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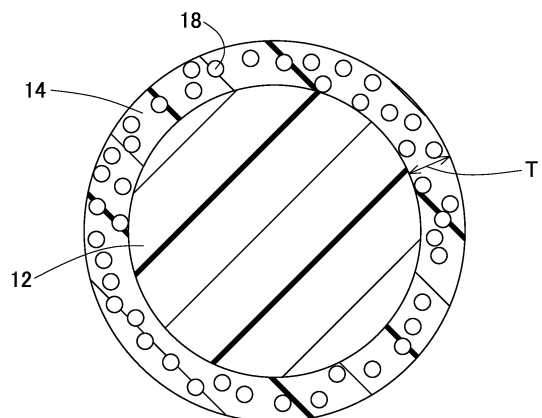
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(54) **CORE-SHEATH COMPOSITE FIBER, PRODUCTION METHOD THEREFOR, AND FIBER STRUCTURE**

(57) Provided are a core-sheath composite fiber, a production method therefor, and a fiber structure. The core-sheath composite fiber includes: a core component (12) including a melt-anisotropic aromatic polyester (a polymer A); and a sheath component having an islands-in-the-sea structure and including a flexible thermoplastic polymer (a polymer B) and a melt-anisotropic aromatic polyester (a polymer C). The polymer B and the polymer C constitute a sea component and an island component of the islands-in-the-sea structure, respectively. The island component includes a plurality of islands (18) dispersed in a sea (14) that is formed of the sea component.

Fig. 3



EP 4 303 347 A1

Description

CROSS REFERENCE TO THE RELATED APPLICATION

5 **[0001]** This application is based on and claims Convention priority to Japanese patent application No. 2021-34707, filed March 4, 2021 in Japan, the entire disclosure of which is herein incorporated by reference as a part of this application.

FIELD OF THE INVENTION

10 **[0002]** The present invention relates to a core-sheath composite fiber comprising a melt-anisotropic aromatic polyester as a core component and having excellent wear resistance with enhanced fibrillation resistance, a production method therefore, and a fiber structure.

BACKGROUND ART

15 **[0003]** Melt-anisotropic aromatic polyester fibers are known to have high tenacities and high elastic moduli. Yet, these fibers have a problem that abrasive force applied to these fibers easily causes fibrillation of fibers because the molecular chains in the fibers are highly oriented in the fiber axial direction. In order to overcome the problem, a composite fiber is proposed which comprises a core component including a melt-anisotropic aromatic polyester and a sheath component surrounding the core component to suppress fibrillations.

20 **[0004]** For example, Patent Document 1 (JP Laid-open Patent Publication No. 2002-20932) discloses a composite fiber comprising a core component which includes a melt-anisotropic aromatic polyester (A) and a sheath component which includes a flexible polyester (B) containing from 0 to 10% of polymer (A), the polyester (B) having an intrinsic viscosity $[\eta]$ of 0.65 dl/g or more.

25 **[0005]** Patent Document 1 describes that blending a polymer used in the core component into the sheath component increases tenacity of the sheath component as well as improves adhesion between the sheath component and the core component.

30 **[0006]** Patent Document 2 (JP Laid-open Patent Publication No. 2008-255535) discloses a core-sheath composite fiber comprising: a core component and a sheath component having an islands-in-the-sea structure in a ratio of the sheath component to the fiber of from 0.2 to 0.7, wherein the core component includes a melt-anisotropic aromatic polyester (a polymer A); the sheath component comprising a sea component which includes a flexible thermoplastic polymer (a polymer B) and an island component which includes a melt-anisotropic aromatic polyester (a polymer C) in a ratio of the island component to the sheath component of from 0 to 0.25; and wherein the core-sheath composite fiber comprises inorganic fine particles comprising a silicate compound as a principal component thereof attached to a surface thereof in a proportion of from 0.03 to 2.5% by mass based on the fiber.

35 **[0007]** Patent Document 2 describes that a polymer without melt-anisotropic property has poor adhesion to a melt-anisotropic aromatic polyester, resulting in delamination from each other, and that the sheath component is formed from a blend of a melt-anisotropic aromatic polyester and a polymer without melt-anisotropic property.

40 RELATED DOCUMENT

PATENT DOCUMENT

[0008]

45 [Patent Document 1] JP Laid-open Patent Publication No. 2002-20932
[Patent Document 2] JP Laid-open Patent Publication No. 2008-255535

SUMMARY OF THE INVENTION

50 **[0009]** However, Patent Document 1 teaches away from increasing the ratio of the melt-anisotropic aromatic polyester in the sheath component because the sheath component containing more than 10% of the melt-anisotropic aromatic polyester promotes the formation of irregularities on the fiber surface so as to cause poor spinnability.

55 **[0010]** Patent Document 2 describes that the composite fiber comprises inorganic fine particles comprising a silicate compound as a principal component thereof attached to a surface thereof in a proportion of from 0.03 to 2.5% by mass based on the fiber in order to suppress adhesion between fibers and thereby to achieve improved unwindability. Yet, regarding the prevention of fibrillations of the fiber, Patent Document 2 only mentions that usage of the flexible thermoplastic polymer as the sea component significantly improves both a fibrillation resistance and a wear resistance.

[0011] It is preferable if a core-sheath composite fiber, which comprises a core component including a melt-anisotropic aromatic polyester and a sheath component surrounding the core component, can contain a melt-anisotropic aromatic polyester at a higher ratio in the sheath component without any loss in spinnability, such a core-sheath composite fiber can achieve stronger adhesion between the core and the sheath to suppress sheath delamination and to thereby provide a better wear resistance than hitherto achieved. Further, for the same reason, the composite fiber can have a thinner sheath, resulting in enhanced tenacity due to higher ratio of melt-anisotropic aromatic polyester as the core in the composite fiber.

[0012] Therefore, an object of the present invention is to provide a core-sheath composite fiber having a higher ratio of a melt-anisotropic aromatic polyester in a sheath component while having an excellent wear resistance by suppressing fibrillations and/or poor spinnability.

[0013] As a result of intensive studies conducted by the inventors of the present invention in an attempt to achieve the above object, i.e., with respect to a core-sheath composite fiber comprising a core component which includes a melt-anisotropic aromatic polyester, the inventors found that (I) by producing a core-sheath composite fiber having the sheath with an islands-in-the-sea structure in which islands comprise a melt-anisotropic aromatic polyester, wherein the amount of the melt-anisotropic aromatic polyester in the islands-in-the-sea structure is increased, such a composite fiber had improved adhesion between the core and the sheath to prevent sheath delamination, enhanced wear resistance, and a thinner sheath so as to enhance tenacity of the composite fiber due to increased amount of the melt-anisotropic aromatic polyester in the core component; whereas the inventors found that (II) such a high ratio of the melt-anisotropic aromatic polyester could cause significantly poor spinning processibility and generate fibrillations of the sheath component; and have, therefore, conceived of the new problem to improve spinning processibility and suppressing fibrillations of the sheath component. According to the further investigation, the inventors have finally found that (III) by kneading a sheath component which includes a high ratio of a melt-anisotropic aromatic polyester at a temperature in a specific range, discharging an as-spun fiber containing the sheath component to take up the as-spun fiber in such a manner to meet a draft value in a specific range, a sheath-core composite fiber can be obtained in which melt-anisotropic aromatic polyester islands having controlled shapes can be finely dispersed in the sea, as a result, despite a high ratio of a melt-anisotropic aromatic polyester in the sheath component, the sheath-core composite fiber can suppress fibrillations while maintaining advantageous spinning processibility; and can improve wear resistance even having a smaller thickness of the sheath; and thus the inventors finally completed the invention.

[0014] Accordingly, the present invention may comprise the following aspects of features.

Aspect 1

[0015] A core-sheath composite fiber comprising:

- a core component including a melt-anisotropic aromatic polyester (a polymer A); and
- a sheath component having an islands-in-the-sea structure and including a flexible thermoplastic polymer (a polymer B) as a sea component and a melt-anisotropic aromatic polyester (a polymer C) as an island component, the islands-in-the-sea structure being provided with a plurality of islands formed of the island component dispersed in a sea formed of the sea component, wherein
- the sheath component has a proportion of the island component of more than 10 wt%;
- among the islands in a cross section cut along a longitudinal direction of the core-sheath composite fiber, an island represented by having a largest width along a direction perpendicular to the fiber has a maximum width W of 0.65 μm or shorter (preferably 0.60 μm or shorter, more preferably 0.55 μm or shorter, and further preferably 0.50 μm or shorter);
- the island having the maximum width W has a maximum diagonal length L1 which is a longest length in the island overlapped with a diagonal line drawn in the sheath component at a fixed angle of 10° relative to the longitudinal direction of the fiber along one end to another end thereof, and has a ratio L1/W of the maximum diagonal length L1 to the maximum width W of said island being 5.0 or more (preferably 5.1 or more, more preferably 5.2 or more, further preferably 5.3 or more, and even more preferably 5.5 or more).

Aspect 2

[0016] The core-sheath composite fiber of Aspect 1, wherein the maximum diagonal length L1 is 1.0 μm or longer (preferably 1.3 μm or longer, more preferably 1.5 μm or longer, and further preferably 1.7 μm or longer).

Aspect 3

[0017] The core-sheath composite fiber of Aspect 1 or 2, wherein said island in the sheath component has a length

L2 along the longitudinal direction of the fiber of from 450 to 1000 μm (preferably from 500 to 800 μm , and more preferably from 550 to 650 μm), in the cross section cut along the longitudinal direction of the core-sheath composite fiber.

Aspect 4

[0018] The core-sheath composite fiber of any one of Aspects 1 to 3, wherein the sheath component has a thickness of from 0.8 to 5.0 μm (preferably from 0.9 to 4.0 μm , and more preferably from 0.9 to 3.8 μm).

Aspect 5

[0019] The core-sheath composite fiber of any one of Aspects 1 to 4, wherein the polymer A and the polymer C comprise a melt-anisotropic aromatic polyester of same species as each other.

Aspect 6

[0020] The core-sheath composite fiber of any one of Aspects 1 to 5, wherein a ratio of the core component / the sheath component in terms of a weight ratio of the core component to the sheath component is from 20/80 to 97/3 (preferably from 50/50 to 96/4, more preferably from 60/40 to 95/5, further preferably from 70/30 to 94/6, even more preferably from 75/25 to 93/7, particularly preferably from 80/20 to 92/8, and most preferably from 82.5/17.5 to 90/10).

Aspect 7

[0021] The core-sheath composite fiber of any one of Aspects 1 to 6, wherein the core-sheath composite fiber has a single fiber fineness of from 1 to 120 dtex (preferably from 2 to 60 dtex, more preferably from 2.5 to 30 dtex, and further preferably from 3 to 15 dtex).

Aspect 8

[0022] A method for producing a core-sheath composite fiber, the core-sheath composite fiber comprising: a core component including a melt-anisotropic aromatic polyester (a polymer A); and a sheath component having an islands-in-the-sea structure and including a flexible thermoplastic polymer (a polymer B) as a sea component and a melt-anisotropic aromatic polyester (a polymer C) as an island component, the islands-in-the-sea structure being provided with a plurality of islands formed of the island component dispersed in a sea formed of the sea component, the method at least comprising:

kneading the polymer B and the polymer C for the sheath component in a twin-screw extruder at a temperature which is equal to $M_b^\circ\text{C}$ or higher, is equal to $(M_c - 20)^\circ\text{C}$ or higher, and is lower than $M_c^\circ\text{C}$, where M_b is a melting point of the polymer B and M_c is a melting point of the polymer C, and melt-kneading the polymer A for the core component in an extruder different from the twin-screw extruder used for the sheath component;

discharging an as-spun composite fiber of the kneaded sheath component and the kneaded core component; and

taking up the discharged as-spun fiber at a draft value of from 13 to 50 (preferably from 15 to 45, more preferably from 16 to 40, further preferably from 19 to 38, and particularly preferably from 20 to 35), the draft value being a ratio of a winding speed to a discharging speed.

Aspect 9

[0023] The production method for the core-sheath composite fiber of Aspect 8, further comprising: subjecting the spun fiber to a heat treatment.

Aspect 10

[0024] A fiber structure comprising, at least in a part thereof, a core-sheath composite fiber of any one of Aspects 1 to 7.

[0025] In the present specification, the phrase "cross section cut along a longitudinal direction of the core-sheath composite fiber" is synonymous with a cross section of the core-sheath composite fiber as viewed by cutting along a plane containing the longitudinal direction of the fiber and will hereinafter be sometimes referred to as a "longitudinal cross section of the fiber." Further, a direction perpendicular to the fiber means, in a longitudinal cross section of the fiber, a direction orthogonal to the longitudinal direction of the fiber (a direction perpendicular to a longitudinal direction of the fiber).

[0026] It should be noted that any combinations of at least two features disclosed in the claims and/or the specification and/or the drawings should also be construed as encompassed by the present invention. Especially, any combinations of two or more of the claims should also be construed as encompassed by the present invention.

[0027] A core-sheath composite fiber according to the present invention comprises a core component including a melt-anisotropic aromatic polyester and a sheath component having an islands-in-the-sea structure and, despite having a high ratio of a melt-anisotropic aromatic polyester constituting islands in the sheath component, can achieve an enhanced fibrillation resistance and an excellent wear resistance of the fiber, thanks to fine dispersion of the islands and associated suppression of aggregation of the island component during a spinning process.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] In any event, the present invention will be more clearly understood from the following description of preferred embodiments made by referring to the accompanying drawings. However, the embodiments and the drawings are given merely for the purpose of illustration and explanation, and should not be used to delimit the scope of the present invention, which scope is to be delimited by the appended claims. In the accompanying drawings, alike numerals are assigned to and indicate alike parts throughout the different figures, and:

Fig. 1A shows a schematic perspective view of a core-sheath composite fiber, in accordance with an embodiment of the present invention;

Fig. 1B shows a schematic cross-sectional view of the core-sheath composite fiber, as viewed in a cut plane along a longitudinal direction of the fiber;

Fig. 2 shows a fragmentary enlarged schematic cross-sectional view of a sheath component of the core-sheath composite fiber;

Fig. 3 shows a schematic cross-sectional view of the core-sheath composite fiber, as viewed in a cut plane perpendicular to a longitudinal direction of the fiber; and

Fig. 4 shows a schematic cross-sectional view of a structure of a spinneret used during a spinning process for the core-sheath composite fiber.

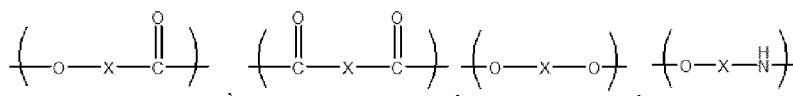
DESCRIPTION OF EMBODIMENTS

[0029] Hereinafter, the present invention is explained in more detail based on exemplification. An embodiment of the present invention is directed to a core-sheath composite fiber comprising a core component and a sheath component which surrounds the core component and has an islands-in-the-sea structure containing a sea component and an island component. The core component includes a melt-anisotropic aromatic polyester (a polymer A). The sheath component includes a flexible thermoplastic polymer (a polymer B) and a melt-anisotropic aromatic polyester (a polymer C). The polymer B and the polymer C constitute the sea component and the island component, respectively,

Core Component

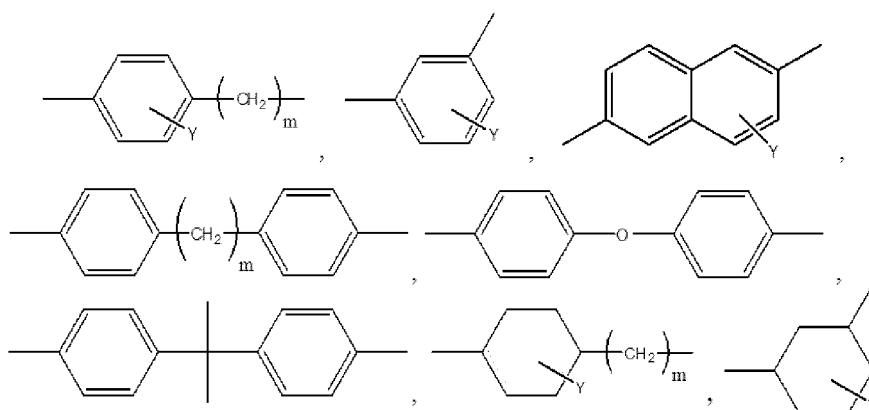
[0030] The melt-anisotropic aromatic polyester (A polymer) for the core component is a polymer capable of forming an optically anisotropic melt phase (liquid crystallinity). For example, liquid crystallinity of the melt-anisotropic aromatic polyester can be recognized, for example, by placing a sample on a hot stage to heat under a nitrogen atmosphere and observing penetration light through the sample using a polarization microscope. The melt-anisotropic aromatic polyester according to the present invention comprises repeating structural units originating from, for example, aromatic diols, aromatic dicarboxylic acids, aromatic hydroxycarboxylic acids, etc. As long as the effect of the present invention is not spoiled, the repeating structural units originating from, for example, aromatic diols, aromatic dicarboxylic acids, aromatic hydroxycarboxylic acids are not limited to a specific chemical composition. The melt-anisotropic aromatic polyester may include the structural units originating from aromatic diamines, aromatic hydroxy amines, or aromatic aminocarboxylic acids in the range which does not spoil the effect of the present invention. For example, the preferable structural units may include units shown in Table 1.

Table 1



In the formula, X is selected from the following

(continued)



m is an integer from 0 to 2, Y is a substituent selected from hydrogen atom, halogen atoms, aryl groups, aralkyl groups, alkoxy groups, aryloxy groups, aralkyloxy groups.

[0031] In the structural units in Table 1, m is an integer from 0 to 2. Y independently represents, as from one substituent to the number of substituents in the range of the replaceable maximum number of aromatic ring, can be selected from the group consisting of a hydrogen atom, a halogen atom (for example, fluorine atom, chlorine atom, bromine atom and iodine atom), an alkyl group (for example, an alkyl group having 1 to 4 carbon atoms such as methyl group, ethyl group, isopropyl group and t-butyl group), an alkoxy group (for example, methoxy group, ethoxy group, isopropoxy group, n-butoxy group, etc.), an aryl group (for example, phenyl group, naphthyl group, etc.), an aralkyl group [benzyl group (phenylmethyl group), phenethyl group (phenylethyl group)], an aryloxy group (for example, phenoxy group etc.), an aralkyloxy group (for example, benzyloxy group etc.), and others.

[0032] As more preferable structural units, there may be mentioned structural units as described in Examples (1) to (18) shown in the following Tables 2, 3, and 4. It should be noted that where the structural unit in the formula is a structural unit which can show a plurality of structures, combination of two or more units may be used as structural units for a polymer.

Table 2

5	(1)	$\left(\text{O}-\text{C}_6\text{H}_4-\text{C}(=\text{O}) \right)_n$, $\left(\text{O}-\text{C}_{10}\text{H}_6-\text{C}(=\text{O}) \right)_n$
10	(2)	$\left(\text{O}-\text{C}_{10}\text{H}_6-\text{C}(=\text{O}) \right)_n$, $\left(\text{C}(=\text{O})-\text{C}_6\text{H}_4-\text{C}(=\text{O}) \right)_n$, $\left[\text{O}-\left(\text{C}_6\text{H}_4 \right)_n-\text{O} \right]$
15	(3)	$\left(\text{O}-\text{C}_{10}\text{H}_6-\text{C}(=\text{O}) \right)_n$, $\left(\text{C}(=\text{O})-\text{C}_6\text{H}_4-\text{C}(=\text{O}) \right)_n$, $\left(\text{O}-\text{C}_6\text{H}_4-\text{NH} \right)_n$
20	(4)	$\left(\text{O}-\text{C}_6\text{H}_4-\text{C}(=\text{O}) \right)_n$, $\left(\text{C}(=\text{O})-\text{C}_{10}\text{H}_6-\text{C}(=\text{O}) \right)_n$, $\left(\text{O}-\text{C}_6\text{H}_5-\text{C}(=\text{O}) \right)_n$, $\left[\text{O}-\left(\text{C}_6\text{H}_4 \right)_n-\text{O} \right]$
25	(5)	$\left(\text{O}-\text{C}_6\text{H}_4-\text{C}(=\text{O}) \right)_n$, $\left(\text{O}-\text{C}_{10}\text{H}_6-\text{C}(=\text{O}) \right)_n$, $\left(\text{C}(=\text{O})-\text{C}_6\text{H}_5-\text{C}(=\text{O}) \right)_n$, $\left[\text{O}-\left(\text{C}_6\text{H}_4 \right)_n-\text{O} \right]$
30	(6)	$\left(\text{O}-\text{C}_6\text{H}_4-\text{C}(=\text{O}) \right)_n$, $\left(\text{C}(=\text{O})-\text{C}_{10}\text{H}_6-\text{C}(=\text{O}) \right)_n$, $\left(\text{O}-\text{C}_6\text{H}_5-\text{C}(=\text{O}) \right)_n$, $\left[\text{O}-\left(\text{C}_6\text{H}_4 \right)_n-\text{O} \right]$
35	(7)	$\left(\text{O}-\text{C}_6\text{H}_4-\text{C}(=\text{O}) \right)_n$, $\left(\text{C}(=\text{O})-\text{C}_{10}\text{H}_6-\text{C}(=\text{O}) \right)_n$, $\left(\text{C}(=\text{O})-\text{C}_6\text{H}_5-\text{C}(=\text{O}) \right)_n$, $\left[\text{O}-\left(\text{C}_6\text{H}_4 \right)_n-\text{O} \right]$
40	(8)	$\left(\text{O}-\text{C}_6\text{H}_4-\text{C}(=\text{O}) \right)_n$, $\left(\text{O}-\text{C}_{10}\text{H}_6-\text{C}(=\text{O}) \right)_n$, $\left(\text{O}-\text{C}_6\text{H}_4-\text{NH} \right)_n$, $\left[\text{O}-\left(\text{C}_6\text{H}_4 \right)_n-\text{O} \right]$, $\left(\text{C}(=\text{O})-\text{C}_6\text{H}_4-\text{C}(=\text{O}) \right)_n$

Table 3

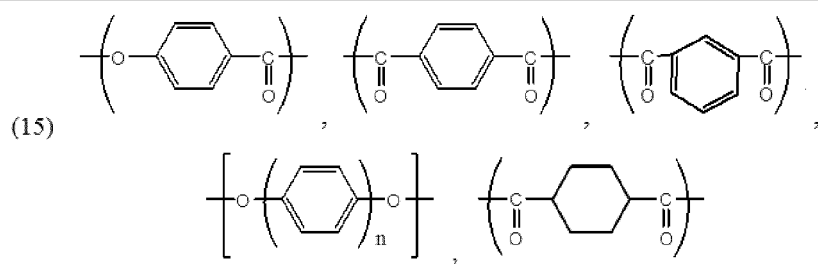
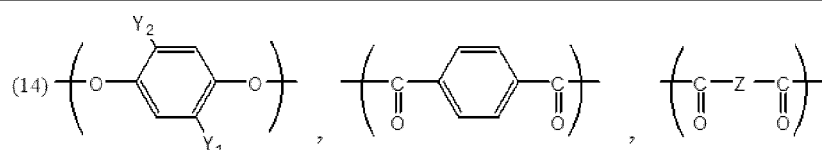
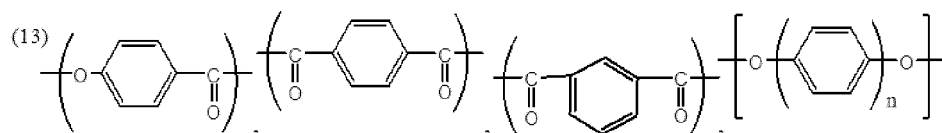
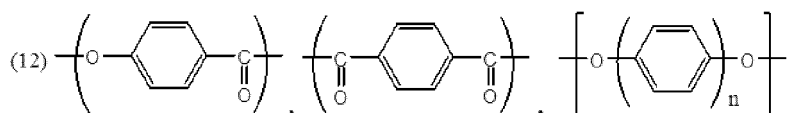
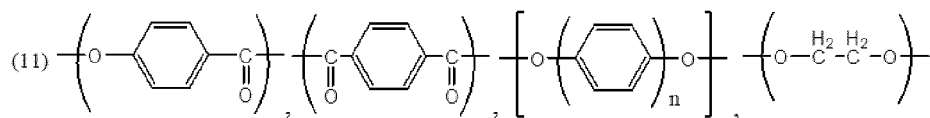
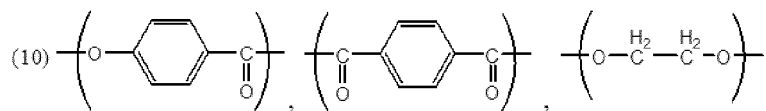
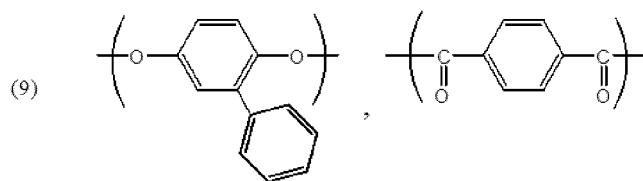
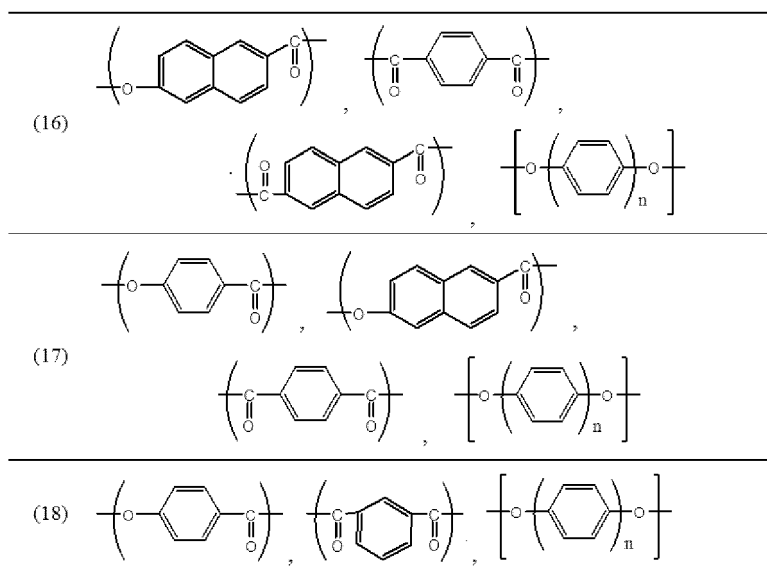


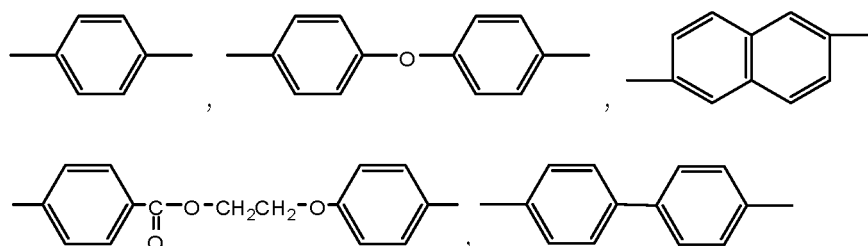
Table 4



[0033] In the structural units shown in Tables 2, 3, and 4, n is an integer of 1 or 2, in each of the structural units, n = 1 and n = 2 may independently exist, or may exist in combination; each of the Y₁ and Y₂ independently represents, hydrogen atom, a halogen atom, (for example, fluorine atom, chlorine atom, bromine atom, iodine atom, etc.), an alkyl group (for example, an alkyl group having 1 to 4 carbon atoms such as methyl group, ethyl group, isopropyl group, and t-butyl group, etc.), an alkoxy group (for example, methoxy group, ethoxy group, isopropoxy group, n-butoxy group, etc.), an aryl group (for example, phenyl group, naphthyl group, etc.), an aralkyl group [benzyl group (phenylmethyl group), phenethyl group (phenylethyl group), etc.], an aryloxy group (for example, phenoxy group etc.), an aralkyloxy group (for example, benzyloxy group etc.), and others. Among these, the preferable one may include hydrogen atom, chlorine atom, bromine atom, and methyl group.

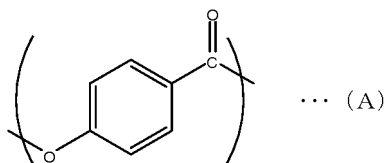
[0034] Z may include substituents denoted by following formulae.

Chem. 1

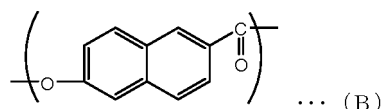


[0035] Preferable melt-anisotropic aromatic polyesters may comprise a naphthalene skeleton as structural units. Especially preferable one may include both the structural unit (A) derived from hydroxybenzoic acid and the structural unit (B) derived from hydroxy naphthoic acid. For example, the structural unit (A) may have a following formula (A), and the structural unit (B) may have a following formula (B). From the viewpoint of ease of enhancing melt-spinnability, the ratio of the structural unit (A) and the structural unit (B) may be in a range of former/latter of from 9/1 to 1/1, more preferably from 7/1 to 1/1, still preferably from 5/1 to 1/1.

Chem. 2



Chem. 3



[0036] The total proportion of the structural units of (A) and (B) may be, based on all the structural units, for example, 65 mol % or more, more preferably 70 mol % or more, and still more preferably 80 mol % or more. Especially referred melt-anisotropic aromatic polyesters have the structural unit (B) at a proportion of from 4 to 45 mol % in the polymers.

[0037] The melt-anisotropic aromatic polyester suitably used in the present invention preferably has a melting point in the range from 250 to 360°C, and more preferably from 260 to 320°C. The melting point here means a temperature at which a main absorption peak is observed in measurement in accordance with JIS K7121 examining method using a differential scanning calorimeter (DSC: differential scanning calorimetry produced by Shimadzu Corporation).

[0038] The melt-anisotropic aromatic polyester may further comprise a thermoplastic polymer such as a polyethylene terephthalate, a modified polyethylene terephthalate, a polyolefin, a polycarbonate, a polyamide, a polyphenylene sulfide, a polyetheretherketone, and a fluororesin to the extent that the effect of the invention is not spoiled. In addition, various additives such as inorganic materials such as titanium dioxide, kaolin, silica, and barium oxide; coloring agents such as a carbon black, a dye, and a pigment; an antioxidant, a UV absorber, and a light stabilizer may also be added.

30 Sheath Component

[0039] The sheath component has an islands-in-the-sea structure, in which the sea component comprises a flexible thermoplastic polymer (B polymer) and the island component comprises a melt-anisotropic aromatic polyester (C polymer).

[0040] The flexible thermoplastic polymer (B polymer) constituting the sea component is a polymer having a main chain without aromatic rings or a polymer having a main chain with aromatic rings and four or more atoms between aromatic rings, such as a polyolefin; a polyamide; a polycarbonate; a polyphenylene sulfide (abbreviated PPS); a polyester such as a polyethylene terephthalate, a modified polyethylene terephthalate, an amorphous polyarylate, a polyethylene naphthalate (abbreviated PEN); a polyetheretherketone; a fluoropolymer; and others. These flexural thermoplastic polymers may be used alone or in combination of two or more. One of them may be used as a major thermoplastic polymer (e.g., accounting for 80 wt% or more) and the others may be used as a thermoplastic polymer to be added. Among them, the PPS and the PEN are preferably used as the major thermoplastic polymer.

[0041] The flexural thermoplastic polymer may also contain various additives such as inorganic materials such as titanium dioxide, silica, barium oxide, coloring agents such as a carbon black, a dye, and a pigment; an antioxidant, a UV absorber, a light stabilizer, and a nucleating agent.

[0042] As the melt-anisotropic aromatic polyester (the polymer C) constituting the island component, there may be mentioned those melt-anisotropic aromatic polyesters discussed with respect to the polymer A. The polymer A and the polymer C may comprise a melt-anisotropic aromatic polyester of same species as each other, or may comprise different melt-anisotropic aromatic polyesters. It is preferred that the polymer A and the polymer C comprise a melt-anisotropic aromatic polyester containing a common structural unit as a principal structural unit, from the viewpoint of affinity. Further, the polymer A and the polymer C may each comprise the same kind of polymer which contains a common structural unit as a principal structural unit, and may differ, for example, only in a thermoplastic polymer or an additive to be added thereto.

[0043] Moreover, a melting point (Mc) for the polymer C can be selected as appropriate from a range that enables the polymer C to be finely dispersed in the polymer B. For example, the polymer C may have a melting point (Mc) in the range of from (Mb - 10) to (Mb + 80)°C or in the range of from Mb to (Mb + 70)°C where Mb is the melting point of the polymer B.

[0044] Furthermore, the polymer C may have a melt viscosity η of, for example, from 10 to 60 Pa s, preferably from

20 to 50 Pa s, and more preferably from 25 to 45 Pa·s, from the viewpoint of spinnability.

[0045] It should be noted that a melt viscosity η in the context of the present invention is a melt viscosity as measured at a temperature T and a shear rate of 1000 sec^{-1} , where T is equal to $(M_c + 10)^\circ\text{C}$ when the melting point (M_c) of the polymer C is 290°C or higher; T is equal to 300°C when the melting point M_c of the polymer C is lower than 290°C .

Production Method for Core-sheath Composite Fiber

[0046] A core-sheath composite fiber according to the present invention can be produced by a production method which comprises at least a kneading step and a discharging step. The production method steps may further comprise a heat treatment step.

[0047] The kneading step involves melt-kneading the polymer B and the polymer C for the sheath component in a twin-screw extruder and melt-kneading the polymer A for the core component in an extruder different from the twin-screw extruder used for the sheath component.

[0048] In particular, when the polymer B and the polymer C are kneaded in a twin-screw extruder, the temperature applied to a kneading section of the twin-screw extruder is set to a temperature which is equal to $M_b^\circ\text{C}$ or higher, and is equal to $(M_c - 20)^\circ\text{C}$ or higher, and lower than $M_c^\circ\text{C}$, where M_b is the melting point of the polymer B and M_c is the melting point of the polymer C; the kneading section uses parallel biaxial screws which is rotatably supported in the kneading section. In this way, fine dispersion of a plurality of islands in the sheath component can be achieved.

[0049] It should be noted that the extruder in which the polymer A for the core component is melt-kneaded may be either a single-screw extruder or a twin-screw extruder. Further, where a feedstock is used which includes the polymer B and the polymer C that are previously compounded under the above conditions, the extruder used for the melt-kneading of the sheath component may also be either a single-screw extruder or a twin-screw extruder, as the plurality of islands are already finely dispersed in the sheath component.

[0050] In the kneading step, a ratio of the core component to the sheath component in terms of a weight ratio of the core component / the sheath component (which will hereinafter be referred to, at times, simply as a core-and-sheath ratio) may be, for example, from 20/80 to 97/3, preferably from 50/50 to 96/4, more preferably from 60/40 to 95/5, further preferably from 70/30 to 94/6, even more preferably from 75/25 to 93/7, particularly preferably from 80/20 to 92/8, and most preferably from 82.5/17.5 to 90/10, from the viewpoint of achieving an enhanced fibrillation resistance and preventing the exposure of the core component. Especially, the ratio of the core component of 50% or more is preferred, as an improved tenacity of the composite fiber can be achieved. The weight ratio of the core component to the sheath component can be determined, for example, from the weight ratio of the amount of the core component to the amount of the sheath component, each introduced into a respective one of the extruders, which will be later discussed, during the production process.

[0051] The proportion of the island component in the sheath component may be more than 10 wt%, preferably 15 wt% or more, and more preferably 20 wt% or more. A higher proportion of the island component can augment the anchoring effect between the core component and the sheath component by the island component. Meanwhile, since an excessively high proportion of the island component may increase the probability of aggregation of the island component, the proportion of the island component in the sheath component may be 40 wt% or less and preferably 35 wt% or less.

[0052] The discharging step involves discharging the sheath component and the core component, each of which is kneaded in the kneading step, from, for example, a spinneret having a configuration shown in Fig. 4, from which a core-sheath composite fiber having a circular shape in a cross section (a transverse cross section of the fiber) can be spun.

[0053] The spinneret temperature (the spinning temperature) for discharging may be, for example, from $(M_a + 10)$ to $(M_a + 60)^\circ\text{C}$, preferably from $(M_a + 15)$ to $(M_a + 40)^\circ\text{C}$, and more preferably from $(M_a + 20)$ to $(M_a + 35)^\circ\text{C}$, where M_a is the melting point of the polymer A.

[0054] The shapes of the finely dispersed islands are controlled as a function of a draft value. A discharged as-spun fiber may be taken up at a draft value of from 13 to 50, preferably from 15 to 45, more preferably from 16 to 40, further preferably from 19 to 38, and particularly preferably from 20 to 35. It should be noted that an as-spun fiber means a fiber which is discharged right out of a nozzle hole without drawing, that is, a fiber having a fiber diameter substantially comparable to the diameter of the nozzle hole. Further, a draft value means a ratio of a winding speed to a discharging speed during a spinning process.

[0055] Further, the spun fiber may be subjected to a heat treatment. The heat treatment can not only raise the degree of orientation-induced crystallization of the polymer B in the sheath component, but can also promote solid-phase polymerization of the melt-anisotropic aromatic polyester to thereby increase the tenacity of the core-sheath composite fiber.

[0056] The heat treatment can involve subjecting the spun fiber to a heat treatment under the atmosphere of an inert gas such as nitrogen or under the atmosphere of an oxygen-containing, active gas (e.g., air), at an ambient pressure or a reduced pressure.

[0057] Where the heat treatment is carried out, preferable atmosphere for heat treatment may include a low-humidity

gas having a dew point of -50°C or lower, preferably having a dew point of -60°C or lower, and more preferably having a dew point of -70°C or lower. The conditions of the heat treatment can include a temperature pattern in which the temperature used is gradually raised from a temperature that is equal to $(M_a - 20)^{\circ}\text{C}$ or lower, preferably equal to $(M_a - 30)^{\circ}\text{C}$ or lower, and more preferably equal to $(M_a - 40)^{\circ}\text{C}$ or lower, up to the melting point of the sheath component or lower, where M_a is the melting point of the polymer A.

[0058] The heat used may be delivered, for example, by a method that uses a gaseous medium, a method that uses radiation from a heating plate, an infrared heater, etc., or an internal heating method that uses a high frequency wave, etc. The fiber may be treated continuously in a roll-to-roll manner, or treated in a batch process in which the as-spun fibers are treated in a hank form, in a tow form, or in a heat treatment bobbin onto which the fibers are rewound.

[0059] If necessary, inorganic fine particles may be applied to the fiber surface during or after spinning, and prior to the heat treatment, from the viewpoint of preventing, for example, a sheath delamination due to adhesion between filaments after the heat treatment. Preferable inorganic fine particles may comprise, as a principal component thereof, a silicate compound such as talc and mica.

[0060] Contrary to the fibers obtained in Patent Document 2, although the present invention offers advantageous unwindability without the attachment of such inorganic fine particles, the inorganic fine particles may optionally be attached to the fiber surface from the viewpoint of achieving further improved unwindability.

[0061] By attaching the inorganic fine particles in a uniform way onto the fiber surface during or after spinning, and prior to the heat treatment, direct contact between filaments can be avoided, thereby preventing adhesion between the filaments. It should be noted that most of the inorganic fine particles containing a silicate compound as a principal component thereof are inert and, therefore, do not lead to any loss in the physical properties of the fiber even if the inorganic fine particles are attached thereto.

[0062] There is no limitation on the method for subjecting the inorganic fine particles attached onto the fiber surface, as long as the inorganic fine particles can be evenly attached to the fiber. For example, it is convenient and preferable to apply the inorganic fine particles dispersed in a spinning lubricant under agitation with an oiling roller or a ruling pen.

[0063] The inorganic fine particles attached onto the surface of the core-sheath composite fiber can have an average particle diameter in the range of, for example, from 0.01 to $10\ \mu\text{m}$, and preferably in the range of from 0.02 to $5\ \mu\text{m}$, from the viewpoint of making the inorganic fine particles attached evenly onto the fiber surface. The amount of the inorganic fine particles attached onto the surface of the core-sheath composite fiber may be in the range of from 0.03 to 2.5% by mass, and preferably in the range of from 0.1 to 2.3% by mass.

Core-sheath Composite Fiber

[0064] Fig. 1A shows a schematic perspective view of a core-sheath composite fiber, in accordance with an embodiment of the present invention. Fig. 1B shows a schematic cross-sectional view of the core-sheath composite fiber, as viewed in a cut plane a longitudinal direction of the core-sheath fiber. A core-sheath composite fiber 10 comprises a core 12 formed of a core component and a sheath 14 formed of a sheath component.

[0065] Fig. 2 shows a fragmentary enlarged schematic cross-sectional view of the part II in Fig. 1B. As depicted in Fig. 1B and Fig. 2, in a cross section of the core-sheath composite fiber as cut along the longitudinal direction of the fiber so as to contain a centerline axis of the fiber (i.e., a longitudinal cross section of the fiber), the sheath 14 forms an islands-in-the-sea structure in which a plurality of islands 18 are present in a sea 16. The islands are finely dispersed in controlled shapes in the sea.

[0066] With a high proportion of the island component in the sea component and through fine dispersion of the islands, a plurality of the islands in the core-sheath composite fiber according to the present invention can not only augment the anchoring of the sheath to the core so as to suppress a sheath delamination, but can also suppress fibrillations of the sheath.

[0067] Each of the finely dispersed islands are basically extend along a longitudinal direction of the fiber in a substantially elliptical shape. Increased sizes of island diameter may facilitate irregularities on the fiber surface caused by the island component. Since the occurrence of fibrils depends on the magnitude of such irregularities on the fiber surface, it is desirable that the maximum diameter of the islands be small. Further, it is preferred that the islands have elongated shapes along the longitudinal direction of the fiber, as this can facilitate an anchoring effect. In other words, just measuring the diameters of the islands in a single transverse cross section of the fiber may overlook a contribution coming from the anchoring effect made possible by the lengths of the islands. By observing the shapes of the islands along a longitudinal direction on a micrograph of the sheath and focusing on an island having the largest width to evaluate its shape in terms of both a width and a length, the unconventional assessment for fibrillation can be achievable in which a contribution coming from the anchoring effect provided by the islands themselves is taken into account. For such a measurement, as depicted in Fig. 2, an island represented by having a largest width W is selected; then focusing on the island, a maximum diagonal length L_1 is measured which is a longest length in the island overlapped with a diagonal line drawn in the sheath component at a fixed angle α (10°) relative to the longitudinal direction of the fiber along one

end to another end thereof; and further a ratio L/W is calculated to evaluate the shape of the island in which the island shape in their elongation along the longitudinal direction of the fiber is taken into account.

[0068] To begin with, an island having the maximum width W can be selected from an enlarged micrograph of a longitudinal cross section of the fiber. More specifically, a scanning probe microscope (SPM), as described later, can be used to observe a portion of the longitudinal cross section of the fiber in a range selected from $100\text{ }\mu\text{m}$ to $1000\text{ }\mu\text{m}$ along the longitudinal direction of the fiber. Then, in the observed range, an island having a largest value in a direction perpendicular to the longitudinal direction of the fiber (i.e., a direction perpendicular to the fiber) is selected to use the value same as a measurement. Note that the observed range does not have to be continuous, but it may be a total of randomly selected, different portions viewed on the micrograph. For example, in the observed range in the longitudinal cross-section of the fiber, are selected several islands having relatively large widths (lengths in the direction perpendicular to the fiber) among a number of islands extending in the longitudinal direction of the fiber. Thereafter, by comparing the widths of the selected islands in the direction perpendicular to the fiber, one island having the largest width or a maximum width can be selected. In the exemplified embodiment, it suffices to observe only one of the top-side segment or the bottom-side segment of the sheath component in the longitudinal cross section of the fiber (e.g., the bottom side segment in Fig. 1B) as an observed range. Moreover, although the exemplified embodiment adopts a scanning probe microscope to observe the longitudinal cross section of the fiber to determine the maximum width of the island, any means that enable the maximum width of the islands to be determined can be used in place of the scanning probe microscope. It should be noted that it is desirable to allow the fiber to be embedded and immobilized in a resin prior to being cut, in order to minimize possible influences from a stress during a cutting process for the fiber.

[0069] The maximum width W of the islands may be $0.65\text{ }\mu\text{m}$ or smaller, preferably $0.60\text{ }\mu\text{m}$ or smaller, more preferably $0.55\text{ }\mu\text{m}$ or smaller, and further preferably $0.50\text{ }\mu\text{m}$ or smaller. Where the maximum width of the islands exceeds the stated upper limits, there is a risk of an insufficient fibrillation resistance. Further, the maximum width W of the islands may be $0.07\text{ }\mu\text{m}$ or larger, or $0.1\text{ }\mu\text{m}$ or larger.

[0070] Once an island having the maximum width W is selected as a representative of the islands, the same island can be consecutively observed to determine a length in a longitudinal direction. As depicted in Fig. 2, is determined a maximum diagonal length $L1$ which is a longest length in the island overlapped with a diagonal line drawn in the sheath component at a fixed angle of 10° relative to the longitudinal direction of the fiber along one end to another end thereof. Where the ratio $L1/W$ of the maximum diagonal length $L1$ to the maximum width W is 5.0 or more, the islands have an augmented anchoring effect while suppressing fibrillations in the core-sheath composite fiber. The ratio $L1/W$ may be preferably 5.1 or more, more preferably 5.2 or more, further preferably 5.3 or more, and even more preferably 5.5 or more. While there is no specific limitation on the upper limit for the ratio $L1/W$, the upper limit of the ratio $L1/W$ may be 10 or less.

[0071] Although the maximum diagonal length $L1$ varies as a function of the maximum width W , the maximum diagonal length $L1$ can be chosen to be, for example, $1.0\text{ }\mu\text{m}$ or longer, preferably $1.3\text{ }\mu\text{m}$ or longer, more preferably $1.5\text{ }\mu\text{m}$ or longer, and further preferably $1.7\text{ }\mu\text{m}$ or longer. Where the maximum diagonal length $L1$ is at least equal to a given one of the stated lower limits, there is a tendency that the islands have enhanced anchoring effect on the core component. Moreover, the maximum diagonal length $L1$ may be $3.3\text{ }\mu\text{m}$ or shorter, preferably $3.1\text{ }\mu\text{m}$ or shorter, and more preferably $2.9\text{ }\mu\text{m}$ or shorter. Where the maximum diagonal length $L1$ is at or below a given one of the stated upper limits, there is a tendency for fibrillations to be suppressed.

[0072] In the longitudinal cross section of the fiber, the island having the maximum width in the sheath component may have a length $L2$ along the longitudinal direction of the island, of, for example, 450 to $1000\text{ }\mu\text{m}$, preferably 500 to $800\text{ }\mu\text{m}$, and more preferably 550 to $650\text{ }\mu\text{m}$. The anchoring effect of islands on the core component enhances with an increase of the length $L2$. The length of the island in the longitudinal direction of the island can be determined from an enlarged micrograph of the longitudinal cross section of the fiber. Alternatively, it can be calculated by determining a length of such an island in an as-spun fiber in the longitudinal direction of the fiber and multiplying the same with a draft value.

[0073] The sheath component may have a thickness of, for example, 0.8 to $5.0\text{ }\mu\text{m}$, preferably 0.9 to $4.0\text{ }\mu\text{m}$, and more preferably 0.9 to $3.8\text{ }\mu\text{m}$, from the viewpoint of preventing the exposure of the core component and ensuring the tenacity of the fiber.

[0074] As depicted in Fig. 3, the thickness of the sheath component can be determined, for example, with an enlarged micrograph of a cross section of the core-sheath composite fiber as viewed in a plane perpendicular to the longitudinal direction of the fiber (which will hereinafter be sometimes referred to as a "transverse cross section of the fiber."). More specifically, an image of a transverse cross section of the fiber can be captured using, for example, a scanning microscope; three points that are randomly selected to define three regular intervals of the outer periphery of the fiber are selected from the image; from each of the points, a measurement of the radial distance between the outer peripheral surface of the core component and the outer peripheral surface of the sheath component is carried out; and an average value of those measurements can be calculated as the thickness of the sheath component. It should be noted that it is desirable that the fiber be embedded and immobilized in resin prior to being cut, in order to minimize possible influences from a

stress during a cutting process for the fiber.

[0075] The core-sheath composite fiber may have a single fiber fineness of, for example, from 1 to 120 dtex, preferably from 2 to 60 dtex, more preferably from 2.5 to 30 dtex, and further preferably from 3 to 15 dtex. A single fiber fineness in this context can be determined, for example, in accordance with JIS L 1013 "Testing methods for man-made filament yarns." Further, the core-sheath composite fiber may be a monofilament fiber or a multifilament fiber that includes two or more monofilaments.

[0076] The core-sheath composite fiber may have a tensile tenacity, as measured under the atmosphere at 25°C, of, for example, 10 cN/dtex or more, preferably 13 cN/dtex or more, more preferably 15 cN/dtex or more, further preferably 18 cN/dtex or more, and even more preferably 20 cN/dtex or more. While there is no specific limitation on the upper limit of the tensile tenacity, the upper limit of a tensile tenacity may be 30 cN/dtex or less. A tensile tenacity in this context is determined on the basis of the JIS L 1013 testing methods. It should be noted that, where the core-sheath composite fiber is a multifilament fiber, the tensile tenacity of a single filament taken out from the multifilament fiber may be determined as the tensile tenacity of the core-sheath composite fiber, in view of the fact that the towing may cause change in tenacity of the filament.

[0077] The core-sheath composite fiber has an excellent fibrillation resistance which can be evaluated as an average number of fluffs per 3 cm length of fiber (5 replication) which is carried out as follows: through three comb guides which are arranged at an angle of 120° from each other, are passed sample fibers respectively, and each of the fibers is subjected to a reciprocating motion with a stroke length of 3 cm at a rate of 95 cycles/min under a tension of 1 g/dtex for 30000 times so as to determine fluffs generated in fiber 3 cm in length. The core-sheath composite fiber may have an average number of fluffs of, for example, 1 or less, and preferably 0.5 or less. A fluff in this context can be observed by checking the core-sheath composite fiber with a camera by a magnification of 20, either as a small fluff having a size of 1 mm or smaller (i.e., a fibril), as a large fluff having a size of larger than 1 mm, or as a sheath delamination.

[0078] A core-sheath composite fiber according to the present invention can be woven and/or knitted in a customarily used method. Further, the core-sheath composite fiber can be dyed in a customarily used method according to the type of the flexible thermoplastic polymer. For example, where the flexible polymer is a polyester-based polymer, a traditional dyeing method for a polyester fiber with the use of a disperse dye can be employed to dye the core-sheath composite fiber.

[0079] A core-sheath composite fiber according to the present invention can be suitably used in various types of a fiber structure. A fiber structure according to the present invention comprises, at least in part thereof, a core-sheath composite fiber according to the present invention. As the fiber structure, there may be mentioned highly processed articles such as one-dimensional structures such as a rope and a commingled yarn and two-dimensional structures such as a woven fabric, a knitted fabric, and a nonwoven fabric. The fiber structure may be solely made of the core-sheath composite fiber or may further comprise an additional structural element to that extent that the effect of the present invention is not spoiled. Once formed, the fiber structure may subsequently be dyed in the aforementioned dyeing method.

[0080] There is no specific limitation on the woven pattern of the fiber structure as a woven fabric, and examples may include a plain weave, a twill weave, a sateen weave, derivatives of a plain weave, derivatives of a twill weave, derivatives of a sateen weave, a fancy weave, a figured weave, a backed weave, a double weave, a combination weave, a warp pile weave, a weft pile weave, and a leno weave. Also, there is no specific limitation on the knitted pattern of the fiber structure as a knitted fabric, and examples include a circular knitting stitch, a warp knitting stitch, a weft knitting stitch (including a Tricot stitch and a Raschel stitch), a pile stitch, a flat stitch, a plain stitch, a rib stitch, a smooth stitch (an interlock stitch), a rib stitch, a purl stitch, a Denbigh stitch, a cord stitch, an Atlas stitch, a chain stitch, and an inlay stitch.

EXAMPLES

[0081] Hereinafter, the present invention will be demonstrated by way of some examples that are presented only for the sake of illustration, which are not to be construed as limiting the scope of the present invention. It should be noted that in the following Examples and Comparative Examples, various properties were evaluated in the following manners.

Fineness

[0082] In accordance with JIS L 1013:2010 8.3.1 A method, a reel available from DAIEI KAGAKU SEIKI MFG. Co., Ltd. was used to take a 100-meter hank of a core-sheath composite fiber and conduct three measurements of the weight (x 100 and in gram) of the same hank, and an average value of these three measurements was used as a fineness (in dtex) of the fiber.

Tensile Tenacity

[0083] In accordance with JIS L 1013, a tensile tester "TENSORAPID5" available from USTER was used to conduct five measurements of the tenacity of a single sample under the conditions including a sample length of 20 cm, a tension

rate of 10 cm/min, and an initial load of 0.33 g/dtex, and an average value of these five measurements was used as a tenacity (in cN/dtex) of the fiber. It should be noted that, where a core-sheath composite fiber was a multifilament fiber, the tensile tenacity of a single filament taken out from the multifilament fiber was determined as the tensile tenacity of the core-sheath composite fiber.

Thickness of Sheath Component

[0084] A core-sheath composite fiber was embedded in epoxy resin. The embedded fiber was cut along a plane perpendicular to a longitudinal direction of the fiber to expose a transverse cross section of the fiber. Under microscope, a measurement of the radial distance between the outer peripheral surface of a core and the outer peripheral surface of a sheath was conducted at three points that were randomly selected to define three regular intervals of the outer periphery of the fiber on the transverse cross section of the fiber, and an average value of these measurements was calculated and used as the thickness of a sheath component.

Island Length and Maximum Island Width

[0085] A core-sheath composite fiber was embedded in epoxy resin. The embedded fiber was cut along a longitudinal direction of the fiber using a cross section polisher (CP) to make a longitudinal cross section of the fiber exposed. A scanning probe microscope (SPM) was used to observe a portion of the longitudinal cross section of the fiber in a range of from 100 μm to 1000 μm along a longitudinal direction of the fiber. In the observed range in the longitudinal cross-section of the fiber, were selected several islands having relatively large widths (lengths in the direction perpendicular to the fiber) among a number of islands extending in the longitudinal direction of the fiber. Thereafter, by comparing the widths of the selected islands, one island having a largest width was selected to determine the maximum width W of the islands. Further, the length L_2 of the island having the maximum width W was measured in the longitudinal direction of the fiber.

Maximum Island Diagonal Length

[0086] Next, focusing on the island having the maximum width W , a maximum diagonal length L_1 is measured which is a longest length in the island overlapped with a diagonal line drawn in the sheath component at a fixed angle α (10°) relative to the longitudinal direction of the fiber along one end to another end thereof.

Wear Resistance

[0087] Using a TM-type, abrasion tester "TM-200" series available from DAIEI KAGAKU SEIKI MFG. Co., Ltd. sample fibers were passed through three comb guides, respectively, which were arranged at an angle of 120° from each other, and each of the fibers was subjected to a reciprocating motion with a stroke length of 3 cm at a rate of 95 cycles/min under a tension of 1 g/dtex for 30000 times so as to determine fluff generation using a camera by a magnification of 20. Five tests were conducted to observe fluff generation in each of the fiber samples per 3 cm in length. It should be noted that an assessment was made using the following criteria, in which fluffs formed were classified into a small fluff having a length of 1 mm or shorter and a large fluff having a length of longer than 1 mm.

Occurrence of Fluffs

[0088] "A" indicates that no fluffs were observed in any of the five passes:

"B" indicates that a fluff was observed in at least one of the five passes, but no fluffs having a length of longer than 1 mm were observed in any of the five passes; and

"C" indicates that a fluff was observed in at least one of the five passes, including a fluff having a length of longer than 1 mm.

[0089] Further, if the occurrence of a fluff was found in at least one of the five passes, the number of fluffs formed was counted to calculate the average number of the fluffs for 5 replicates.

Example 1

[0090] A core-sheath composite fiber was prepared according to the following procedure.

[0091] As a core component, was used a polymer A which was a melt-anisotropic aromatic polyester [with a melting

point (Ma) of 278°C and a melt viscosity (MVa) of 32.1 Pa·s] comprising a structural unit (P: HBA) and a structural unit (Q: HNA) at a mole ratio of 73/27. As a sea component in a sheath component, was used a polymer B which was a polyethylene naphthalate (PEN) with a melting point (Mb) of 266.3°C and a melt viscosity (MVb) of 100 Pa·s. As an island component in the sheath component, was used a polymer C which was a melt-anisotropic aromatic polyester with a melting point (Mc) of 278°C and a melt viscosity (MVc) of 32.1 Pa·s similar to that used in the polymer A.

[0092] In the kneading step, the core component and the sheath component were melt-kneaded in respective extruders. In the kneading step for the sheath component, the polymer B was mixed with the polymer C in the proportion of 30 wt% of the polymer B in the sheath component. Once the kneading and extruding process started, the temperature defined in a kneading section of the twin-screw extruder was set to 266°C (i.e., (Mc - 12)°C) at which the kneading of the sheath component was adequately performed (a low-temperature kneading step). Then, a discharging step was carried out from a spinneret having the structure in Fig. 4, having a ratio of the sheath component at 0.35 (i.e., at a core-sheath ratio of 65/35 (in mass ratio) at a spinning temperature of 310°C and a draft value of 22.3 to produce a core-sheath composite fiber as a monofilament having fineness of 10.3 dtex. The fiber was taken up without causing a breakage and thereby exhibited excellent spinnability.

[0093] Next, in the heat treatment step, thus-obtained fiber was rewound onto a heat treatment bobbin and subjected to a heat treatment under the atmosphere of nitrogen gas for a duration of 18 hours at a treatment temperature which was elevated in a stepwise manner up to the maximum temperature of 260°C. The heat-treated fibers unwound from the bobbin without problem, and the heat-treated fiber showed properties listed in Table 5.

Examples 2 to 8

[0094] Core-sheath composite fibers were prepared in the same way as that in Example 1, except that different core-sheath ratios, different ratios of an island component in a sheath component, different filament numbers, different single fiber finenesses, and different draft values were used as summarized in Table 5. Table 5 shows the resulting properties of the fibers. Each of the fibers was taken up without causing a breakage and thereby exhibited excellent spinnability.

Comparative Example 1

[0095] A core-sheath composite fiber was prepared through the same spinning process and heat treatment as those in Example 1, except: that a chip blend obtained by manually mixing chips for the polymer B and chips for the polymer C with a hand was used for the sheath component having an island proportion of 30 wt% for the polymer B in the sheath component; that the mixture was melt-kneaded in a low-temperature kneading step using a single-screw extruder at 310°C; and that discharging step was carried out from a spinneret having the structure as shown in Fig. 4 having a ratio of the sheath component at 0.35 (i.e., at a core-sheath ratio of 65/35 (in mass ratio) at a spinning temperature of 310°C and a draft value of 9.9. The fiber often caused a breakage and thereby exhibited poor spinnability. Table 5 shows the resulting properties of the fiber.

Comparative Example 2

[0096] A core-sheath composite fiber was prepared in the same way as Comparative Example 1, except that the island component was mixed to have an island proportion of 20 wt% in the sheath component. The fiber often caused a breakage and thereby exhibited poor spinnability. Table 5 shows the resulting properties of the fiber.

Comparative Example 3

[0097] A core-sheath composite fiber was prepared through the same spinning process and heat treatment as those in Comparative Example 1, except that the island component was mixed to have an island proportion of 5 wt% in the sheath component. The fiber was taken up without causing a breakage and thereby exhibited fair spinnability, because the island component was incorporated in the sheath component in the island proportion of 10 wt% or less, similarly to those discussed in Patent Document 1. Table 5 shows the resulting properties of the fiber.

Comparative Example 4

[0098] A core-sheath composite fiber was prepared in the same way as Comparative Example 1, except that the fiber was spun at a ratio of the sheath component of 0.15 (i.e., at a core-sheath ratio of 85/15 (in mass ratio)) and a draft value of 15.5. The fiber often caused a breakage and thereby exhibited poor spinnability. Table 5 shows the resulting properties of the fiber.

Comparative Example 5

[0099] A core-sheath composite fiber was prepared through the same spinning process and heat treatment as those in Comparative Example 1, except that a low-temperature kneading step similar to that in Example 1 was performed as a kneading step for the sheath component. The fiber was taken up without causing a breakage and thereby exhibited fair spinnability. Table 5 shows the resulting properties of the fiber.

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Table 5

	Ex.1	Ex.2	Ex.3	Ex.4	Ex.5	Ex.6	Ex.7	Ex.8	Com. Ex.1	Com. Ex.2	Com. Ex.3	Com. Ex.4	Com. Ex.5
Single fiber fineness [dtex]	10.2	9.9	13.9	14.0	10.1	4.5	56.0	56.1	10.3	10.1	10.0	10.3	10.1
Filament Number	1	1	16	16	1	1	1	1	1	1	1	1	1
Core-sheath Ratio	65/35	65/35	65/35	85/15	85/15	80/20	85/15	95/5	65/35	65/35	65/35	85/15	65/35
Island Component in Sheath Component [wt%]	30	20	30	30	30	30	30	30	30	20	5	30	30
Kneading Method for Sheath Resin	LK*1	LK	LK	LK	LK	LK	LK	LK	CB*2	CB	CB	CB	LK
Draft Value	22.3	22.3	21.6	21.6	22.3	22.0	21.6	21.6	9.9	9.9	9.9	15.5	9.9
Thickness of Sheath Component [μm]	2.9	2.8	3.5	1.4	1.2	1.1	2.9	0.9	3.0	2.9	3.0	1.4	2.9
Island Diagonal Length L1 [μm]	2.50	1.72	2.12	2.71	2.61	2.28	2.44	2.53	3.92	3.62	3.31	3.10	2.89
Maximum Island Width W [μm]	0.45	0.31	0.39	0.49	0.46	0.42	0.46	0.48	0.80	0.73	0.69	0.64	0.59
Ratio L1/W	5.56	5.55	5.44	5.53	5.67	5.43	5.30	5.27	4.90	4.96	4.80	4.84	4.90
Island Length L2 [μm]	557	502	582	637	608	522	538	510	356	329	398	535	270
Evaluation of 30000 Cycle Wear Test	B	A	A	A	A	B	B	B	C	C	C	C	C
No. of Fluffs (5-replicate avg.)	0.2	0	0	0	0	0.6	0.4	0.8	2.2	2.8	1.8	1.2	0.8
Tensile Tenacity [cN/dtex]		19.2	18.7	19.4	22.9	23.2	21.5	20.1	22.2	17.3	16.5	20.8	18.4
*1) LK denotes low-temperature kneading using twin-screw extruder.													
*2) CB denotes chip blend kneading using single-screw extruder.													

[0100] As shown in Table 5, despite a high ratio of the melt-anisotropic aromatic polyester in the sheath component, each of Examples 1 to 8 achieves both high wear resistance and advantageous spinnability, thanks to the controlled shapes of the islands in the islands-in-the-sea structure of the sheath component.

[0101] All of Examples 1 to 8 excel in wear resistance because of no generation of fluffs having a size of larger than 1 mm nor occurrence of a sheath delamination in the wear test involving 30000 cycles of the reciprocating motions. In particular, the sheath-core composite fibers obtained in Examples 2 and 3 does not show even a small fibril having a size of 1 mm or smaller, perhaps because of their small maximum widths of the islands. Further, despite of having maximum widths of the islands greater than those of Examples 2 and 3, Examples 1, 4, and 5 does not show even a small fibril having a size of 1 mm or smaller or observed to have such a fluff in only one of the five replicates, perhaps because their large ratios of the maximum island diagonal length L 1 to the maximum island width W thanks to the small widths and long lengths of the islands.

[0102] Especially, despite having a thin sheath, each of Examples 4 and 5 likewise show advantageous wear resistance thanks to the controlled shapes of the islands in the sheath component, and also exhibited a high tenacity due to their high ratios of the core component.

[0103] Further, Example 6 having a small single fiber fineness and Examples 7 and 8 having large single fiber finenesses, they exhibit better wear resistances than those of Comparative Examples 1 to 3, thanks to the controlled shapes of the islands in the sheath component.

[0104] In contrast, Comparative Example 1 exhibited poor spinnability by causing a fiber breakage during the spinning process, because a prescribed melt-kneading step was not performed for the sheath component. Further, despite having a core-sheath ratio and a proportion of the island component in the sheath component similar to those of Example 1, the core-sheath composite fiber prepared in Comparative Example 1 shows having large-sized islands in the sheath with a maximum width greater than that of Example 1. Furthermore, perhaps because of a small ratio of the maximum island diagonal length to the maximum island width, Comparative Example 1 fails to achieve a sufficient anchoring effect by the sheath component and, when assessed with respect to fluffs formed in the wear resistance test, not only has small fluffs with a size of 1 mm or smaller (i.e., fibrils) but also has a greater number of fluffs than that of Example 1, including fluffs having a size of larger than 1 mm and together with a sheath delamination. Finally, the fiber of Comparative Example 1 exhibits a lower tenacity than that of Example 1.

[0105] Because a prescribed melt-kneading step was not performed for the sheath component, Comparative Example 2 shows large-sized islands with a maximum width greater than that of Example 2, despite having a core-sheath ratio and a proportion of the island component in the sheath component, both similar to those of Example 2. With respect to fluff evaluation in the wear resistance test, Comparative Example 2 has a greater number of fluffs than that of Example 2, including fluffs having a size of larger than 1 mm and together with a sheath delamination. Further, the fiber of Comparative Example 2 exhibits a lower tenacity than that of Example 2.

[0106] Comparative Example 3 shows large-sized islands with a maximum width greater than those of Examples 1 and 2, despite having a lower ratio of the melt-anisotropic aromatic polyester in the sheath component than those of Examples 1 and 2. With respect to fluffs in the wear resistance test, Comparative Example 3 has a greater number of fluffs than those of Examples 1 and 2, including fluffs having a size of larger than 1 mm and together with a sheath delamination. Further, the fiber of Comparative Example 3 exhibits a lower tenacity than those of Examples 1 and 2.

[0107] Comparative Example 4, despite having a core-sheath ratio and a proportion of the island component in the sheath component both similar to those of Example 5, has fluffs having a size of larger than 1 mm, and generates a sheath delamination, because a prescribed melt-kneading step was not performed for the sheath component and a ratio of the maximum island diagonal length to the maximum island width was therefore low.

[0108] Comparative Example 5 has a core-sheath ratio and a proportion of the island component in the sheath component both similar to those of Example 1, as well as a small maximum width of the islands because of a prescribed melt-kneading step for the sheath component. However, Comparative Example 5 causes fluffs having a size of larger than 1 mm and generates a sheath delamination, because of a low draft value during the spinning process and a resulting low ratio of the maximum island diagonal length to the maximum island width.

INDUSTRIAL APPLICABILITY

[0109] A core-sheath composite fiber according to the present invention comprises a high proportion of the melt-anisotropic aromatic polyester in the sheath component to attain a high tenacity and a high elastic modulus while also being able to suppress fibrillations and, therefore, can find applications for use in, for examples, highly processed products such as tensioning members (e.g., cables for various electrical and electronic products, like a wire, an optical fiber, an umbilical cable, a heater wire core, and an earphone cable), sailcloth, ropes (e.g., a marine rope, a climbing rope, a crane rope, a sailboat rope, and a tug rope), climbing ropes, nets for on-land use, slings, lifelines, fishing lines, sewing threads, window screen cords, fishing nets, longlines, geogrids, protective gloves, ripstops for protective clothing and outdoor clothing, riding wear, sport rackets, catguts, reinforcements for medical catheters, sutures, screen meshes,

filters, fabric substrates for PCBs, mesh conveyor belts, papermaking belts, dryer canvases, airships, balloons, airbags, speaker cones, reinforcements for various types of hoses and pipes, and reinforcements made of rubber, a plastic, etc. for tires, conveyor belts, etc. Furthermore, a core-sheath composite fiber according to the present invention can be dyed in a conventional method and, therefore, can be advantageous for use in, for example, highly processed products such as, in particular, sailcloth, climbing ropes, nets for on-land use, fishing lines, fishing nets, longlines, ripstops for protective clothing and outdoor clothing, reinforcements made of rubber, a plastic, etc., and general clothing.

[0110] Although the present invention has thus been fully described in connection with the preferred embodiments thereof with reference to the drawings, those skilled in the art will readily conceive of numerous changes and modifications within the framework of obviousness of the present invention. Accordingly, such changes and modifications are, unless they depart from the scope of the present invention as delivered from the claims annexed hereto, to be construed as included therein.

Claims

1. A core-sheath composite fiber comprising:

a core component including a melt-anisotropic aromatic polyester (a polymer A); and
a sheath component having an islands-in-the-sea structure and including a flexible thermoplastic polymer (a polymer B) as a sea component and a melt-anisotropic aromatic polyester (a polymer C) as an island component, the islands-in-the-sea structure being provided with a plurality of islands formed of the island component dispersed in a sea formed of the sea component, wherein

the sheath component has a proportion of the island component of more than 10 wt%;

among the islands in a cross section cut along a longitudinal direction of the core-sheath composite fiber, an island represented by having a largest width along a direction perpendicular to the fiber has a maximum width W of 0.65 μm or shorter;

the island having the maximum width W has a maximum diagonal length L1 which is a longest length in the island overlapped with a diagonal line drawn in the sheath component at a fixed angle of 10° relative to the longitudinal direction of the fiber along one end to another end thereof, and has a ratio L1/W of the maximum diagonal length L1 to the maximum width W of said island being 5.0 or more.

2. The core-sheath composite fiber of claim 1, wherein the maximum diagonal length L1 is 1.0 μm or longer.

3. The core-sheath composite fiber of claim 1 or 2, wherein said island in the sheath component has a length L2 along the longitudinal direction of the fiber of from 450 to 1000 μm , in the cross section cut along the longitudinal direction of the core-sheath composite fiber.

4. The core-sheath composite fiber of any one of claims 1 to 3, wherein the sheath component has a thickness of from 0.8 to 5.0 μm .

5. The core-sheath composite fiber of any one of claims 1 to 4, wherein the polymer A and the polymer C comprise a melt-anisotropic aromatic polyester of same species as each other.

6. The core-sheath composite fiber of any one of claims 1 to 5, wherein a ratio of the core component / the sheath component in terms of a weight ratio of the core component to the sheath component is from 20/80 to 97/3.

7. The core-sheath composite fiber of any one of claims 1 to 6, wherein the core-sheath composite fiber has a single fiber fineness of from 1 to 120 dtex.

8. A method for producing a core-sheath composite fiber, the core-sheath composite fiber comprising: a core component including a melt-anisotropic aromatic polyester (a polymer A); and a sheath component having an islands-in-the-sea structure and including a flexible thermoplastic polymer (a polymer B) as a sea component and a melt-anisotropic aromatic polyester (a polymer C) as an island component, the islands-in-the-sea structure being provided with a plurality of islands formed of the island component dispersed in a sea formed of the sea component, the method at least comprising:

kneading the polymer B and the polymer C for the sheath component in a twin-screw extruder at a temperature which is equal to Mb°C or higher, is equal to (Mc - 20)°C or higher, and is lower than Mc°C, where Mb is a

melting point of the polymer B and M_c is a melting point of the polymer C, and melt-kneading the polymer A for the core component in an extruder different from the twin-screw extruder used for the sheath component; discharging an as-spun composite fiber of the kneaded sheath component and the kneaded core component; and taking up the discharged as-spun fiber at a draft value of from 13 to 50, the draft value being a ratio of a winding speed to a discharging speed.

9. The production method for the core-sheath composite fiber of claim 8, further comprising:
subjecting the spun fiber to a heat treatment.

10. A fiber structure comprising, at least in a part thereof, a core-sheath composite fiber recited in any one of claims 1 to 7.

Fig. 1A

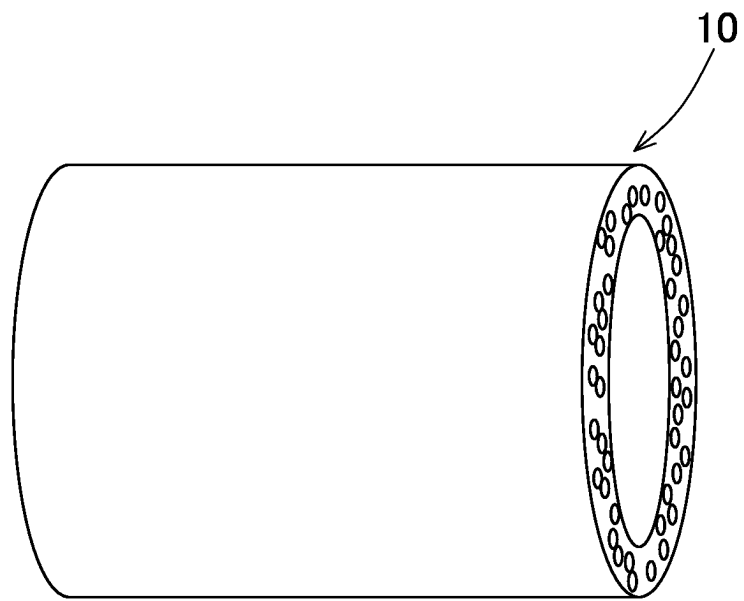


Fig. 1B

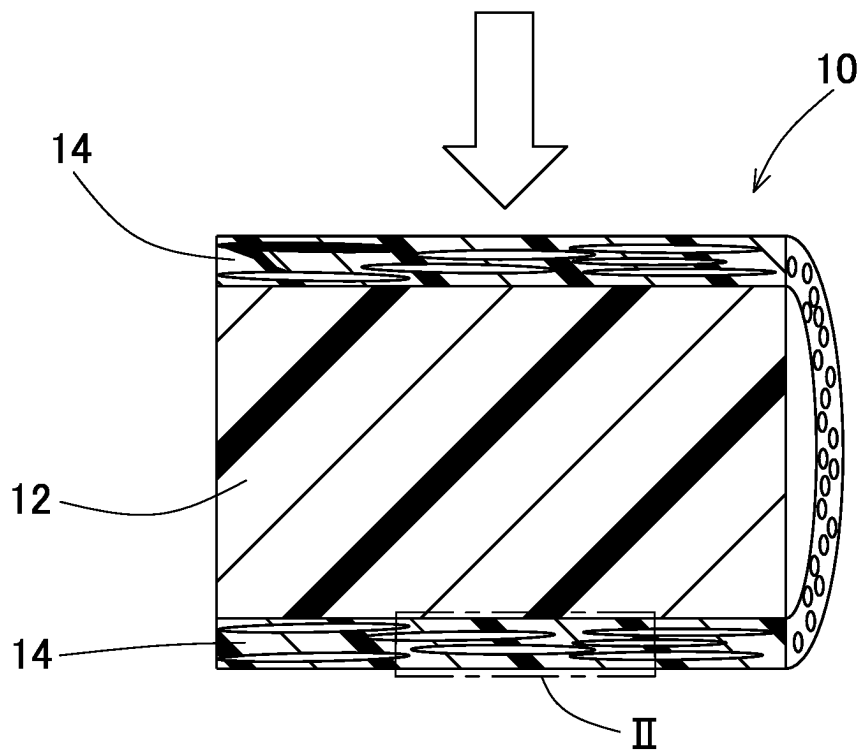


Fig. 2

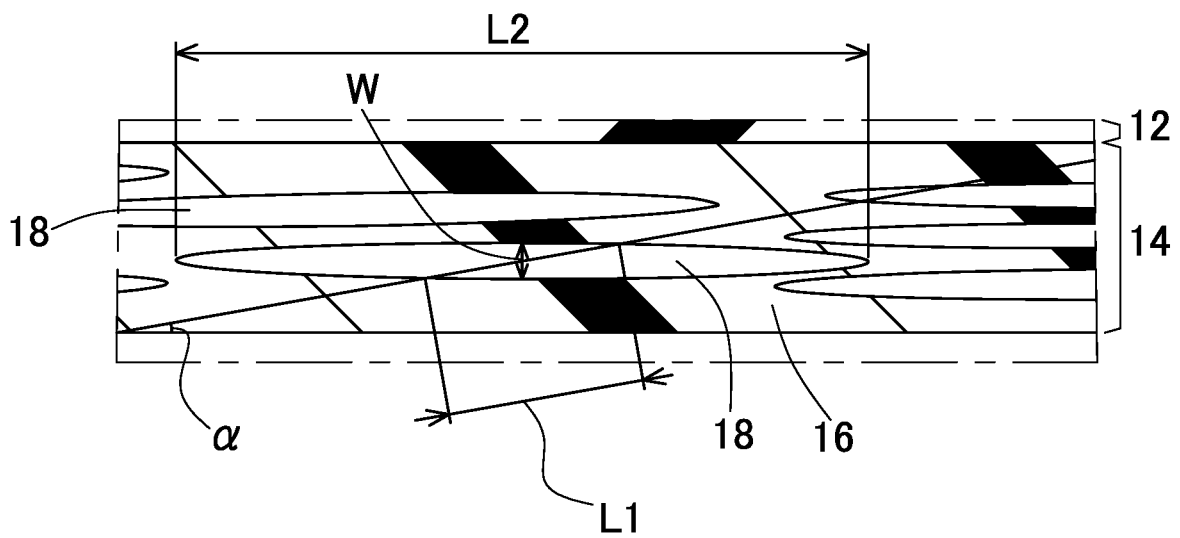


Fig. 3

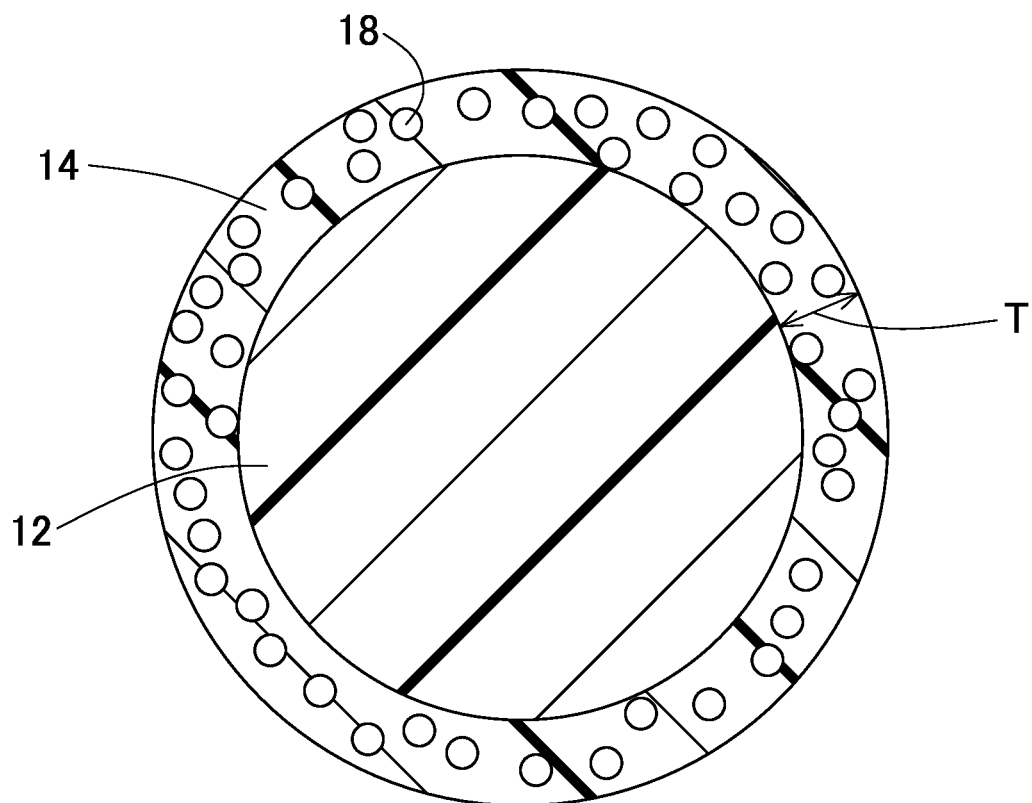
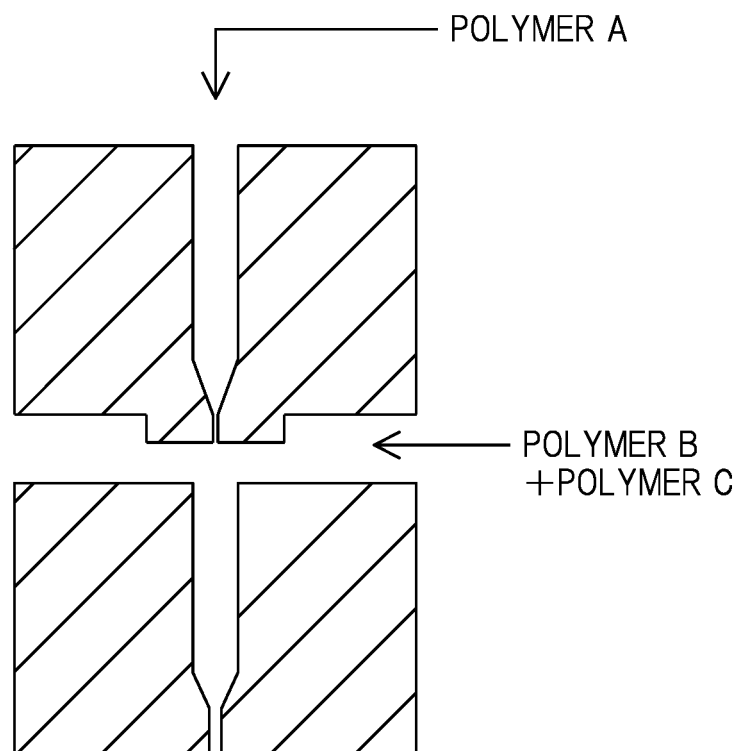


Fig. 4



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2022/008341

A. CLASSIFICATION OF SUBJECT MATTER <i>D01F 8/14</i> (2006.01)i; <i>D01D 5/08</i> (2006.01)i; <i>D01D 5/34</i> (2006.01)i; <i>D01D 7/00</i> (2006.01)i; <i>D02J 13/00</i> (2006.01)i FI: D01F8/14 B; D01D5/08 Z; D01D5/34; D01D7/00 Z; D02J13/00 A 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) D01F8/00-8/18; D01D1/00-13/02 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 1971-2022 Registered utility model specifications of Japan 1996-2022 Published registered utility model applications of Japan 1994-2022 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.
Y A	JP 2010-77540 A (KURARAY CO LTD) 08 April 2010 (2010-04-08) claims 1, 4, paragraph [0029], examples, fig. 1	8-9 1-7, 10
Y A	JP 2007-126760 A (TORAY IND INC) 24 May 2007 (2007-05-24) claims 1-3, 5, paragraphs [0001], [0039], examples	8-9 1-7, 10
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A	JP 2009-179908 A (TORAY IND INC) 13 August 2009 (2009-08-13)	1-10
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
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Date of the actual completion of the international search 11 April 2022	Date of mailing of the international search report 26 April 2022	
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/JP2022/008341

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