit basis weight INDEX and smaller in fiber diameter than the spunbonded nonwoven fabric obtained in Experimental Example 5.

[0178] The methods of manufacturing spunbond nonwoven fabrics in Experimental Examples 1 to 3 and 5 had better spinning stability than the production conditions for spunbonded nonwoven fabrics in Experimental Examples 4 and 6.

[0179] The entire contents of the disclosures by Japanese Patent Application No. 2021-204376 filed on December 16, 2021, are incorporated herein by reference.

[0180] All the literature, patent application, and technical standards cited herein are also herein incorporated to the same extent as provided for specifically and severally with respect to an individual literature, patent application, and technical standard to the effect that the same should be so incorporated by reference.

Explanation of Symbols

[0181]

1...Extruder
2... Spinneret
3...Cooling Chamber
4...Cooling section
5...Air-permeable partition
6...Filaments
7...Diffuser
8...Mesh belt
9... Suction device
10...Nonwoven web
11...non-air-permeable partition
4A... First cooling air supply section

4B... Second cooling air supply section
100...Spunbond nonwoven fabric manufacturing apparatus

Claims

1. A nonwoven fabric comprising a fiber,
wherein a ratio of daughter lamellae is 0.10 or less.

2. The nonwoven fabric according to claim 1, wherein the ratio of daughter lamellae is 0.09 or less.

3. The nonwoven fabric according to claim 1 or 2, wherein a fineness of the fiber is 0.8 d or less.

4. The nonwoven fabric according to claim 3, wherein the fineness of the fiber is 0.6 d or less.

5. The nonwoven fabric according to any one of claims 1 to 4, wherein the fiber contains a thermoplastic resin.

6. The nonwoven fabric according to claim 5, wherein the thermoplastic resin contains a propylene homopolymer.

7. The nonwoven fabric according to claim 6, wherein a melt flow rate (MFR) of the propylene homopolymer is from 10 g/10 min to 100 g/10 min.

8. The nonwoven fabric according to any one of claims 1 to 7, comprising a spunbond nonwoven fabric.

9. A sanitary material, comprising the nonwoven fabric according to any one of claims 1 to 8.

10. A method of manufacturing a nonwoven fabric comprising discharging a thermoplastic resin or a resin composition containing the thermoplastic resin from a nozzle, supplying a cooling air to filaments made of the discharged thermoplastic resin or resin composition, and melt-spinning the filaments,

    wherein the thermoplastic resin has a mesophase ratio of 22% or more, and
    wherein a ratio of cooling air volume per 1 m width (m^3/h/m) with respect to discharge volume per nozzle hole (g/min) is from 10,000 to 40,000.

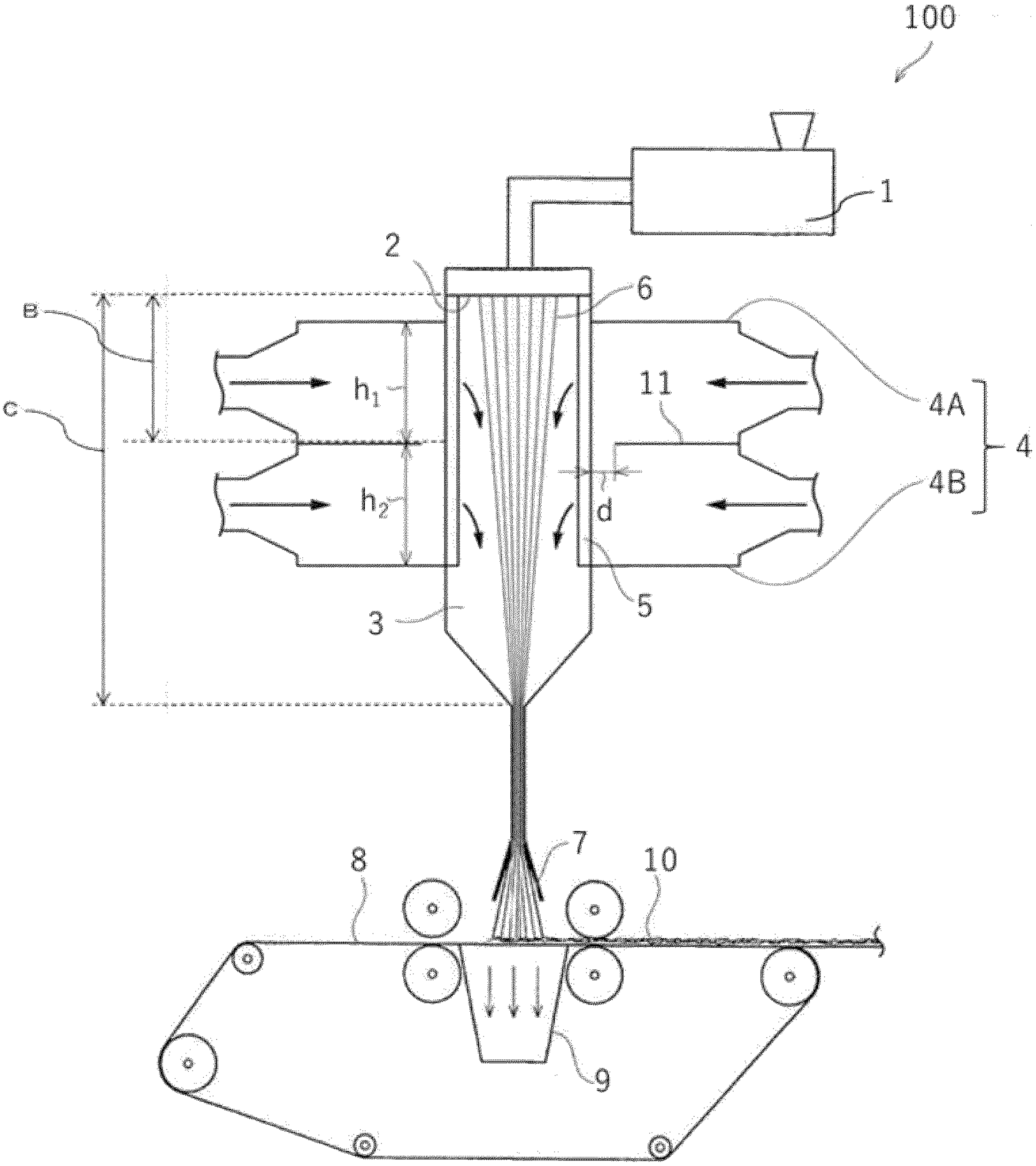
11. The method of manufacturing a nonwoven fabric according to claim 10, wherein the ratio of cooling air volume per 1 m width (m^3/h/m) with respect to discharge volume per nozzle hole (g/min) is from 15,000 to 40,000.

12. The method of manufacturing a nonwoven fabric according to claim 11, wherein the ratio of cooling air volume per 1 m width (m^3/h/m) with respect to discharge volume per nozzle hole (g/min) is from 30,000 to 40,000.

13. The method of manufacturing a nonwoven fabric according to any one of claims 10 to 12, wherein the nonwoven fabric includes a spunbond nonwoven fabric.

14. The method of manufacturing a nonwoven fabric according to any one of claims 10 to 13, wherein a temperature of the cooling air is from 15°C to 30°C.

FIG. 1



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2022/046281

A. CLASSIFICATION OF SUBJECT MATTER

D04H 3/007(2012.01)i
FI: D04H3/007

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

D04H1/00-18/04; D01F1/00-9/04

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2023
Registered utility model specifications of Japan 1996-2023
Published registered utility model applications of Japan 1994-2023

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2021-509930 A (LG CHEM, LTD.) 08 April 2021 (2021-04-08) claims, paragraph [0021]	1-14
A	EP 0753606 A2 (J.W. SUOMINEN OY) 15 January 1997 (1997-01-15) claims	1-14
A	WO 2020/129256 A1 (MITSUI CHEMICALS, INC.) 25 June 2020 (2020-06-25) claims, examples	1-14

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
02 February 2023	**14 February 2023**
Name and mailing address of the ISA/JP **Japan Patent Office (ISA/JP)** **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2022/046281

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2021-509930 A	08 April 2021	EP 3744741 A1 claims, paragraph [0020] US 2021/0061931 A1 WO 2020/096250 A1 KR 10-2020-0052220 A CN 111670205 A	
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WO 2020/129256 A1	25 June 2020	EP 3690086 A1 claims, examples JP 6510158 B1 CN 113195803 A KR 10-2021-0089768 A	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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- WO 2019065306 A **[0167]**
- JP 2021204376 A **[0179]**

Non-patent literature cited in the description

- **A. ZAMBELLI et al.** *Macromolecules,* 1973, vol. 6, 925 **[0152]**
- **A. ZAMBELLI et al.** *Macromolecules,* 1975, vol. 8, 687 **[0153]**