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(54) **MANUFACTURING METHOD FOR COMPOSITE SPINNERET AND COMPOSITE FIBER**

(57) Provided is a composite spinneret for discharging a composite polymer stream composed of an island component polymer and a sea component polymer, including one or more distribution plates in which distribution holes and distribution grooves for distributing the polymer components are formed; and a lowermost layer distribution plate positioned to the downstream side of the distribution plate in the direction of the polymer spinning path and provided with a plurality of island component discharge holes and a plurality of sea component discharge holes, wherein the composite spinneret has a plurality of hole groups composed of n island component discharge holes centered on a center O and arranged on a circular line C1 with a radius R1, n sea component discharge holes centered on the center O and arranged on a circular line C2 with a radius R2, n group centers P centered on the center O and arranged on a circular line C3 with a radius R3, n island component discharge holes centered on the group center P and arranged on a circular line C5 with a radius R1, and n sea component discharge holes centered on the P and arranged on a circular line C6 with a radius R2 are present; and R1, R2 and R3 satisfy the following expression (1) and (2):

(1)

$$R1 \leq R2 \cdot \cos(180/n \text{ [degree]}) \quad \text{expression (1)}$$

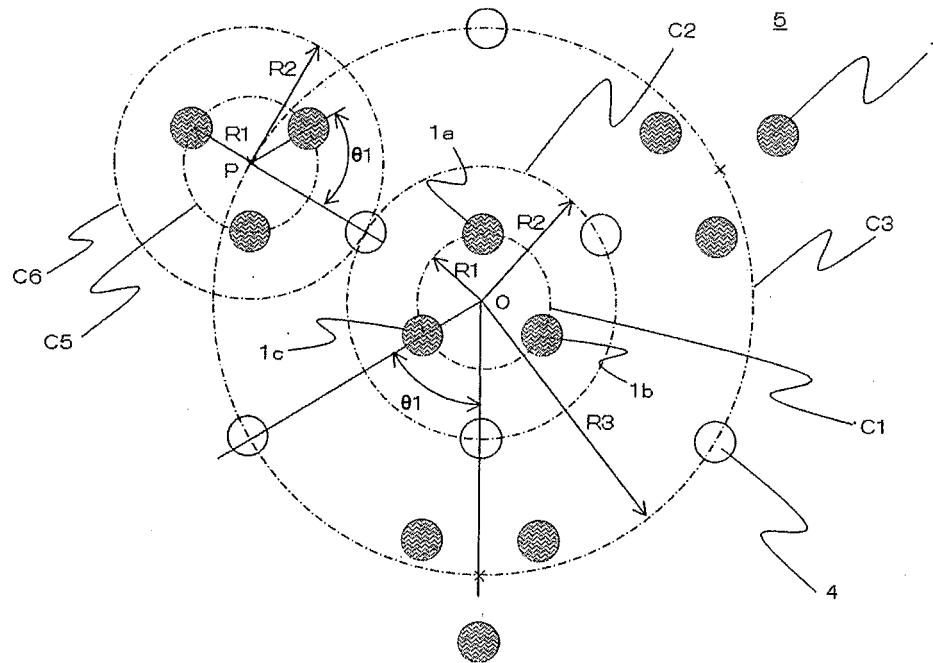
(2)

$$R3 = 2 \cdot R2 \quad \text{expression (2)}$$

and each discharge hole is arranged according to predetermined conditions.

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Fig. 1



Description

TECHNICAL FIELD

[0001] The present invention relates to a composite spinneret and a method of manufacturing a composite fiber.

BACKGROUND ART

[0002] Fibers using a thermoplastic polymer such as polyester or polyamide are excellent in mechanical characteristics and dimensional stability, and therefore, the fibers have a variety of uses and many fibers provided with various functionalities are developed.

[0003] For example, in clothing applications, there are made various improvements of reducing the fineness of a single yarn and increasing the number of filaments aiming at imparting soft textures; changing a cross section of a single yarn to a heteromorphic cross section aiming at improving water absorption and quick drying and modifying a gloss feeling; and modifying a polymer aiming at providing a new functionality such as realization of dyeing excellent in clearness. Further, in industrial material applications, there are made similar improvements of reducing the fineness of a single yarn and increasing the number of filaments, changing a cross section of a single yarn to a heteromorphic cross section, and modifying a polymer aiming at providing a new functionality such as high strength, high elasticity, weatherability and flame retardancy. Moreover, in addition to the above improvements, active development of a composite fiber is performed, in which performance that is insufficient by a polymer of single component is complemented or completely a new function is provided by combining two types or more of polymers into one.

[0004] The composite fiber includes a core-sheath type fiber, a side-by-side type fiber and an islands-in-the-sea fiber which are attained by using the composite spinneret, and an alloy type fiber which is attained by melt-kneading polymers with each other. The core-sheath type enables to provide sensitive effects such as textures and bulkiness or mechanical properties such as strength, elastic modulus and abrasion resistance which cannot be achieved by fibers of a single component only since a core component is covered with a sheath component. Further, the side-by-side type enables to exhibit a crimping property which cannot be obtained by fibers of a single component only and provide a stretching property and the like.

[0005] In the islands-in-the-sea type, only a hard-to-elute component (island component) remains, and ultrafine fibers having a yarn diameter of monofilament of nano-order can be obtained by eluting an easy-to-elute component (sea component) after melt spinning. In the case of such extremely ultrafine fibers, in clothing applications, the ultrafine fibers exhibit the soft touch and delicacy unavailable from general fibers, and can be applied to artificial leathers and textiles exhibiting new feelings and senses, and since fiber clearances become compact, the ultrafine fibers can be developed for sports clothing requiring wind-breaking capability and water-repelling capability as high-density woven fabrics. Further, industrial material applications, since the ultrafine fibers have large specific surface areas and high dust collectability, these can be applied to high performance filters or the like, and since ultrafine fibers enter into fine grooves and wipe out dirt, these can also be applied to wiping cloths and precision polishing cloths for precision apparatuses, etc.

[0006] Further, the core-sheath type enables to provide sensitive effects such as textures and bulkiness or mechanical properties such as strength, elastic modulus and abrasion resistance which cannot be achieved by fibers of a single component only since a core component is covered with a sheath component. Further, the side-by-side type enables to exhibit a crimping property which cannot be obtained by fibers of a single component only and provide a stretching property and the like.

[0007] In addition, a technique of manufacturing a composite fiber by a composite spinneret is generally referred to as a composite spinning method, and a technique of manufacturing a composite fiber by melt-kneading polymers with one another is generally referred to as a polymer alloy method. In order to manufacture the ultrafine fibers described above, the polymer alloy method can be employed; however, there is a limitation in controlling a fiber diameter, and it is difficult to obtain uniform and homogeneous ultrafine fibers. In contrast, the composite spinning method is supposed to be superior to the polymer alloy method in that a composite polymer stream is precisely controlled by the composite spinneret, and a highly precise form of a yarn cross section can be uniformly and homogeneously formed in the running direction of a yarn. Naturally, a composite spinneret technology in the composite spinning method is extremely important in stably determining the form of the yarn cross section, and various proposals are heretofore made.

[0008] For example, Patent Document 1 discloses a composite spinneret as shown in Fig. 11. Fig. 11(b) is a plan view of the composite spinneret of Patent Document 1, and Fig. 11(a) is a partially enlarged plan view of Fig. 11(b). In the drawings, a black circle 1 indicates an island component discharge hole for discharging an island component polymer, an open circle 4 indicates a sea component discharge hole for discharging a sea component polymer, and reference numerals 5 and 8 indicate a lowermost layer distribution plate and a distribution groove, respectively. Hereinafter, in each drawing, when a member corresponding to a drawing previously described is present, a description of the drawing may not be given by use of the same reference symbol or numeral.

[0009] Patent Document 1 describes that a plurality of distribution plates are overlaid, and a lowermost layer distribution plate 5, which is provided with distribution grooves 8, island component discharge holes 1 and sea component discharge holes 4, is arranged at the lowest layer of the distribution plates, and an island component polymer of a hard-to-elute component and a sea component polymer of an easy-to-elute component are previously distributed as many streams to the lowermost layer distribution plate 5 by the distribution plate, and then the polymers of both components are discharged from the island component discharge holes 1 and the sea component discharge holes 4, respectively, of the lowermost layer distribution plate 5 to be combined into one immediately after discharging, and thereby, islands-in-the-sea composite fibers can be manufactured. Patent Document 1 also describes that a composite fiber, in which an island form has a hexagonal cross section (honeycomb form) and 61 pieces are uniformly distributed, can be manufactured by using this composite spinneret. In addition, the composite spinneret is generally referred to as a spinneret of a distribution plate system.

[0010] However, according to findings by the present inventors, in the composite spinneret of Patent Document 1, an island form has a hexagon in cross section by disposing the sea component discharge holes 4 so as to form a hexagon around the island component discharge hole 1 as a disposition pattern of a hole group; however, another disposition pattern of a hole group is not presented, and islands-in-the-sea composite fibers having a variety of island forms may not be obtained in some cases. Further, since the island component discharge hole 1 and the sea component discharge hole 4 are arranged at the same plane as that of the lowermost layer distribution plate 5, a great number of the island component discharge holes 1 may not be arranged and the hole packing density may not be increased, and consequently, the ultrafine fibers having a diameter of nano-order may not be obtained in some cases. Particularly, since a plurality of the sea component discharge holes 4 are arranged around one island component discharge hole 1 in order to prevent the island component polymer streams from joining with one another. The sea component discharge holes 4 more than the island component discharge holes 1 are arranged at the lowermost layer distribution plate 5, and therefore, a location to which the island component discharge hole 1 is arranged is limited, and a great number of the island component discharge holes 1 may not be arranged in some cases. In the composite spinneret, as described in Examples of Patent Document 1, a denier value of the resulting fiber is 0.06 denier (fiber diameter in a trial calculation: about 2.5 μm) of a micron size and does not reach a nano-order size. Thus, when many island component discharge holes 1 are arranged, the composite spinneret may become larger to cause problems that productivity and operability are low in spinning facility of a multi-spindle type in a textile area in some cases.

[0011] Further, as hole disposition patterns different from those of Patent document 1, Fig. 9 and Fig. 10 are disclosed. Fig. 9 and Fig. 10 are partially enlarged plan views of the composite spinnerets of Patent Document 3 and Patent Document 5. According to findings by the present inventors, the pattern in Patent Document 3 or Patent Document 5 is a pattern in which three or four sea component discharge holes 4 are equally arranged around the island component discharge hole 1 (zigzag alignment), and it appears that islands-in-the-sea composite fibers in which the island component form is polygonal can be obtained at a glance; however, according to findings by the present inventors, in actual, the island component polymer streams may join with one another. Particularly, it is preferred from the viewpoint of productivity that since the sea component polymer is eluted after melt spinning, a discharge ratio of the sea component polymer to be eluted is decreased and a discharge ratio of the island component polymer is increased; however, in this case, island component polymer streams may join with one another more remarkably in some cases. Further, according to findings by the present inventors, when the island component polymer streams join with one another once, the problem may not be solved in some cases even when changing spinning conditions such as discharge amounts and a ratio between discharge amounts of the respective component polymers, and in the worst case, the production may become impossible and the productivity may be deteriorated in some cases if not changing the composite spinneret.

[0012] Further, although a detailed hole distribution pattern is not shown, a composite spinneret manufacturing an islands-in-the-sea composite fiber having a variety of island shapes is disclosed in Patent Document 2. Fig. 14(a) is a sectional view showing a cross section form of a composite fiber manufactured with the composite spinneret of Patent Document 2. It is described that in the composite spinneret of Patent Document 2, a plurality of the island component discharge holes 1 are gathered into an arbitrary shape and arranged, and thereby an island shape can be formed into an arbitrary shape. It is described in Patent Document 2 that a cross section form of the resulting composite fiber, as shown in Fig. 14(a), has a plurality of star-type cross section shapes in a cross section of one composite fiber.

[0013] However, according to findings by the present inventors, in the composite spinneret of Patent Document 2, since a plurality of the island component discharge holes 1 need to be arranged in a close-packed state (island component discharge holes 1 are arranged in a close-packed state so as to surround an edge of an arbitrary cross section shape) in order to form one arbitrary island shape, the number of the island component discharge holes 1 which can be arranged per a spinneret may not be increased in some cases, and consequently, a composite fiber having a great number of islands in one composite fiber may not be obtained in some cases, namely, there are limitation to an increase in island.

[0014] As is the case with a core-sheath type having one island shape in one composite fiber, Patent Document 5 discloses a composite spinneret using a distribution plate system and manufacturing a composite fiber having a complicated island shape. Fig. 12 is a partially enlarged plan view of a lowermost layer distribution plate of the composite

spinneret of Patent Document 5, and Fig. 14 (b) is a sectional view showing a cross section form of a composite fiber manufactured with a composite spinneret of Patent Document 5. Further, Figs. 14(c), 14(d) are sectional views showing a cross section form of a composite fiber obtained by using the composite spinneret (employing a distribution plate system) of Patent Document 4 though the hole distributing pattern of the lowermost layer distribution plate 5 is not shown. It is described that in the composite spinneret of Patent Document 5, a cross-type cross section form can be formed by arranging 4 pieces of the sea component discharge holes 4 at an outer circumference of the island component discharge hole 1. It is described in Patent Document 5 that a cross section form of the resulting composite fiber, as shown in Fig. 14 (b), has one cross-type cross section form in a cross section of one composite fiber. Further, it is described in Patent Document 4 that one star-type or trilobal cross section can be formed in a cross section of one composite fiber by disposing a plurality the island component discharge holes 1 in a close-packed state so as to be a star-type or trilobal shape.

[0015] However, according to findings by the present inventors, in the composite spinnerets of Patent Document 4 and Patent Document 5, the composite spinneret is a core-sheath type in which one island-shaped cross section exists in a cross section of one composite fiber, and a plurality of island shapes cannot be formed as distinct from an islands-in-the-sea type, that is, a hole disposition pattern of the composite spinneret of a core-sheath type may not be applied directly to the composite spinneret of an islands-in-the-sea type. Further, since the composite spinneret is not an islands-in-the-sea type, the resulting fiber diameter may not reach a micron-order size and hence a nano-order size in some cases. As described above, in the composite spinnerets of Patent Document 4 and Patent Document 5, a composite fiber having a cross-section shape with a complicated island shape and having a few hundred to a few thousand island components in one fiber may not be attained in some cases.

[0016] Further, as a spinneret which can manufacture islands-in-the-sea fibers by a method different from the spinneret of a distribution plate system, the composite spinneret as shown in Fig. 13 is disclosed. Fig. 13 is a schematic sectional view of the composite spinneret of Patent Document 6, and the spinneret is referred to as a pipe system spinneret. In Fig. 13, a reference numeral 30 indicates a pipe, a reference numeral 31 indicates a sea component polymer introduction flow path, a reference numeral 32 indicates an island component polymer introduction flow path, a reference numeral 33 indicates an upper spinneret plate, a reference numeral 34 indicates a middle spinneret plate, a reference numeral 35 indicates a lower spinneret plate, a reference numeral 40 indicates a distribution chamber for a sea component polymer, a reference numeral 41 indicates a pipe insertion hole, and a reference numeral 42 indicates a spinneret discharge hole, respectively. The spinneret of Patent Document 6 is composed of the upper spinneret plate 33 provided with the sea component polymer introduction flow paths 31, the island component polymer introduction flow paths 32 and the pipes 30; the middle spinneret plate 34 provided with the pipe insertion hole 41 with a diameter equal to or larger than an outer diameter of the pipe 30; and the lower spinneret plate 35 provided with the spinneret discharge holes 42. It is described herein that, the sea component polymer of an easy-to-elute component is guided from the sea component polymer introduction flow paths 31 to the distribution chamber 40 for a sea component polymer to fill the outer circumference of the pipe 30, but on the other hand, the island component polymer of a hard-to-elute component is guided from the island component polymer introduction flow path 32 to the pipes 30, and discharged from the pipe 30, and thereby, polymers of both components join with each other to form a sea-island composite cross section, and then a composite polymer is discharged from the spinneret discharge hole 42 through the pipe insertion holes 41, and thereby, islands-in-the-sea composite fibers can be manufactured.

[0017] However, the pipe system spinneret of Patent Document 6 has a large problem that since a pipe thickness is added for manufacturing an island, an area per a pipe is increased. Further, since the pipe 30 is press-fitted in the upper spinneret plate 33 and fixed to the upper spinneret plate 33 by welding for manufacturing a spinneret, a welding clearance is required, and since a hole for insertion of the pipe 30 is arranged, a space between pipes cannot be narrowed because of a problem of strength. Accordingly, the pipes 30 may not be arranged in a close-packed state per a unit area, and thus it may be difficult to manufacture ultrafine fibers with a fiber diameter of nano-order size in some cases. Further, since the cylindrical pipe 30 is used, the resulting shape of island is limited to a circular shape or an elliptical shape similar to the circular shape, the islands-in-the-sea composite fibers having a complicated shape such as a polygonal shape of island may not be obtained in some cases. Since this spinneret has a low degree of freedom for an arrangement of the pipes 30 and a controllable fiber cross section form is limited, it may be difficult to manufacture fibers in which complicated cross sections are layered in some cases.

[0018] Further, in order to attain a desired fiber form, it is necessary that a plurality of spinnerets are manufactured experimentally and a spinning evaluation is repeated; however, since a structure of the composite spinneret is very complicated, it requires time, labor and cost for manufacturing the spinneret, and the spinneret has a problem that facility cost is expensive in this respect. Further, since the sea component polymer introduction flow path 31 is arranged at the outer circumference of a pipe group where the pipes 30 are arranged in a close-packed state, it is difficult to supply an adequate sea component polymer to the center of the pipe group, and particularly the island component polymer streams discharged from the pipes 30 at the center of the pipe group may join with one another in some cases. Particularly when the pipes 30 are arranged in a state of being more close-packed in order to increase the hole packing density, the above-

mentioned problem becomes more remarkable. According to findings by the present inventors, it may be structurally difficult to freely arrange the sea component polymer introduction flow path 31 in the pipe group of the pipes 30 in some cases. The spinneret has a problem that the spinneret has a very complicated structure and facility cost is expensive since for example, in order to arrange the sea component polymer introduction flow path 31 in the group of pipes, it is necessary to arrange the sea component polymer introduction flow path 31 by bending the pipe 30 on the way.

PRIOR ART DOCUMENTS

PATENT DOCUMENTS

[0019]

Patent Document 1: Japanese Patent Laid-open Publication No. 7-26420

Patent Document 2: Japanese Patent Laid-open Publication No. 2011-208313

Patent Document 3: Japanese Patent Laid-open Publication No. 2008-38275

Patent Document 4: WO 2011/093331 A

Patent Document 5: WO 1989/02938 A

Patent Document 6: Japanese Patent Laid-open Publication No. 2001-192924

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0020] As described above, it is desired to prevent the island component polymer streams from joining with one another at a high ratio of the island component (a low ratio of the sea component) while increasing the hole packing density of the island component discharge holes to obtain ultrafine fibers having a heteromorphic shape; however, various problems remain as described above, and interfere with the manufacture of the islands-in-the-sea composite fibers. Accordingly, it is industrially meaningful to solve the problem. Thus, it is an object of the present invention, in a composite spinneret for the manufacture of islands-in-the-sea composite fibers, to provide a composite spinneret which can prevent the island component polymer streams from joining with one another while increasing the hole packing density of the discharge holes for the island component polymer, and thereby, can form various fiber cross section forms, particularly heteromorphic cross sections having high degree of heteromorphy, with high accuracy while maintaining high dimensional stability of the cross section, and a method of manufacturing composite fibers in which melt spinning is performed by a composite spinning machine using the composite spinneret.

SOLUTIONS TO THE PROBLEMS

[0021] In order to solve the above-mentioned problems, a composite spinneret according to the present invention has the following constitutions. That is, in accordance with the present invention, there is provided a composite spinneret for discharging a composite polymer stream composed of an island component polymer and a sea component polymer, comprising one or more distribution plates in which distribution holes and distribution grooves for distributing the polymer components are formed; and a lowermost layer distribution plate positioned to the downstream side of the distribution plate in the direction of the polymer spinning path and provided with a plurality of island component discharge holes and a plurality of sea component discharge holes, wherein the composite spinneret has a plurality of hole groups composed of n (n is a natural number of 3 or more, the same shall apply hereafter) island component discharge holes centered on a virtual center O and arranged on a virtual circular line $C1$ with a radius $R1$, n sea component discharge holes centered on the virtual center O and arranged on a virtual circular line $C2$ with a radius $R2$, n virtual group centers P centered on the virtual center O and arranged on a virtual circular line $C3$ with a radius $R3$, n island component discharge holes centered on the virtual group center P and arranged on a virtual circular line $C5$ with a radius $R1$, and n sea component discharge holes centered on the virtual group center P and arranged on a virtual circular line $C6$ with a radius $R2$ are present; $R1$, $R2$ and $R3$ satisfy the following expression (1) and (2):

(1)

$$R1 \leq R2 \cdot \cos(180/n \text{ [degree]})$$

(2)

$$R3 = 2 \cdot R2,$$

and each discharge hole is arranged according to the following conditions (3) and (4):

(3) C1, C5: n island component discharge holes are arranged equally at a center angle of $360/n$ degrees

C2, C6: n sea component discharge holes are arranged equally at a center angle of $360/n$ degrees

C3: n virtual group centers are arranged equally at a center angle of $360/n$ degrees

01: a phase angle between two discharge holes, one arranged on C1 and the other arranged on C2, and one arranged on C5 and the other arranged on C6, is $180/n$ degrees

02: a phase angle between the discharge hole on C2 and the virtual group center on C3 is 0 degree,

(4) a sea component discharge hole is arranged at a point of intersection of a line segment connecting the virtual center O and the virtual group center P, the virtual circular line C2, and the virtual circular line C6.

Further, in accordance with a preferred embodiment of the present invention, there is provided the composite spinneret satisfying the expression (5) at the number n of discharge holes of 4.

(5)

$$R1 \leq R2/2$$

Further, in accordance with a preferred embodiment of the present invention, there is provided the composite spinneret satisfying the expression (6) at the number n of discharge holes of 6.

(6)

$$R1 \leq R2 \cdot 3\sqrt{3}/8$$

[0022] Further, in accordance with a preferred embodiment of the present invention, there is provided the composite spinneret which has a similar hole arrangement also when the virtual group center P adjacent to the virtual center O is taken as the virtual center O.

[0023] Further, in accordance with a preferred embodiment of the present invention, there is provided the composite spinneret, wherein a hole packing density of the island component discharge hole is 0.5 hole/mm² or more.

[0024] Further, in accordance with another embodiment of the present invention, there is provided a method of manufacturing a composite fiber, wherein melt spinning is performed by a composite spinning machine using the above-mentioned composite spinneret in which flow-path pressure losses at the respective flow paths from the distribution plate to the island component discharge holes of the lowermost layer distribution plate are the same, and flow-path pressure losses at the respective flow paths from the distribution plate to the sea component discharge holes of the lowermost layer distribution plate are the same.

[0025] Further, in accordance with another embodiment of the present invention, there is provided a method of manufacturing a composite fiber, wherein melt spinning is performed at a ratio of the island component polymer of 50% or more by a composite spinning machine using the composite spinneret.

[0026] In the present invention, "the distribution hole" refers to a hole which is formed by combining a plurality of distribution plates into one and plays a role of distributing a polymer in the direction of the polymer spinning path.

[0027] In the present invention, "the distribution groove" refers to a groove which is formed by combining a plurality of distribution plates into one and plays a role of distributing a polymer in the direction perpendicular to the direction of the polymer spinning path. Here, the distribution groove may be a long and thin hole (slit), or a long and thin groove may be cut.

[0028] In the present invention, "the direction of the polymer spinning path" refers to a main direction in which the respective polymer components flow from a metering plate to a spinneret discharge hole of a discharge plate.

[0029] In the present invention, "the direction perpendicular to the direction of the polymer spinning path" refers a direction perpendicular to the main direction in which the respective polymer components flow from a metering plate to a spinneret discharge hole of a discharge plate.

[0030] In the present invention, "the virtual circular line C1 with a radius R1" refers to a circular line C1 of a virtual circle with a radius R1 centered on a virtual center O at the time when a virtual polygonal shape is formed with line segments connecting the centers of n island component discharge holes, the barycenter of the virtual polygonal shape is taken as a virtual center O, and a center distance between the virtual center O and the island component discharge

hole forming the virtual polygonal shape is take as a radius R1.

[0031] In the present invention, "the virtual circular line C2 with a radius R2" refers to a circular line C2 of a vertical circle with a radius R2 centered on a virtual center O at the time when a center distance between the virtual center O and the sea component discharge hole closest to the virtual center O is take as a radius R2.

[0032] In the present invention, "the virtual circular line C3 with a radius R3" refers to a circular line C3 of a virtual circle with a radius R3 centered on a virtual center O at the time when the barycenter of a hole group of the island component discharge holes forming n virtual polygonal shapes, which are positioned on an outer circumference of the virtual circular line C2 and are closest to the virtual center O, is taken as a virtual group center P, and a center distance between the virtual center O and the virtual group center P is take as a radius R3.

[0033] In the present invention, "the virtual circular line C5 with a radius R1" refers to a circular line C5 of a virtual circle with a radius R1 centered on a virtual group center P at the time when a center distance between the island component discharge hole closest to the virtual group center P and the virtual group center P is take as a radius R1.

[0034] In the present invention, "the virtual circular line C6 with a radius R2" refers to a circular line C6 of a virtual circle with a radius R2 centered on a virtual group center P at the time when a center distance between the sea component discharge hole closest to the virtual group center P and the virtual group center P is take as a radius R2.

[0035] In the present invention, the phase angle θ_1 between the discharge holes arranged on the C1 and the C2 refers to an angle at which a line segment connecting the virtual center O and the center of the sea component discharge hole arranged on the virtual circular line C2, and a line segment connecting the virtual center O and the center of the island component discharge hole arranged on the virtual circular line C1 intersect. Further, the phase angle θ_1 between the discharge holes arranged on the C5 and the C6 refers to an angle at which a line segment connecting the virtual group center P and the center of the sea component discharge hole arranged on the virtual circular line C6, and a line segment connecting the virtual group center P and the center of the island component discharge hole arranged on the virtual circular line C5 intersect.

[0036] In the present invention, the phase angle θ_2 refers to an angle at which a line segment connecting the virtual center O and the center of the sea component discharge hole arranged on the virtual circular line C2, and a line segment connecting the virtual center O and the virtual group center P arranged on the virtual circular line C3 intersect.

[0037] In the present invention, "the center angle" refers to an intersection angle of two line segments connecting the virtual center O and the centers of two island component discharge holes which are arranged on the virtual circular line C1 and are adjacent to each other in a circumferential direction or the centers of two sea component discharge holes which are arranged on the virtual circular line C2 and are adjacent to each other in a circumferential direction, or an intersection angle of two line segments connecting the virtual group center P and the centers of two island component discharge holes which are arranged on the virtual circular line C5 and are adjacent to each other in a circumferential direction or the centers of two sea component discharge holes which are arranged on the virtual circular line C6 and are adjacent to each other in a circumferential direction, or an intersection angle of two line segments connecting the virtual center O and two virtual group centers P which are virtually arranged on the virtual circular line C3 and are adjacent to each other in a circumferential direction.

In the present invention, "the polymer flow through path" refers to a path formed by communicating the distribution hole formed within the distribution plate with the distribution groove formed within the distribution plate.

[0038] In the present invention, "the hole packing density" refers to a value determined by referring to n island component discharge holes arranged on the virtual circular line C1 as one hole group for an island component, and dividing the number of hole groups for an island component by a cross section area of the discharge introduction hole. When the hole packing density is larger, a composite fiber is obtained which is composed of more island component polymers.

EFFECTS OF THE INVENTION

[0039] In accordance with the composite spinneret of the present invention, it is possible that the island component polymer is uniformly distributed and the island component polymer streams are prevented from joining with one another while increasing the hole packing density of the discharge holes for the island component polymer, and thereby, various fiber cross sections, particularly heteromorphic cross section forms, are formed with high accuracy while maintaining high dimensional stability of the cross section.

BRIEF DESCRIPTION OF THE DRAWINGS

[0040]

Fig. 1 is a partially enlarged plan view of a lowermost layer distribution plate used in an embodiment of the present invention.

Fig. 2 is a partially enlarged plan view of a lowermost layer distribution plate used in another embodiment of the

present invention.

Fig. 3 is a partially enlarged plan view of a lowermost layer distribution plate used in another embodiment of the present invention.

Fig. 4 is a schematic view of a cross section of a typical composite fiber manufactured with a composite spinneret used in an embodiment of the present invention.

Fig. 5 is a schematic sectional view of a composite spinneret used in an embodiment of the present invention.

Fig. 6 is a schematic sectional view of a composite spinneret, and surroundings of a spin pack and a cooling apparatus, which are used in an embodiment of the present invention.

Fig. 7 is a view taken in the direction of arrows X-X in Fig. 5.

Fig. 8 is a schematic partially sectional view of a distribution plate and a lowermost layer distribution plate used in an embodiment of the present invention.

Fig. 9 is a partially enlarged plan view of a lowermost layer distribution plate of a composite spinneret of a conventional example.

Fig. 10 is a partially enlarged plan view of a lowermost layer distribution plate of the conventional example.

Fig. 11 is a partially enlarged plan view of a lowermost layer distribution plate of a composite spinneret of the conventional example.

Fig. 12 is a partially enlarged plan view of a lowermost layer distribution plate of the conventional example.

Fig. 13 is a schematic sectional view of a composite spinneret of the conventional example.

Fig. 14 is a sectional view showing a cross section of a typical composite fiber manufactured with a composite spinneret used in an embodiment of the conventional example.

EMBODIMENTS OF THE INVENTION

[0041] Hereinafter, while referring to drawings, an embodiment of a composite spinneret of the present invention will be described in detail with reference to drawings. Fig. 5 is a schematic sectional view of a composite spinneret used in an embodiment of the present invention, Fig. 7 is a view taken in the direction of arrows X-X in Fig. 5, Fig. 1 is a partially enlarged plan view of Fig. 7, Figs. 2 and 3 are respectively a partially enlarged plan view of a lowermost layer distribution plate used in another embodiment of the present invention, Fig. 6 is a schematic sectional view of a composite spinneret, and surroundings of a spin pack and a cooling apparatus, which are used in an embodiment of the present invention, and Fig. 8 is a schematic partial sectional view of a distribution plate and a lowermost layer distribution plate used in an embodiment of the present invention. In addition, these are conceptual drawings for correctly expressing the essential points of the present invention and are simplified, and the composite spinneret of the present invention is not limited to these, and the number of holes and grooves, and a dimensional ratio of holes and grooves may be changed according to the embodiment.

[0042] As shown in Fig. 6, a composite spinneret 18 used in an embodiment of the present invention is fitted in a spin pack 15 and fixed in a spin block 16, and a cooling apparatus 17 is configured immediately below the composite spinneret 18. Two types or more of polymers introduced into the composite spinneret 18 respectively pass through a metering plate 9, a distribution plate 6 and a lowermost layer distribution plate 5, and are discharged from a spinneret discharge hole 42 of a discharge plate 10 and then cooled by an air stream blown out from the cooling apparatus 17 and provided with a spinning oil, and then the polymers are taken up as islands-in-the-sea composite fibers. In addition, in Fig. 6, the annular cooling apparatus 17 which blows an air stream annually-inwardly is employed; however, a cooling apparatus which blows an air stream from one direction may be used. As a member arranged to the upstream side of the metering plate 9, a flow path or the like used in the existing spin pack 15 may be used, and the member does not need to be exclusive.

[0043] As shown in Fig. 5, the composite spinneret 18 used in an embodiment of the present invention is configured by stacking the metering plate 9, at least one distribution plate 6, the lowermost layer distribution plate 5 and the discharge plate 10 in turn, and particularly the distribution plate 6 and the lowermost layer distribution plate 5 are preferably composed of a thin plate. In this case, the metering plate 9 and the distribution plate 6, and the lowermost layer distribution plate 5 and the discharge plate 10 are positioned so as to be aligned with the center position (core) of the spin pack 18 by a locating pin, stacked, and then may be fixed by a screw or bolt, or may be metal-joined (diffusion-bonded) by thermocompression bonding. Particularly, the distribution plates 6, and the distribution plate 6 and the lowermost layer distribution plate 5 are preferably metal-joined (diffusion-bonded) with each other by thermocompression bonding since a thin plate is used for these plates.

[0044] Here, the thickness of the thin plate is preferably in the range of 0.01 to 0.5 mm, and further suitably 0.05 to 0.3 mm. When the thickness of the thin plate is small, there are advantages that hole diameters, groove widths and hole pitches/groove pitches of processable holes/grooves can be reduced and hence the hole packing density can be increased. Specifically, when a diameter DMIN of the minimum hole among island component discharge holes 1 and a plate thickness BT of the lowermost layer distribution plate 5 in which the minimum hole is formed satisfy the expression (7), the hole packing density can be more increased. Also, when a distribution groove 8 is formed, DMIN is taken as a

groove width, and when the DMIN and a plate thickness BT of the distribution plate 6 satisfy the expression (7), the hole packing density can be more increased as with the above-mentioned case.

$$BT/DMIN \leq 2 \quad \dots (7)$$

[0045] Here, when $BT/DMIN > 2$, as described above, the hole packing density can be more increased; however, further in order to minimize uneven discharge of the island component polymer, the BT and the DMIN more preferably satisfy the expression (7).

[0046] However, when the thicknesses of the distribution plate 6 and the lowermost layer distribution plate 5 are reduced within the range of 0.01 to 0.5 mm, since the strength of the thin plate is deteriorated and bending tends to occur, a type of a polymer capable of being used may be limited in some cases (with a high viscous polymer, a pressure loss is increased and bending occurs). In this case, a whole thickness may be increased by stacking and metal-joining a plurality of thin plates to improve the strength. Further, since the strength per a plate is improved by increasing the thickness of the thin plate, there is an advantage of increasing a type of polymer capable of being used. However, when the plate thickness is too large, hole diameters, groove widths and hole pitches/groove pitches of processable holes/grooves cannot be reduced and hence the hole packing density may not be increased in some cases. In this case, the thickness of the distribution plate having a great number of holes may be reduced, and the thickness of the distribution plate having a smaller number of holes may be increased.

[0047] Then, polymers of the respective components supplied from the metering plate 9 pass through the distribution groove 8 and a distribution hole 7 of the distribution plate 6 formed by stacking at least one plate, and then are discharged from the island component discharge hole 1 for discharging an island component polymer and a sea component discharge hole 4 for discharging a sea component polymer of the lowermost layer distribution plate 5, and thereby, the polymers of the respective components join with each other to form a composite polymer stream. Thereafter, the composite polymer stream passes through a discharge introduction hole 11 and a contracting hole 12 of the discharge plate 10, and is discharged from the spinneret discharge hole 42.

[0048] Here, all of diameters of the island component discharge holes 1 arranged in the lowermost layer distribution plate 5 are preferably the same, and all of diameters of the sea component discharge holes 4 arranged in the lowermost layer distribution plate 5 are preferably the same. This can make the discharge velocities of the island component polymer discharged from the island component discharge hole 1 and the sea component polymer discharged from the sea component discharge hole 4 uniform, and therefore an island component cross section having excellent regularity can be attained. Further, the hole diameter of the island component discharge hole 1 may be different from that of the sea component discharge hole 4, and these hole diameters may be appropriately determined according to the ratio of the island component to the sea component. It is preferred that when the proportion of the island component polymer is high, the hole diameter of the island component discharge hole 1 from which a larger amount of a polymer is discharge is increased, or the hole diameter of the sea component discharge hole 4 from which a smaller amount of a polymer is discharge is decreased so that the discharge velocity (the discharge velocity refers to a value obtained by dividing a discharge flow rate by a cross section area of the island component discharge hole 1 or the sea component discharge hole 4) of the island component polymer discharged from one island component discharge hole 1 is roughly equal to the discharge velocity of the sea component polymer discharged from one sea component discharge hole 4. This makes it possible to significantly stabilize a resulting cross section form of the island component and to maintain the form with high accuracy. The diameters of the island component discharge hole 1 and the sea component discharge hole 4 are preferably in the range of 0.01 to 0.5 mm, and further suitably in the range of 0.05 to 0.3 mm.

[0049] First, a principle of the most important point of the present invention will be described, by which the island component polymer streams can be prevented from joining with one another, and various fiber cross section forms, particularly cross sections with high degree of heteromorphy (in the degree of heteromorphy referred to in the present invention, the degree of heteromorphy is high when a ratio (circumscribed circle/inscribed circle) of the diameter of a circumscribed circle to the diameter of an inscribed circle of a yarn with a heteromorphic cross section is high), can be formed with high accuracy, and this can be achieved at a high hole packing density.

[0050] For example, as shown in Fig. 11, in order to prevent the island component polymer streams from joining with one another to form a heteromorphic cross section, if the arrangement of surrounding one island component discharge hole 1 from six directions with the sea component discharge holes 4 for discharging a sea component polymer is employed, an island polymer discharged from the island component discharge hole 1 is surrounded with sea polymer streams discharged from six sea component discharge holes 4, and therefore, fibers in which the island component has a hexagonal cross section while suppressing joining of neighboring island component polymer streams can be obtained. However, according to findings by the present inventors, in the hexagonal cross section of the obtained fiber, a high degree of heteromorphy cannot be attained since the cross section has an edge portion in contrast to a circular shape;

however an angle of an edge (corner) is large.

[0051] Further, as shown in Fig. 9 and Fig. 10, when the island component discharge hole 1 and the sea component discharge hole 4 are regularly arranged, it is expected on first glance that a fiber, in which an island component has a trigonal cross section or a tetragonal cross section, is obtained; however, according to findings by the present inventors, in fact, the island component polymer streams join with one another between the edge portions of the neighboring island components. According to findings by the present inventors, the reason for this is that in the case where the cross section form of the island component is a circular shape or a cross-section shape with a low degree of heteromorphy (hexagonal cross section, etc.) similar to the circular shape, the island component polymer streams join with one another mainly on a line connecting between the centers of neighboring island component discharge holes 1, whereas, in the cross-section shape with a high degree of heteromorphy having an acute edge (corner) portion, the island component polymer streams join with one another not only on a line connecting between the barycenters of the island component discharge holes 1 but also between the edge portions of the neighboring island components. Moreover, in consideration of production efficiency, it is preferred to increase a ratio of island component polymer, and reduce a ratio of sea component polymer since the sea component polymer is eluted after melt-spinning; however, in this case, the island component polymer streams join with one another more remarkably. That is, according to findings by the present inventors, the island component polymer streams more easily join with one another when the degree of heteromorphy of the cross-section shape of the island component becomes larger, and it becomes more difficult to achieve the high degree of heteromorphy with high production efficiency.

[0052] In order to form a cross-section shape with a high degree of heteromorphy, there is a method in which a plurality of the island component discharge holes 1 are arranged in a close-packed state so as to form a desired shape, and the island polymer streams discharged from the island component discharge holes 1 join with one another. However, according to findings by the present inventors, since a plurality of the island component discharge holes 1 are required in order to form one cross section form of an island component, the number of holes which can be arranged at the composite spinneret is restricted, and consequently, the hole packing density cannot be increased, and there are limitation to formation of a few hundred to a few thousand cross section forms of an island component.

[0053] Examples of other method capable of forming a high degree of heteromorphy include, as an example of a core-sheath type composite spinneret, a method of arranging diagonally four sea component discharge holes 4 around the island component discharge hole 1, as shown in Fig. 12. In this case, the island polymer discharged from the island component discharge hole 1 joins with the sea polymer discharged from the sea component discharge hole 4 to ultimately obtain a throwing star-shaped cross section form. However, according to findings by the present inventors, when the above hole arrangement is applied to an islands-in-the-sea type as-is, as shown in Fig. 12, the island component polymer streams discharged from the neighboring island component discharge holes 1 join with one another, and consequently the throwing star-shaped cross section form cannot be obtained. As described above, the hole arrangement of the lowermost layer distribution plate 5 obtained in the composite spinneret of the core-sheath type (an island component is surrounded with one sea component) cannot be applied directly to the islands-in-the-sea type where the number of the island components is a few hundred to a few thousand.

[0054] Accordingly, it is an extremely important technology to increase the hole packing density, to prevent the island component polymer streams from joining with one another, and to manufacture fibers having highly precise fiber cross section forms. Thus, the present inventors have made earnest investigations concerning the above-mentioned problems to which no consideration is given to conventional technologies, and consequently they have found an innovative technology of the present invention.

[0055] That is, the lowermost layer distribution plate 5 of an embodiment of the present invention has n island component discharge holes 1 forming virtual polygonal shapes centered on a virtual center O on a virtual circular line $C1$ with a radius $R1$, n sea component discharge holes 4 arranged on a virtual circular line $C2$ with a radius $R2$, and n virtual group centers P on a virtual circular line $C3$ with a radius $R3$, n island component discharge holes 1 centered on the virtual group center P and arranged on a virtual circular line $C5$ with a radius $R1$, and n sea component discharge holes 4 centered on the virtual group center P and arranged on a virtual circular line $C6$ with a radius $R2$ are collectively referred to as a hole group; and a plurality of the hole groups are arranged. When n is 3, 4 or 6, a plurality of hole groups can be periodically arranged, a density of arrangement of the hole group can be increased, and hence the hole packing density can be increased by arranging the discharge holes so as to have a similar hole arrangement also when the virtual group center P adjacent to the virtual center O is taken as the virtual center O . Further, when n is, for example, 5 other than 3, 4 and 6, the hole group cannot be periodically arranged; however, a composite fiber having a plurality of cross sections of an island component can be obtained by arranging the hole group at regular intervals, and arranging the sea component discharge holes 4 between the hole groups.

[0056] Herein, there is shown an arrangement pattern of the island component discharge holes 1 and the sea component discharge holes 4 which form an island component having a Y-shaped cross section when n is 3, form an island component having a cross-type cross section when n is 4, and form an island component having a so-called asteroid-type cross section, in which projections are formed at the edge portions of a hexagonal shape, when n is 6. When n is

a number other than the above-mentioned numbers, a cross section has a shape in which the edge portions of an n-gonal cross section have projections. Further, when n is a small number, a cross-section shape with a high degree of heteromorphy can be attained.

[0057] As a pattern in which n is 3, there is a pattern as shown in Fig. 1, in which a virtual polygonal shape is formed by line segments connecting the centers of three neighboring island component discharge holes 1a, 1b and 1c, the barycenter of the virtual polygonal shape is taken as the virtual center O, and a center distance between the virtual center O and the island component discharge hole 1 is taken as the radius R1, and then a center distance between the virtual center O and the nearest sea component discharge hole 4 is taken as the radius R2, and then the barycenter of a hole group of the island component discharge holes 1 forming three virtual polygonal shapes, which are positioned on an outer circumference of the virtual circular line C2 and are closest to the virtual center O, is taken as the virtual group center P, and a center distance between the virtual center O and the virtual group center P is taken as the radius R3, R1, R2 and R3 satisfy the following expression (1) and (2), and each discharge hole is arranged according to the conditions (3) and (4). Here, in the expression (1), the fourth place of decimals is rounded.

(1)

$$R1 \leq R2 \cdot R \cos(180/n \text{ [degree]}) \quad \text{expression (1)}$$

(2)

$$R3 = 2 \cdot R2 \quad \text{expression (2)}$$

(3) C1, C5: n island component discharge holes are arranged equally at a center angle of 360/n degrees

C2, C6: n sea component discharge holes are arranged equally at a center angle of 360/n degrees

C3: n virtual group centers are arranged equally at a center angle of 360/n degrees

θ1: a phase angle between two discharge holes, one arranged on C1 and the other arranged on C2, and one arranged on C5 and the other arranged on C6, is 180/n degrees

θ2: a phase angle between the discharge hole on C2 and the virtual group center on C3 is 0 degree,

(4) a sea component discharge hole is arranged at a point of intersection of a line segment connecting the virtual center O and the virtual group center P, the virtual circular line C2, and the virtual circular line C6

[0058] Accordingly, island component polymer streams discharged from the three island component discharge holes 1b and 1c on the virtual circular line C1 join with one another, and therefore depressions are formed at sides of a triangular cross section and simultaneously island component polymer streams are prevented from joining with one another at a location between the hole group of the island component discharge holes 1 on the virtual circular line C1 and the hole group of the island component discharge holes 1 on the virtual circular line C3, where stream joining tends to occur most easily. Thus, it is possible to obtain fibers in which the island component has a uniform and highly heteromorphic cross section (Y-shaped cross section).

[0059] To explain the above-mentioned principle of the present invention along a flow pattern of the polymer, both the island component polymer and the sea component polymer are discharged all together toward the discharge introduction hole 11 located the downstream side of the lowermost layer distribution plate 5, flow in the direction of the polymer spinning path while expanding their width in the direction perpendicular to the direction of the polymer spinning path, and join with one another to form a composite polymer stream. At this time, in order to prevent island component polymer streams discharged from the hole group of the island component discharge holes 1b and 1c centered on the virtual center O and the hole group of the three island component discharge holes 1 centered on the virtual group center P from joining with one another, it is effective to interpose a sea component polymer which physically isolates island component polymer streams from each other, and a sea component polymer discharged from the sea component discharge hole 4 on the virtual circular line C2 plays this role. In order to achieve this, the radius R2 of the virtual circular line C2 forming the hole group of the sea component discharge holes 4 may be determined so as to satisfy the expressions (1) and (2) in the case where the sea component discharge holes 4 are arranged between the hole group (island component discharge holes 1b, 1c) of the island component discharge holes 1 arranged on the virtual circular line C1 and the hole group of the island component discharge holes 1 arranged on the virtual circular line C5.

[0060] Another important point of the present invention is that the island component polymer streams discharged from the three island component discharge holes 1b and 1c join with one another to form one heteromorphic cross section of the island component. When the island component polymer streams discharged from the three island component

discharge holes 1b and 1c join with one another, a triangular cross section whose apexes are roughly the island component discharge holes 1 is formed. In this time, the sea component polymer streams are discharged from the sea component discharge holes 4 to spaces between the island component discharge holes 1a and 1b, and the island component discharge holes 1b and 1c, and the island component discharge holes 1c and and a part of the sea component polymer penetrates into a space between the island component polymer streams to join with each other, so that depressions can be formed at sides of a triangular cross section, and consequently a cross section form with a high degree of heteromorphy (Y-shaped cross section) can be formed.

[0061] That is, as an arrangement of discharge holes for achieving formation of the Y-shaped cross section, the island component discharge holes 1b and 1c centered on the virtual center O and arranged on the virtual circular line C1 are arranged equally at a center angle of 120 degrees, the sea component discharge holes 4 on the virtual circular line C2 are arranged equally at a center angle of 120 degrees with a phase angle of 60 degrees, the three island component discharge holes 1 centered on the virtual group center P and arranged on the virtual circular line C5 with a radius R1 are arranged equally at a center angle of 120 degrees as with the pattern of hole arrangement centered on the virtual center O, and the sea component discharge holes 4 are arranged on the virtual circular line C6 with a radius R2 equally at a center angle of 120 degrees with a phase angle of 60 degrees. Then, a sea component discharge hole 4 is arranged at a point of intersection of a line segment connecting the center points of the virtual center O and the virtual group center P, the virtual circular line C2, and the virtual circular line C6.

[0062] Here, in the case where $R1 > R2 \cdot \cos(60 [\text{degrees}])$ in the expression (1) (the case where n is 3), the island component polymer streams discharged from the island component discharge holes 1 arranged on the virtual circular line C1 may join with the island component polymer streams discharged from the island component discharge holes 1 arranged on the virtual circular line C5 in some cases. Further, when R1 in the expression (1) is reduced, the above-mentioned joining between the island component polymer streams can be suppressed; however, the degree of heteromorphy of the resulting cross-section shape of an island component is lowered, and therefore R1 may be determined according to a desired cross section form. Here, with respect to a lower limit capable of reducing R1, it is preferred that a radius of the island component discharge hole 1, denoted by r, satisfies the relationship of $R1 \geq \sqrt{3} \cdot r$, and when R1 is in this range, a yarn with a Y-shaped cross section having a high degree of heteromorphy can be formed.

[0063] A hole arrangement pattern of forming the yarn with a Y-shaped cross section is characterized in that a ratio of the island component polymer can be increased, and fibers can be obtained in which the island component polymer streams do not join with one another even when the ratio of the island component polymer is as high as 70% or more and the island component has a uniform Y-shaped cross section. Moreover, since many islands can be arranged to increase the island packing density, this arrangement pattern is suitable for obtaining a composite fiber having a fiber diameter of nano-order size such as a nanofiber.

[0064] Next, as shown in Fig. 2, an arrangement pattern in which the island component has a cross-type cross section includes a pattern in which n is 4. This is a pattern in which four island component discharge holes 1 centered on the virtual center O and arranged on the virtual circular line C1 with a radius R1 are arranged equally at a center angle of 90 degrees, four sea component discharge holes 4 on the virtual circular line C2 with a radius R2 are arranged equally at a center angle of 90 degrees with a phase angle of 45 degrees, four island component discharge holes 1 centered on the virtual group center P and arranged on the virtual circular line C5 with a radius R1 are arranged equally at a center angle of 90 degrees, four sea component discharge holes 4 on the virtual circular line C6 with a radius R2 are arranged equally at a center angle of 90 degrees with a phase angle of 45 degrees, and sea component discharge holes 4 are arranged at points of intersection of line segments connecting the center points of the virtual center O and the virtual group center P, the virtual circular line C2, and the virtual circular lines C6. A hole arrangement pattern of forming a yarn with the cross-type cross section is characterized by arranging the sea component discharge holes 4 on the virtual circular line C2 between the hole group of the island component discharge holes 1 on the virtual circular line C1 and the hole group of the island component discharge holes 1 on the virtual circular line C5 so as to satisfy the expression (5) which is a narrower condition than the expression (1).

(5)

$$R1 \leq R2/2$$

expression (5)

[0065] Here, with respect to a lower limit capable of reducing R1, it is preferred that a radius of the island component discharge holes 1, denoted by r, satisfies the relationship of $R1 \geq 1.5 \cdot \sqrt{2} \cdot r$. By employing such an arrangement, it is possible to prevent the island component polymer streams discharged from the hole group of the four island component discharge holes 1 on the virtual circular line C1 and the hole group of the four island component discharge holes 1 on the virtual circular line C5 from joining with one another, and to attain a fiber having a high degree of heteromorphy (cross-type cross section) at a ratio of an island component polymer of 50% or more.

[0066] Next, as shown in Fig. 3, an arrangement pattern in which the island component has an asteroid-type cross section includes a pattern in which n is 6. This is a pattern in which six island component discharge holes 1 centered on the virtual center O and arranged on the virtual circular line $C1$ with a radius $R1$ are arranged equally at a center angle of 60 degrees, six sea component discharge holes 4 on the virtual circular line $C2$ with a radius $R2$ are arranged equally at a center angle of 60 degrees with a phase angle of 30 degrees, six island component discharge holes 1 centered on the virtual group center P and arranged on the virtual circular line $C5$ with a radius $R1$ are arranged equally at a center angle of 60 degrees, six sea component discharge holes 4 on the virtual circular line $C6$ with a radius $R2$ are arranged equally at a center angle of 60 degrees with a phase angle of 30 degrees, and sea component discharge holes 4 are arranged at points of intersection of line segment connecting center points of the virtual center O and the virtual group center P , the virtual circular line $C2$, and the virtual circular lines $C6$. A hole arrangement pattern of forming a yarn with the asteroid-type cross section is characterized by arranging the sea component discharge holes 4 on the virtual circular line $C2$ between the hole group of the island component discharge holes 1 on the virtual circular line $C1$ and the hole group of the island component discharge holes 1 on the virtual circular line $C5$ so as to satisfy the expression (6) which is a narrower condition than the expression (1).

$$R1 \leq R2 \cdot 3\sqrt{3}/8 \quad \text{expression (6)}$$

[0067] Further, with respect to a lower limit capable of reducing $R1$, it is preferred that a radius of the island component discharge hole 1, denoted by r , satisfies the relationship of $R1 \geq 3 \cdot r$. By employing such an arrangement, it is possible to prevent the island component polymer streams discharged from the hole group of the six island component discharge holes 1 on the virtual circular line $C1$ and the hole group of the six island component discharge holes 1 on the virtual circular line $C5$ from joining with one another, and to attain a fiber having a high degree of heteromorphy (asteroid-type cross section) particularly at a ratio of an island component polymer of 50% or more.

[0068] As described above, it comes to find the range of $R1$ in which a cross section form with a high degree of heteromorphy can be achieved at a high ratio of an island component polymer while preventing the island component polymer streams from joining with one another according to the number n of discharge holes since the range of the radius $R1$ of the virtual circular line $C1$ is narrowed relative to the radius $R2$ of the virtual circular line $C2$ as the number n of the holes is increased.

[0069] Further, as shown in Fig. 8, the stacked plural distribution plates 6 are configured in such a way that the number of the distribution holes 7 formed in the distribution plate 6 increases toward the downstream side in the direction of the polymer spinning path, and the distribution groove 8 is formed so as to communicate the distribution hole 7 positioned to the upstream side in the direction of the polymer spinning path with the distribution hole 7 positioned to the downstream side in the direction of the polymer spinning path by alternately stacking a distribution plate 6 in which a distribution hole 7 guiding a polymer in the direction of the polymer spinning path is formed, and a distribution plate 6 in which the distribution groove 8 guiding a polymer in the direction perpendicular to the direction of the polymer spinning path is formed.

[0070] Then, a flow through path of a polymer of a sequential branch system is formed, in which one distribution groove 8 in communication with a position at the downstream side in the direction of the polymer spinning path is formed per one distribution hole 7 and a plurality (two in Fig. 8) of the distribution holes 7 in communication with an end of the distribution groove 8 are formed.

[0071] In the flow through path of a polymer of a sequential branch system, the lengths of paths from the distribution hole 7 or the distribution groove 8 of the distribution plate 6 positioned at the highest end in the direction of the polymer spinning path to the island component discharge holes 1 of the lowermost layer distribution plate 5 are equal. Also, the flow through path of a polymer has a structure in which hole diameters of the distribution holes 7, and widths, depths and lengths of the distribution grooves 8 are equalized in each distribution plate 6 of the stacked plural distribution plates 6. In this case, since a flow rate of a polymer passing through the distribution groove 8 or the distribution hole 7 is increased sequentially to increase a flow-path pressure loss as the number of sequential branch flow paths is decreased toward the upstream side of the direction of the polymer spinning path, it is preferred that in conformity with this, a hole diameter of the distribution hole 7 or a width or depth of the distribution groove 8 is increased sequentially to suppress an increase in the flow-path pressure loss. Further, as shown in Fig. 8, the flow through path of a polymer of a sequential branch system of two-way branch is suitable, in which one distribution groove 8 is communicated with two distribution holes 7 at the downstream side in the direction of the polymer spinning path; however, the sequential branch system is not limited to this. In the case where the distribution groove 8 is communicated with two or more distribution holes 7 (the case of a flow path of a sequential branch system of two-way or more branch), it is preferred to equalize flow-path pressure losses of the flow through paths of the respective polymers by respectively equalizing groove lengths, groove widths and groove depths of the distribution groove 8 from the distribution hole 7 on the upstream side to the distribution

hole 7 on the downstream side in the direction of the polymer spinning path. Further, by disposing the distribution hole 7 at an end part of the distribution groove 8, this structure has an advantage of eliminating abnormal retention of a polymer, and uniformly distributing and precisely controlling a polymer.

[0072] Here, examples of other structures, in which flow-path pressure losses of the flow through paths of the respective polymers are equalized, include structures with respect to a plurality of polymer flow through paths composed of the distribution hole 7 and the distribution groove 8 within the distribution plate 6, a diameter of the distribution hole 6 in a path in which a length of the polymer flow through path from an upper end of the distribution plate 6 to the lowermost layer distribution plate 5 is comparatively long is larger than a diameter of the distribution hole 6 in a path in which a length of the polymer flow through path is comparatively short, and thereby, it becomes possible to equalize flow-path pressure losses. Further, examples of other structures, in which flow-path pressure losses of the flow through paths of the respective polymers are equalized, include structures in which a diameter of the island component discharge hole 1 of the lowermost layer distribution plate 5 is adjusted so that flow-path pressure losses are equalized in the respective flow paths of the distribution plate 6 on the upstream side thereof. Specifically, it becomes possible to equalize flow-path pressure losses by increasing a diameter of the island component discharge hole 1 in communication with a flow path having a large flow-path pressure loss, and decreasing a diameter of the island component discharge hole 1 in communication with a flow path having a smaller flow-path pressure loss on the upstream side.

[0073] Next, respective members and shapes of the respective members common to the composite spinnerets 18 of embodiments of the present invention shown in Figs. 1 to 3 and Figs. 5 to 8 will be described in detail.

[0074] A shape of the composite spinneret 18 in the present invention is not limited to a circular shape, and may be a tetragonal shape or a polygonal shape. Further, an array of the spinneret discharge holes 42 in the composite spinneret 18 may be appropriately determined according to the number of the islands-in-the-sea composite fibers, the number of lines of yarn, and the cooling apparatus 17. With respect to the cooling apparatus 17, for an annular cooling apparatus, the spinneret discharge holes 42 may be arrayed in an annular form over one column or plural columns, and for a cooling apparatus of one way, the spinneret discharge holes 42 may be arrayed in zigzag alignment. A cross section of the spinneret discharge hole 42 in the direction perpendicular to the direction of the polymer spinning path is not limited to a circular shape, and may be a cross section other than the circular shape or a hollow cross section. However, when a cross section other than the circular shape is employed, a length of the spinneret discharge hole 42 is preferably lengthened in order to ensure the polymer metering capability.

[0075] Further, in the island component discharge hole 1 in the present invention, a cross section in the direction perpendicular to the direction of the polymer spinning path is not limited to a circular shape, and may be a cross section other than the circular shape or a hollow cross section. In the case, all shapes of the island component discharge holes 1 arranged in the lowermost layer distribution plate 5 are preferably the same. In the case of a cross section other than a circular shape, when in order to impart a desired shape to the island component, the island component discharge hole 1 is previously shaped to a similar shape, so that fibers with a heteromorphic cross section are easily obtained. Further, in fibers in which an island component has a heteromorphic cross section, it becomes easy to form a corner part more sharply (a curvature radius is easily reduced). However, when the island component discharge hole 1 has a cross section other than a circular shape, it is preferred that by arranging the distribution hole 7 with a circular cross section in communication with the island component discharge hole 1 immediately above the island component discharge hole 1, the metering capability of a polymer is ensured by the distribution hole 7 with a circular cross section, and then the polymer is discharged by the island component discharge hole 1 having a cross section other than a circular shape.

[0076] The discharge introduction hole 11 in the present invention can mitigate a difference in flow velocities immediately after the island component polymer stream joins with the sea component polymer stream by providing a certain entrance section from a bottom surface of the lowermost layer distribution plate 5 in the direction of the polymer spinning path to stabilize a composite polymer stream. Further, a diameter of the discharge introduction hole 11 is preferably configured to be larger than an outer diameter of a virtual circle 19 of a group of discharge holes of the island component discharge holes 1 and the sea component discharge holes 4 arranged in the lowermost layer distribution plate 5, and is preferably configured in such a way that a ratio of a cross section area of the virtual circle 19 to a cross section area of the discharge introduction hole 11 is as small as possible. Accordingly, each polymer stream discharged from the lowermost layer distribution plate 5 is prevented from expanding in width and a composite polymer stream can be stabilized.

[0077] Further, in the contracting hole 12 in the present invention, it is possible to reduce a size of the composite spinneret 18 and inhibit unstable phenomena such as draw resonance of the composite polymer stream and supply the composite polymer stream stably by setting a taper angle α , of a flow path from the discharge introduction hole 11 to the spinneret discharge hole 42 to the range of 50° to 90°.

[0078] The island component discharge hole 1, the sea component discharge hole 4 and the distribution hole 7 in the present invention preferably have a hole cross section area which is constant in the direction of the polymer spinning path; however, the hole cross section area may gradually decrease or may increase, or may gradually decrease and increase. The reason for this is that in the distribution plate 6 and the lowermost layer distribution plate 5 in the present invention, since hole processing is mainly performed by using etching processing, the hole cross section area may not

become constant in some cases in processing minute holes, and in this case, processing conditions and the like may be appropriately made to be proper.

[0079] Further, the number of the lowermost layer distribution plates 5 in the present invention may be one; however, a plurality of the lowermost layer distribution plates 5 may be stacked. In this case, one lowermost layer distribution plate 5 cannot achieve the polymer metering capability of the island component discharge holes 1 and the sea component discharge holes 4, and in the case where a fiber form varies with time, the metering capability of a polymer can be ensured by stacking a plurality of the lowermost layer distribution plates 5.

[0080] Further, in one distribution plate 6 of the present invention, the distribution hole 7 may be arranged on the upstream side of the distribution plate 6, and the distribution groove 8 (downstream side) may be arranged in communication with the distribution hole 7, or the distribution groove 8 may be arranged on the upstream side of the distribution plate 6, and the distribution hole 7 (downstream side) may be arranged in communication with the distribution groove 8. As described above, the polymer can be distributed by communicating the distribution hole 7 with the distribution groove 8 and repeating the communication once or more.

[0081] Here, in order to increase the hole packing density of the island component discharge holes 1 of the lowermost layer distribution plate 5, that is, in order to reduce a gap between the island component discharge hole 1 on the virtual circular line C1 or the virtual circular line C5 and the sea component discharge hole 4 on the virtual circular line C2 or the virtual circular line C6, the distribution plate 6 and the lowermost layer distribution plate 5 of the present invention have a stack structure of thin plates. The distribution hole 7 arranged at the distribution plate 6 distributes a polymer mainly in the direction of the polymer spinning path, and the distribution groove 8 distributes a polymer mainly in a direction perpendicular to the direction of the polymer spinning path. By alternately stacking the distribution plate 6 having the distribution hole 7 arranged and the distribution plate 6 having the distribution groove 8 arranged, a polymer can be freely and easily distributed in a direction of the fiber cross section. By the use of this, the island component discharge holes 1 and the sea component discharge holes 4 can be arranged in an extremely narrow region.

[0082] Next, a method of manufacturing a composite fiber common to the composite spinnerets 18 of embodiments of the present invention shown in Figs. 1, 2, 3, 5 and 6 will be described in detail.

[0083] In the method of manufacturing a composite fiber of the present invention, the composite spinneret 18 of the present invention may be used in a publicly known composite spinning machine. For example, in the case of melt spinning, as a spinning temperature, a temperature at which principally a polymer with a high melting point or high viscosity of two types or more of polymers exhibits flowability is selected. As the temperature exhibiting flowability, although depending on a molecular weight, a melting point of the polymer is a standard, and the spinning temperature may be set to melting point + 60°C or lower. When the spinning temperature is melting point + 60°C or lower, a reduction in molecular weight is suppressed without any thermal decomposition or the like of the polymer in a spinning head or a spinning pack, and therefore, it is preferred. A spinning velocity varies depending on the properties of the polymer and an object of the composite fibers, and can be set to about 500 to 6000 m/min. Particularly, when high mechanical properties are required in industrial material applications, preferably, a high molecular weight polymer is used and spun at a spinning velocity of 500 to 2000 m/min, and thereafter the resultant is stretched at a high ratio. In stretching, it is preferred that a temperature at which a polymer can be softened such as the glass transition temperature of the polymer is used as a standard, and a pre-heating temperature is appropriately set. As an upper limit of the pre-heating temperature, a temperature is preferably set at which fluctuations of a yarn route due to self-extension of a fiber does not occur in a pre-heating process. For example, in the case of PET in which the glass transition temperature thereof is about 70°C, the pre-heating temperature is generally set to about 80 to 95°C.

[0084] A discharge velocity ratio between polymers of the respective components discharged from the island component discharge holes 1 and the sea component discharge holes 4 of the present invention is preferably controlled by a discharge amount, a hole diameter and the number of holes. With respect to the range of the discharge velocity, when a discharge velocity of the island component polymer per a single hole is denoted by V_a and a discharge velocity of the sea component polymer is denoted by V_b , a ratio thereof (V_a/V_b or V_b/V_a) is preferably in the range of 0.05 to 20, and more preferably in the range of 0.1 to 10, and when the ratio is in this range, since a polymer discharged from the lowermost layer distribution plate 5, as a laminar flow, is guided to the contracting hole 12 through the discharge introduction hole 11, a cross section form is significantly stabilized and can be maintained accurately.

[0085] When a melt viscosity ratio of the polymer used in the present invention is less than 2.0, a composite polymer stream can be stably formed. When the melt viscosity ratio is 2.0 or more, a composite polymer stream becomes unstable when the island component polymer joins with the sea component polymer, and uneven thickness of the resulting fiber cross section may occur in a running direction in some cases.

[0086] Next, as a method of preparing the distribution plate 6 and the lowermost layer distribution plate 5 of the present invention, etching such as fine processing by transferring a pattern to a thin plate and chemically treating the transferred pattern, which is generally used for processing electric/electronic parts, is suitable. Here, etching processing is a processing method in which a thin plate is etched (dissolved/chemically cut) with the use of a chemical reaction/corrosive action by chemicals such as an etching solution, and in this method, an objective processing shape is subjected to anti-corrosion

treatment by masking (required partial surface is partially coated/protected), and an unnecessary portion is removed with a corrosive agent such as an etching solution, and thereby, an objective processing shape can be obtained with significantly high precision. A common corrosive agent is sufficient for the corrosive agent such as an etching solution. For example, nitric acid, sulfuric acid and hydrochloric acid can be used. In this processing method, it is not necessary to consider distortion of a material to be processed, there is no limitation on a lower limit of the thickness of the material to be processed as compared with the above-mentioned other processing methods, and the joining groove 8, the distribution hole 7, the island component discharge hole 1 or the sea component discharge hole 4, referred to in the present invention, can be bored in an extremely thin metal plate. Further, since the thicknesses per one of the distribution plate 6 and the lowermost layer distribution plate 5 respectively prepared by etching processing can be reduced, even when plural plates are stacked, there is little effect on the overall thickness of the composite spinneret 18, and it is unnecessary that another pack member is added newly according to composite fibers with a desired cross section form. In other words, the cross section form can be altered by replacing only the distribution plate 6 and the lowermost layer distribution plate 5, and therefore this is a preferable feature recently in the progress of high performance and various kinds of fiber products. As other methods of preparing the distribution plate and the lowermost layer distribution plate, it is possible to employ a method of using a turning machine, machining, press, laser machining and the like which are drilling or metal precision processing used in conventional spinneret preparation. However, since the processing has a limitation on a lower limit of the thickness of a plate to be processed from the viewpoint of suppressing distortion of the processed materials, it is necessary to consider the thickness of the distribution plate 6 for applying the processing to the composite spinneret of the present invention formed by stacking a plurality of distribution plates.

[0087] Next, the fibers obtained by the composite spinneret of the present invention means fibers formed by combining two types or more of polymers into one, and refer to fibers in which two types or more of polymers exist in the form of islands-in-the-sea or the like at the transverse section of the fiber. Here, needless to say, two types or more of polymers referred to in the present invention includes that two types or more of polymers having different molecular structures such as polyester, polyamide, polyphenylenesulfide, polyolefin, polyethylene, and polypropylene are used; however, this also includes that within a range not impairing the stability of yarn-making, the addition amounts of delustering agents such as titanium dioxide; various functional particles such as silicon oxide, kaolin, anticoloring agent, stabilizer, antioxidant agent, deodorant, flame retarder, anti-yarn friction agent, color pigment and surface modifier; and additives or particles of organic compounds are different, and that molecular weights thereof are different, and that copolymerization thereof is performed, and the like.

[0088] A cross section of a single yarn of fibers obtained by the composite spinneret 18 of the present invention may have a shape such as a triangle shape or a flat shape other than a circular shape in addition to a circular shape, or may be hollow. Further, the present invention is an extremely versatile invention, and it is not particularly limited by a single yarn fineness of the composite fibers, nor particularly limited by the number of single yarns of the composite fibers, nor particularly limited by the number of lines of yarns of the composite fibers, and may be one line of yarn or multi lines of two or more lines of yarns.

[0089] The islands-in-the-sea composite fiber obtained by the composite spinneret of the present invention refers to, as shown in Figs. 4 (a), 4(b) and 4(c), a fiber in which different two types or more of polymers form an islands-in-the-sea structure (the islands-in-the-sea structure referred to herein is a structure in which an island portion composed of an island component polymer 13 is separated into plural portions by a sea portion composed of a sea component polymer 20) in the cross section perpendicular to the direction of a fiber axis. It is possible to obtain an islands-in-the-sea composite fiber which has a Y-shaped cross section shown in Fig. 4(a) by employing the arrangement of the island component discharge hole 1 and the sea component discharge hole 4 as shown in Fig. 1, has a cross-type cross section shown in Fig. 4(b) by employing the hole arrangement as shown in Fig. 2, and has an asteroid-type cross section shown in Fig. 4(c) by employing the hole arrangement as shown in Fig. 3.

[0090] The number of islands achieved by using the composite spinneret of the present invention can be theoretically from 2 to infinite as far as a space allows; however, a substantially applicable and preferable range is 2 to 10000. A range where the superiority of the composite spinneret of the present invention is attained is more preferably 100 to 10000.

[0091] Further, in the present invention, the hole packing density is preferably 0.5 hole/mm² or more. When the hole packing density is 0.5 hole/mm² or more, the difference from conventional composite spinneret technology is more apparent. Within a range where the present inventors have investigated concerning the hole packing density, a hole packing density of 0.5 to 20 hole/mm² can be performed. From the viewpoint of the hole packing density, it is preferably in a range of 1 to 20 hole/mm² as the range where the superiority of the composite spinneret of the present invention can be achieved.

[0092] The islands-in-the-sea composite fibers in the present invention, by eluting a sea component polymer 20, can prepare highly uniform filament type nanofibers having a circumscribing fiber diameter of 10 to 1000 nm and a fiber diameter CV% of 0 to 30% which represents fiber diameter variation, as highly reduced extremely ultrafine heteromorphic fibers unavailable from spinning of a single component. This filament type nanofibers can be suitably used for finish processing an aluminum alloy substrate or a glass substrate used for magnetic recording disks with ultra high precision

by forming the fibers into a sheet. Further, as other applications, sheet-like products can be prepared, in which a part of islands are made to join together intentionally to control a fiber diameter distribution freely.

[0093] AS described above, composite forms which can be manufactured by the composite spinneret 18 of the present invention have been described by way of examples of conventionally known cross section forms; however, since in the composite spinneret 18 of the present invention, the cross section form can be arbitrarily controlled, a free form can be prepared without limiting to the above-mentioned forms.

[0094] The strength of the composite fiber of the present invention is preferably 2 cN/dtex or more, and preferably 5 cN/dtex or more in consideration of mechanical properties required in industrial material applications. A practical upper limit of the strength is 20 cN/dtex. An elongation is preferably set to 2 to 60% for stretched yarns, and 2 to 25% for an industrial material field in which particularly high strength is required, and 25 to 60% for clothing. The composite fiber of the present invention can be formed into multipurpose fiber products such as fiber take-up package, tow, cut fiber, cotton, fiber ball, cord, pile, textile, nonwoven fabric, paper and liquid dispersion.

Example

[0095] The effects of the composite spinneret of the present embodiment will be specifically described by way of Examples.

(1) Precipitation of Island Component from Islands-in-the-sea Composite Fiber

[0096] In order to precipitate an island component from islands-in-the-sea composite fibers, the islands-in-the-sea composite fibers were immersed in a solution in which a sea component of an easy-to-elute component can be eluted to remove the sea component to obtain multifilaments of the island component of a hard-to elute component. When the easy-to-elute component is copolymerized PET formed by copolymerization of 5-sodium sulfoisophthalic acid and the like, polylactic acid (PLA) or the like, an alkali aqueous solution such as sodium hydroxide aqueous solution was used. Since the alkali aqueous solution can accelerate the progress of hydrolysis when it is heated to 50°C or higher, if a fluid dyeing machine or the like is used for treatment, a large amount can be treated at a time.

(2) Fiber Diameter of Multifilaments and Fiber Diameter Variation of Multifilaments (CV%)

[0097] The obtained multifilaments composed of ultrafine fibers were embedded with an epoxy resin, and the embedded sample was frozen by Cryosectioning System FC•4E manufactured by Reichert, and the frozen sample was cut by Reichert-Nissei Ultracut N (ultramicrotome) equipped with a diamond knife, and the cut surfaces were photographed at a magnification of 5000 times by using VE-7800 scanning electron microscope (SEM) manufactured by KEYENCE CORPORATION. From the obtained photographs, 150 ultrafine fibers selected at random were sampled, and all circumscribed-circle diameters (fiber diameters) were measured from the photographs using image processing software (WINROOF), and an average fiber diameter and a fiber diameter standard deviation were determined. Herein, the circumscribed-circle refers to a broken line 14 in Fig. 4 (a). Using these results, the fiber diameter CV% (coefficient of variation) was calculated based on the following formula. All the above values were measured on photographs of three locations to determine an average value of three locations, and measured to the first place of decimals in a unit of nm and obtained by rounding the first place of decimals.

$$\text{Fiber diameter variation (CV\%)} = (\text{fiber diameter standard deviation} / \text{average fiber diameter}) \times 100$$

(3) Degree of Heteromorphy and Variation of Degree of Heteromorphy (CV%)

[0098] In the same manner as in the "Fiber Diameter of Multifilaments and Fiber Diameter Variation of Multifilaments" described above, a cross section of the multifilament was photographed. From the resulting image, a diameter of a complete circle circumscribing the cut cross section was taken as a circumscribed-circle diameter (fiber diameter) and a diameter of a complete circle inscribing the cut cross section was taken as an inscribed-circle diameter, and the degree of heteromorphy was determined by calculating the following expression: degree of heteromorphy = circumscribed-circle diameter/inscribed-circle diameter, to the third place of decimals, and rounding the third place of decimals of the calculated value as the degree of heteromorphy. Herein, the inscribed-circle refers to a broken line 19 in Fig. 4 (a). The degree of heteromorphy was measured with 150 ultrafine fibers sampled at random from the same image, and a variation of degree of heteromorphy (CV% (coefficient of variation)) was calculated based on the following formula from the average value

and standard deviation of the degree of heteromorphy. The variation of the degree of heteromorphy is determined by rounding the second place of decimals.

$$\text{Variation of degree of heteromorphy (CV\%)} = (\text{standard deviation of degree of heteromorphy} / \text{average degree of heteromorphy}) \times 100 (\%)$$

(4) Fineness

[0099] The islands-in-the-sea composite fibers were circularly knitted, and 99% or more of the easy-to-solve component in the knitted fabric was removed by immersing the composite fiber in a 3 wt% sodium hydroxide aqueous solution (80°C, bath ratio 1:100), and then multifilaments composed of ultrafine fibers were drawn out by releasing knitted fibers, and 1 m of the multifilament was weighed and was multiplied by 10000 to determine fineness. This determination was repeated 10 times, and the second place of decimals of the simple average value was rounded to determine the fineness.

(5) Melt Viscosity of Polymer

[0100] A polymer in a chip shape was dried to a water content of 200 ppm or less by a vacuum drying machine, and the melt viscosity was measured using "Capillograph 1B" manufactured by Toyo Seiki Seisaku-sho, Ltd., while stepwisely changing the strain rate. In addition, the measurement temperature was the same as the spinning temperature, and each Example or Comparative Example describes a melt viscosity at 1216/s. Incidentally, the measurement was started at 5 minutes after charging a sample into a heating furnace, and it was performed in a nitrogen atmosphere.

[Example 1]

[0101] Polyethylene terephthalate (PET, melt viscosity: 120 Pa·s) having an intrinsic viscosity (IV) of 0.63 dl/g as an island component and PET copolymerized with 5.0 mol% 5-sodium sulfoisophthalic acid (copolymerized PET, melt viscosity: 140 Pa·s) having an IV of 0.58 dl/g as a sea component polymer were separately melted at 290°C, then metered and made to flow into a spin pack including the composite spinneret of the present embodiment shown in Fig. 6, and islands-in-the-sea composite polymer streams were discharged from discharge holes of the spinneret. In addition, 700 island component discharge holes per one discharge introduction hole were holed at equal intervals in a lowermost layer distribution plate for island component polymers. A ratio between the sea component and the island component was set to 30/70, and the discharged composite polymer streams were cooled/solidified, and then provided with a spinning oil, and wound at a spinning speed of 1500 m/min, to obtain non-stretched fibers of 110 dtex-15 filaments (discharged amount of a single hole 2.25 g/min). The wound non-stretched fibers were drawn by 3.0 times between rollers heated to 90°C and 130°C to form islands-in-the-sea composite fibers of 50 dtex-15 filaments, and 99% or more of the sea component was dissolved by the above-mentioned method to obtain 11000 multifilaments.

[0102] Here, in the composite spinneret used in Example 1, a distribution plate having holed distribution holes and a distribution plate having cut distribution grooves are alternately stacked, and at the downstream side of the distribution plate, a lowermost layer distribution plate shown in Fig. 1 is stacked thereon. The distribution plate has a thickness of 0.1 mm, and holes and grooves are holed and cut under the conditions of a hole diameter of 0.2 mm, a groove width of 0.3 mm, a groove depth of 0.1 mm and a minimum hole pitch of 0.4 mm. The lowermost layer distribution plate has a thickness of 0.1 mm, and island component discharge holes and sea component discharge holes respectively having a hole diameter of 0.2 mm are arranged on virtual circular lines C1 and C5 with a radius R1 of 0.22 mm and virtual circular lines C2 and C6 with a radius R2 of 0.44 mm so that n is 3 according to the expressions (1), (2) and the condition (3). As described in Table 1, the island component had a Y-shaped cross section, the island component polymer streams did not join with one another, fiber diameter variation was 5.3%, the degree of heteromorphy was 2.3, and variation of the degree of heteromorphy was 4.5%, and a fiber diameter of the multifilament was 870 nm.

[Example 2]

[0103] As shown in Fig. 2, the same composite spinneret as in Example 1 was used except for changing the arrangement of the island component discharge holes and the sea component discharge holes of the lowermost layer distribution plate so that n is 4 according to the expressions (1), (2) and the condition (3). Six hundred island component discharge holes per one discharge introduction hole were holed at equal intervals in a lowermost layer distribution plate for island

component polymers. Spinning was carried out in the same manner (same polymer, same fineness and same spinning conditions) as in Example 1 except for changing the ratio between the sea component and the island component to 50/50 to obtain 9000 multifilaments. Here, in the composite spinneret used in Example 2, island component discharge holes and sea component discharge holes respectively having a hole diameter of 0.2 mm are holed on a virtual circular line C1 with a radius R1 of 0.25 mm and a virtual circular line C2 with a radius R2 of 0.5 mm. As described in Table 1, the island component had a cross-type cross section, the island component polymer streams did not join with one another, fiber diameter variation was 5.9%, the degree of heteromorphy was 2.4, and variation of the degree of heteromorphy was 4.4%, and a fiber diameter of the multifilament was 710 nm.

[Example 3]

[0104] As shown in Fig. 3, the same composite spinneret as in Example 1 was used except for changing the arrangement of the island component discharge holes and the sea component discharge holes of the lowermost layer distribution plate so that n is 6 according to the expressions (1), (2) and the condition (3). Five hundred island component discharge holes per one discharge introduction hole were holed at equal intervals in a lowermost layer distribution plate for island component polymers. Spinning was carried out in the same manner (same polymer, same fineness and same spinning conditions) as in Example 1 except for changing the ratio between the sea component and the island component to 50/50 to obtain 7500 multifilaments. Here, in the composite spinneret used in Example 3, island component discharge holes and sea component discharge holes respectively having a hole diameter of 0.2 mm are holed on a virtual circular line C1 with a radius R1 of 0.33 mm and a virtual circular line C2 with a radius R2 of 0.51 mm. As described in Table 1, the island component had an asteroid-type cross section, the island component polymer streams did not join with one another, fiber diameter variation was 5.9%, the degree of heteromorphy was 2.3, and variation of the degree of heteromorphy was 4.8%, and a fiber diameter of the multifilament was 994 nm.

[Comparative Example 1]

[0105] The same composite spinneret as in Example 1 was used except for changing the arrangement of the island component discharge holes and the sea component discharge holes of the lowermost layer distribution plate as shown in Fig. 12. Here, one island component discharge hole for an island component polymer per one discharge introduction hole and four sea component discharge holes around the island component discharge hole were holed in the lowermost layer distribution plate. With respect to spinning conditions, a ratio between the sea component and the island component was set to 50/50, and the discharged composite polymer streams were cooled/solidified, and then provided with a spinning oil, and wound at a spinning speed of 1500 m/min to obtain non-stretched fibers of 110 dtex-150 filaments (discharged amount of a single hole 2.25 g/min). The wound non-stretched fibers were drawn by 3.0 times between rollers heated to 90°C and 130°C to form islands-in-the-sea composite fibers of 36 dtex-150 filaments, and 99% or more of the sea component was dissolved by the above-mentioned method to obtain 150 multifilaments.

[0106] Here, in the composite spinneret used in Comparative Example 1, island component discharge holes and sea component discharge holes respectively having a hole diameter of 0.2 mm are holed with a 0.6-mm dot pitch. As described in Table 1, fibers in which the degree of heteromorphy was 1.5 and the island component had a cross-type cross section are obtained; however, a fiber diameter was 11000 nm of micron order.

[Comparative Example 2, Comparative Example 3]

[0107] Next, Comparative Example 2 and Comparative Example 3 will be described as a comparative example in which the same composite spinneret as in Example 1 except for changing a ratio of the radius R2 of the virtual circular line C2 to the radius R1 of the virtual circular line C1 was used, spinning was carried out in the same manner (same polymer, same fineness and same spinning conditions) as in Example 1, and the ratio between the sea component and the island component was varied. Here, the respective discharge holes were arranged so that the radius R1 of the virtual circular line C1 on which the island component discharge holes were arranged was 0.33 mm and the radius R2 of the virtual circular line C2 on which the sea component discharge holes were arranged was 0.44 mm, and the ratio between the sea component and the island component was set to 30/70 in Comparative Example 2 and the ratio between the sea component and the island component was set to 50/50 in Comparative Example 3 to manufacture islands-in-the-sea composite fibers. As described in Table 1, when the ratios of the island component polymers were as high as 50% or 70%, island component polymer streams joined with one another, and multifilaments having a Y-shaped cross section could not be obtained.

[Comparative Example 4]

[0108] Next, Comparative Example 4 will be described as a comparative example in which the same composite spinneret as in Example 2 except for changing a ratio of the radius R2 of the virtual circular line C2 to the radius R1 of the virtual circular line C1 was used, spinning was carried out in the same manner (same polymer, same fineness and same spinning conditions) as in Example 2, and the ratio between the sea component and the island component was varied. Here, the respective discharge holes were arranged so that the radius R1 of the virtual circular line C1 on which the island component discharge holes were arranged was 0.35 mm and the radius R2 of a virtual circular line C2 on which the sea component discharge holes were arranged was 0.44 mm, and the ratio between the sea component and the island component was set to 50/50 to manufacture islands-in-the-sea composite fibers. As described in Table 1, the island component polymer streams joined with one another, and multifilaments having a cross-type cross section could not be obtained.

[Comparative Example 5]

[0109] Next, Comparative Example 5 will be described as a comparative example in which the same composite spinneret as in Example 3 except for changing a ratio of the radius R2 of the virtual circular line C2 to the radius R1 of the virtual circular line C1 was used, spinning was carried out in the same manner (same polymer, same fineness and same spinning conditions) as in Example 3, and the ratio between the sea component and the island component was varied. Here, the respective discharge holes were arranged so that the radius R1 of the virtual circular line C1 on which the island component discharge holes were arranged was 0.44 mm and the radius R2 on the virtual circular line C2 on which the sea component discharge holes were arranged was 0.51 mm, and the ratio between the sea component and the island component was set to 50/50 to manufacture islands-in-the-sea composite fibers. As described in Table 1, the island component polymer streams joined with one another, and multifilaments having an asteroid-type cross section could not be obtained.

[Table 1]

	Example 1	Example 2	Example 3	Comparative Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 4	Comparative Example 5
Resulting Cross-section Shape of Island Component	Y-SHAPED CROSS SECTION	Cross-type Cross Section	Asteroid-type Cross Section	Cross-type Cross Section	Y-SHAPED CROSS SECTION	Y-SHAPED CROSS SECTION	Cross-type Cross Section	Asteroid-type Cross Section
Number n of Island Component Discharge Holes on Virtual Circular Line C1	3	4	6	-	3	3	4	6
Radius R2 of Virtual Circular Line C2/Radius R1 of Virtual Circular Line C1	2	2	1.54	-	1.33	1.33	1.41	1.15
Ratio between Sea Component and Island Component [%]	30	50	50	50	30	50	50	50
	70	50	50	50	70	50	50	50
Hole Packing Density [hole/mm ²]	0.8	0.7	0.5	0.01	0.8	0.8	0.7	0.5
Fiber Diameter [nm]	870	710	994	11000	-	-	-	-
Fiber Diameter Variation [CV%]	5.3	5.9	5.9	-	-	-	-	-
Degree of Heteromorphy [-]	2.3	2.4	2.3	1.5	-	-	-	-
Variation of Degree of Heteromorphy [CV%]	4.5	4.4	4.8	-	-	-	-	-

INDUSTRIAL APPLICABILITY

[0110] The present invention can be applied not only to composite spinnerets used in a common solution spinning method, but also to composite spinnerets used in a melt blowing method and a spunbonding method and further to spinnerets used in a wet spinning method and a dry-wet spinning method; however, its application range is not limited to these.

DESCRIPTION OF REFERENCE SIGNS

[0111]

- 1: Island component discharge hole
- 4: Sea component discharge hole
- 5: Lowermost layer distribution plate
- 6: Distribution plate
- 7: Distribution hole
- 8: Distribution groove
- 9: Metering plate
- 10: Discharge plate
- 11: Discharge introduction hole
- 12: Contracting hole
- 13: Island component polymer (island portion)
- 14: Circumscribed-circle
- 15: Spin pack
- 16: Spin block
- 17: Cooling apparatus
- 18: Composite spinneret
- 19: Inscribed circle
- 20: Sea component polymer (sea portion)
- 21: Island component discharge part
- 22: Extended line
- 24: Sea component discharge part
- 25: Discharge hole
- 26: External common tangent
- 27: Radial groove
- 28: Groove on concentric circle
- 29: Upper layer plate
- 30: Pipe
- 31: Sea component polymer introduction flow path
- 32: Island component polymer introduction flow path
- 33: Upper spinneret plate
- 34: Middle spinneret plate
- 35: Lower spinneret plate
- 40: Distribution chamber for sea component polymer
- 41: Pipe insertion hole
- 42: Spinneret discharge hole
- α : Taper angle
- L: Entrance section

Claims

1. A composite spinneret for discharging a composite polymer stream composed of an island component polymer and a sea component polymer, comprising one or more distribution plates in which distribution holes and distribution grooves for distributing the polymer components are formed; and a lowermost layer distribution plate positioned to the downstream side of the distribution plate in the direction of the polymer spinning path and provided with a plurality of island component discharge holes and a plurality of sea component discharge holes, wherein the composite spinneret has a plurality of hole groups composed of n (n is a natural number of 3 or more, the same shall apply

hereafter) island component discharge holes centered on a virtual center O and arranged on a virtual circular line C1 with a radius R1, n sea component discharge holes centered on the virtual center O and arranged on a virtual circular line C2 with a radius R2, n virtual group centers P centered on a virtual center O and arranged on a virtual circular line C3 with a radius R3, n island component discharge holes centered on the virtual group center P and arranged on a virtual circular line C5 with a radius R1, and n sea component discharge holes centered on the virtual group center P and arranged on a virtual circular line C6 with a radius R2 are present; R1, R2 and R3 satisfy the following expression (1) and (2):

(1)

$$R1 \leq R2 \cdot \cos(180/n \text{ [degree]})$$

(2)

$$R3 = 2 \cdot R2,$$

and each discharge hole is arranged according to the following conditions (3) and (4):

(3) C1, C5: n island component discharge holes are arranged equally at a center angle of $360/n$ degrees

C2, C6: n sea component discharge holes are arranged equally at a center angle of $360/n$ degrees

C3: n virtual group centers are arranged equally at a center angle of $360/n$ degrees

$\theta 1$: a phase angle between two discharge holes, one arranged on C1 and the other arranged on C2, and one arranged on C5 and the other arranged on C6, is $180/n$ degrees

$\theta 2$: a phase angle between the discharge hole on C2 and the virtual group center on C3 is 0 degree,

(4) a sea component discharge hole is arranged at a point of intersection of a line segment connecting the virtual center O and the virtual group center P, the virtual circular line C2, and the virtual circular line C6.

2. The composite spinneret according to claim 1, wherein at the number n of discharge holes of 4, the composite spinneret satisfies the expression (5):

(5)

$$R1 \leq R2/2$$

3. The composite spinneret according to claim 1, wherein at the number n of discharge holes of 6, the composite spinneret satisfies the expression (6):

(6)

$$R1 \leq R2 \cdot 3\sqrt{3}/8.$$

4. The composite spinneret according to any one of claims 1 to 3, wherein the composite spinneret has a similar hole arrangement also when the virtual group center P adjacent to the virtual center O is taken as the virtual center O.

5. The composite spinneret according to any one of claims 1 to 4, wherein a hole packing density of the island component discharge hole is 0.5 hole/mm² or more.

6. A method of manufacturing a composite fiber, wherein melt spinning is performed by a composite spinning machine using the composite spinneret according to any one of claims 1 to 5 in which flow-path pressure losses at the respective flow paths from the distribution plate to the island component discharge holes of the lowermost layer distribution plate are the same, and flow-path pressure losses at the respective flow paths from the distribution plate to the sea component discharge holes of the lowermost layer distribution plate are the same.

7. A method of manufacturing a composite fiber, wherein melt spinning is performed at a ratio of the island component polymer of 50% or more by a composite spinning machine using the composite spinneret according to any one of claims 1 to 5.

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Fig. 1

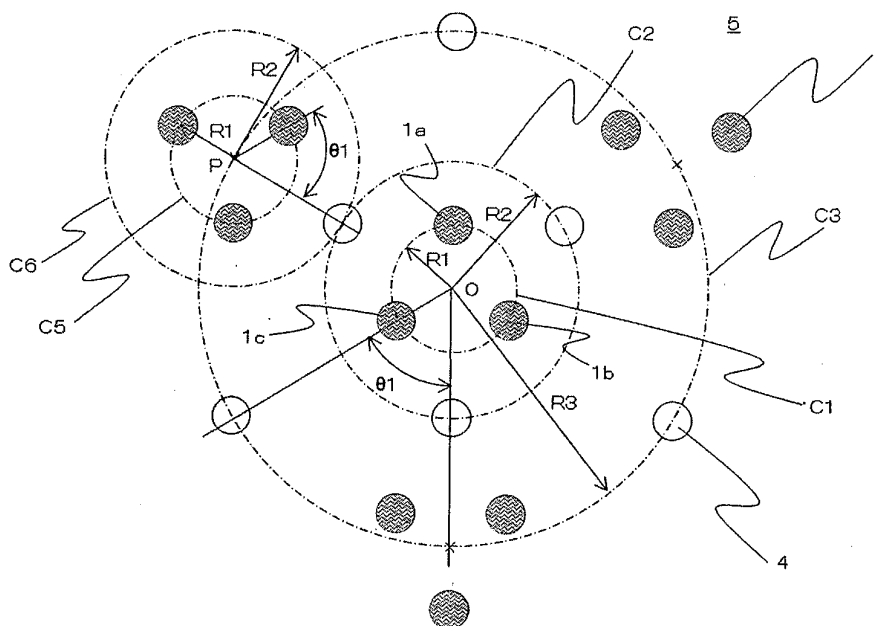


Fig. 2

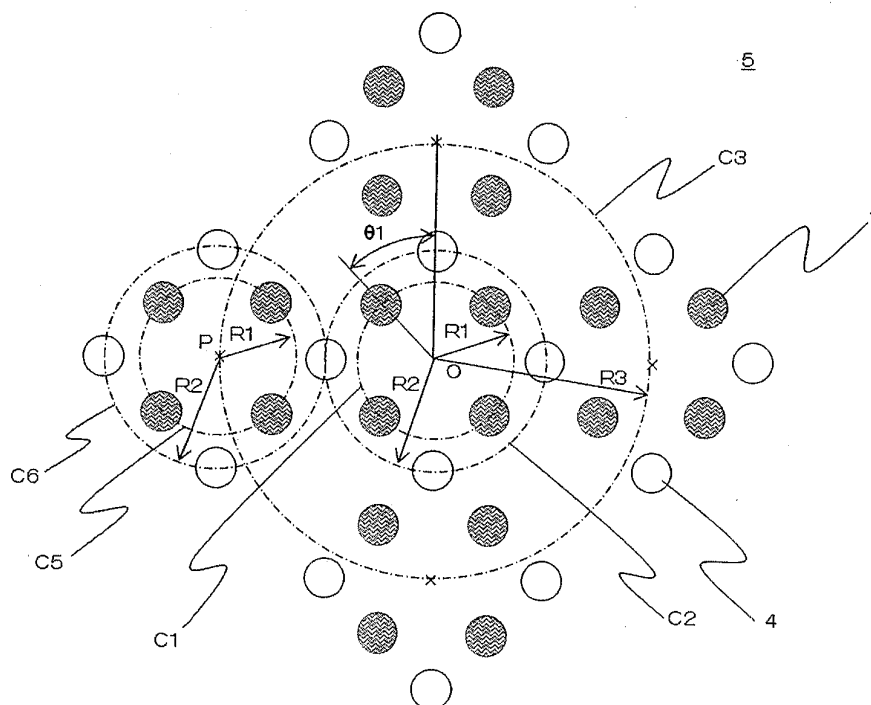


Fig. 3

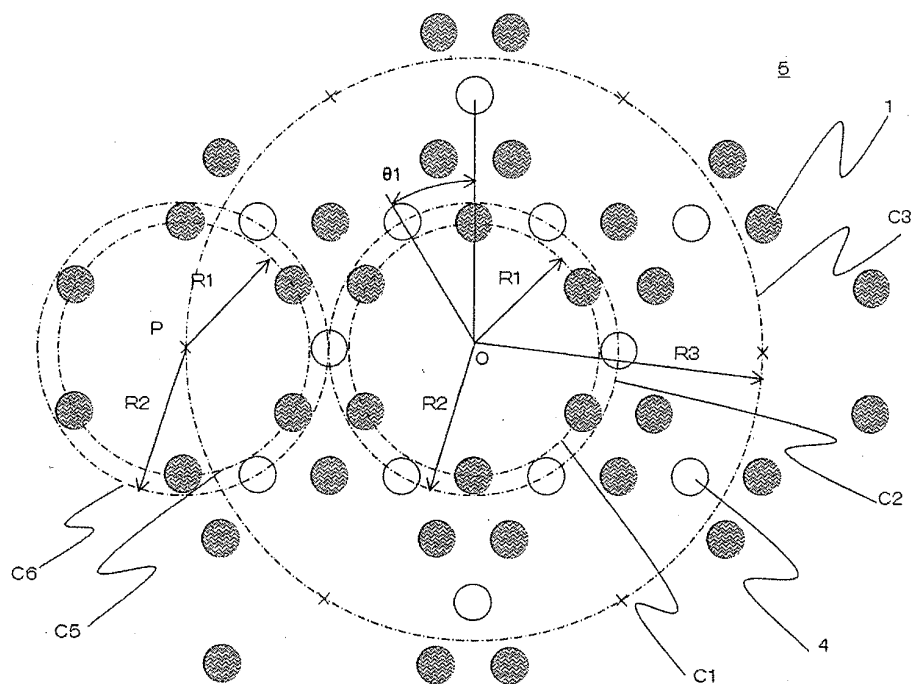


Fig. 4

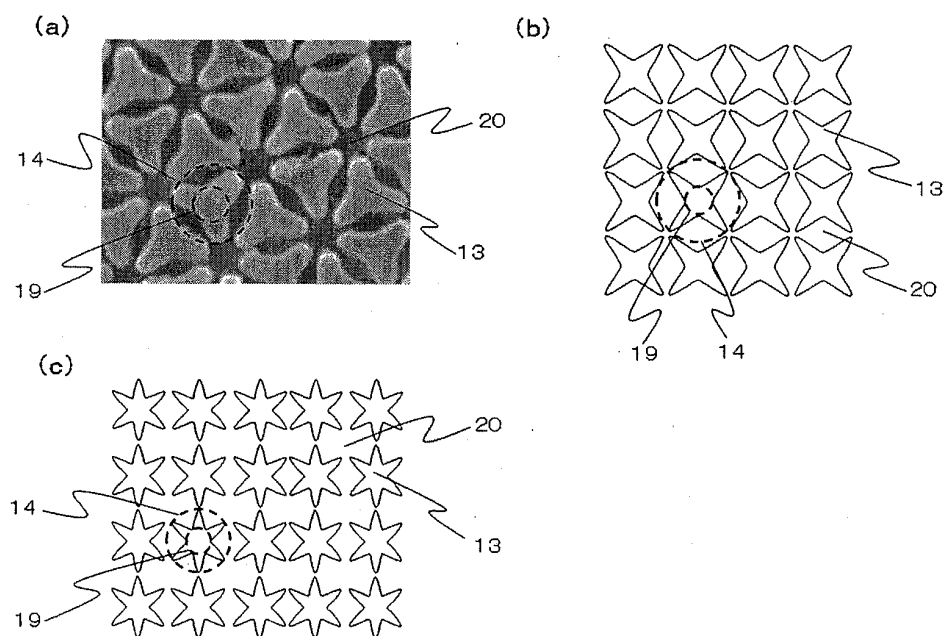


Fig. 5

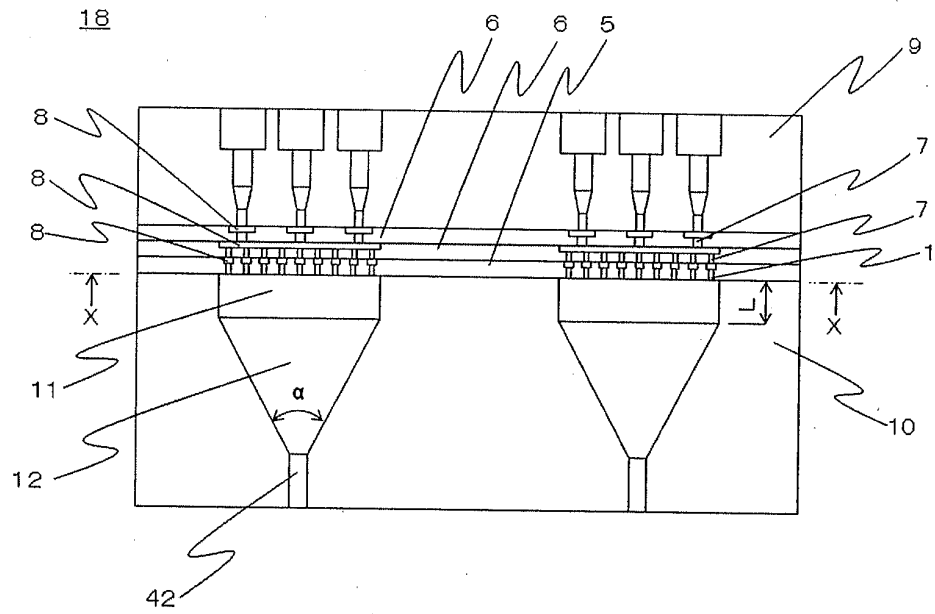


Fig. 6

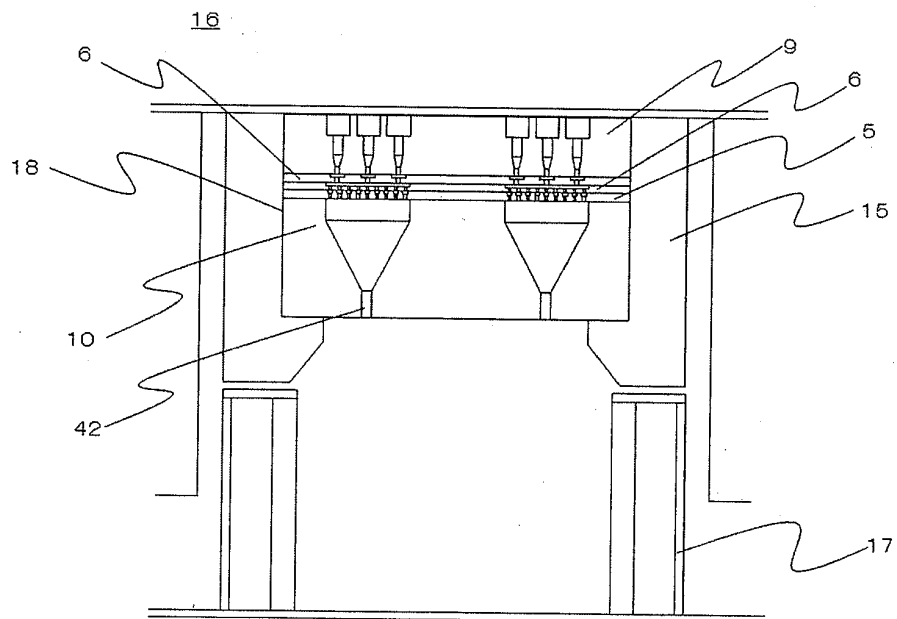


Fig. 7

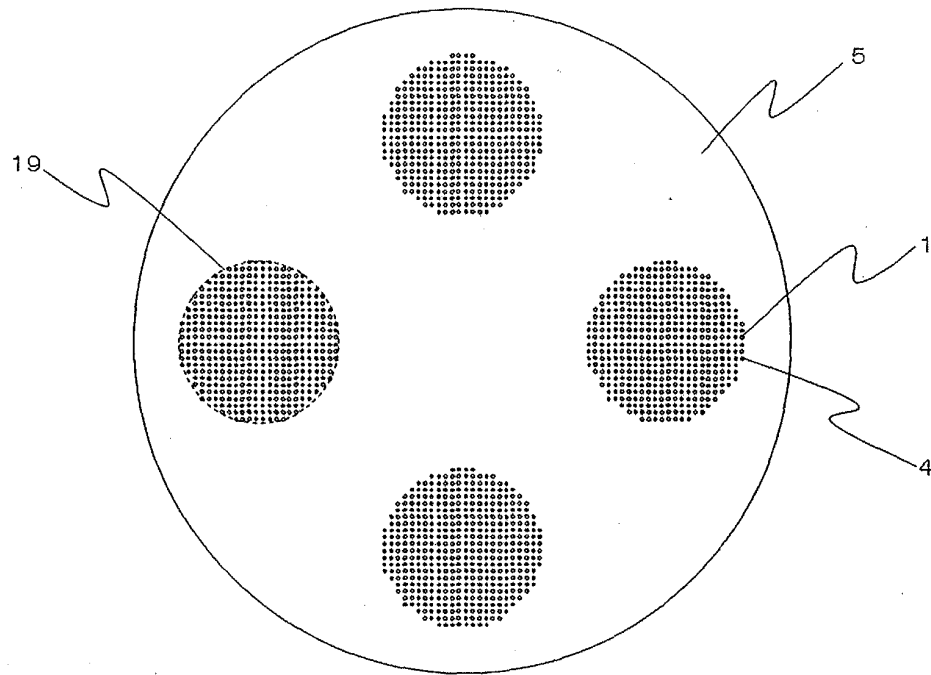


Fig. 8

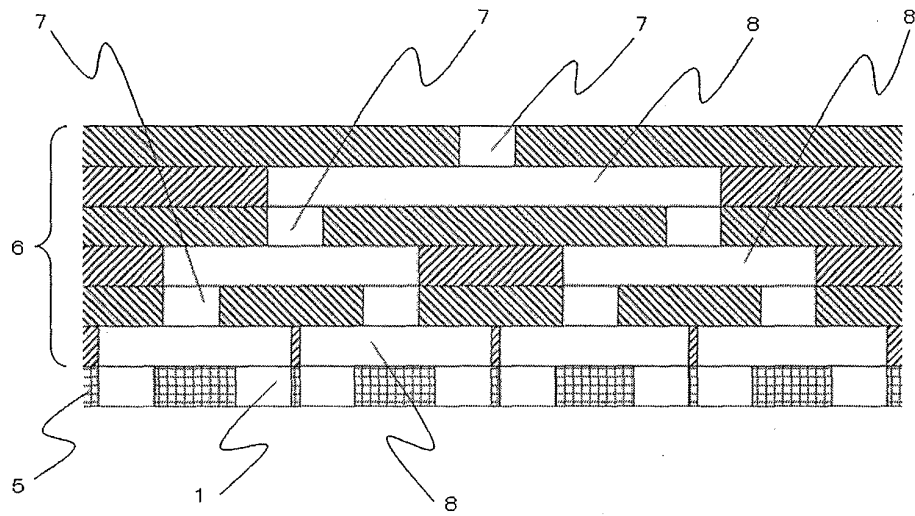


Fig. 9

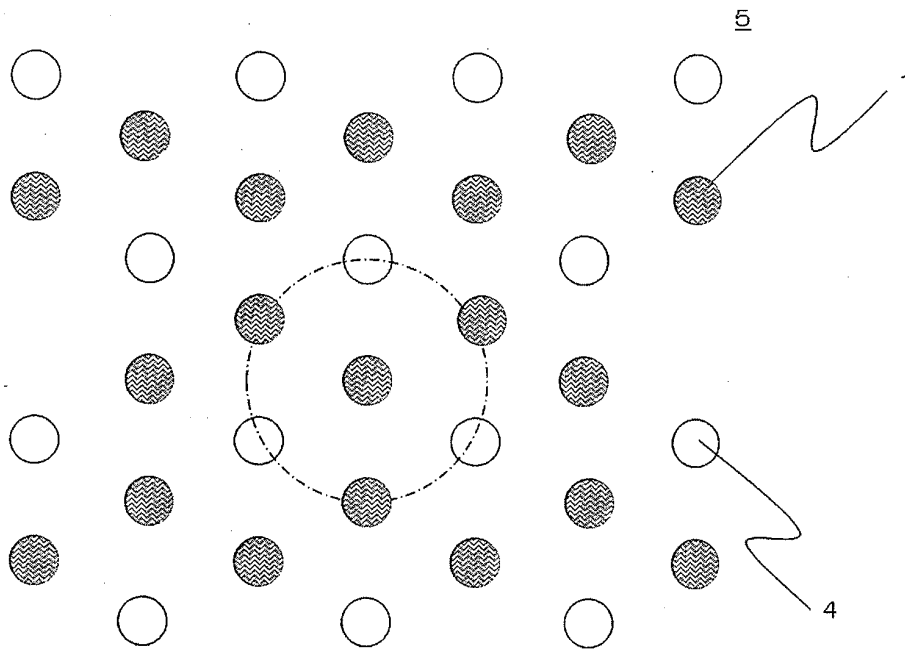


Fig. 10

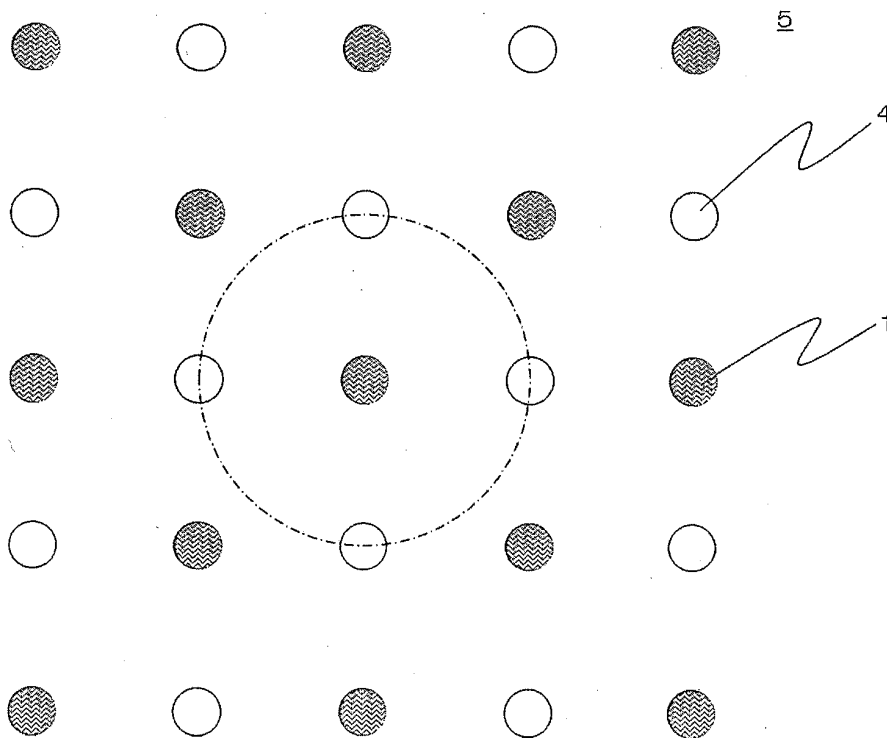


Fig. 11

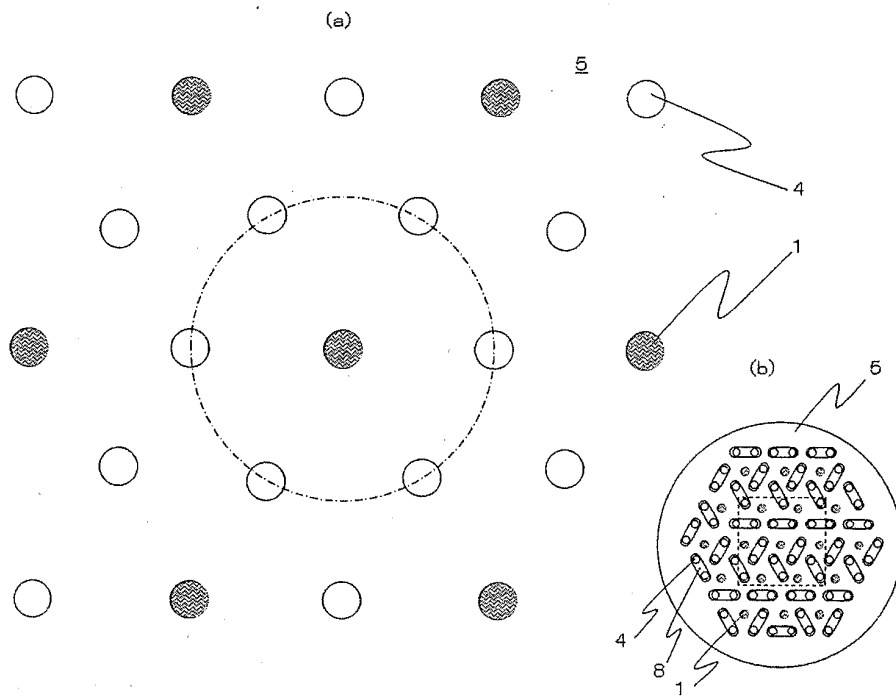


Fig. 12

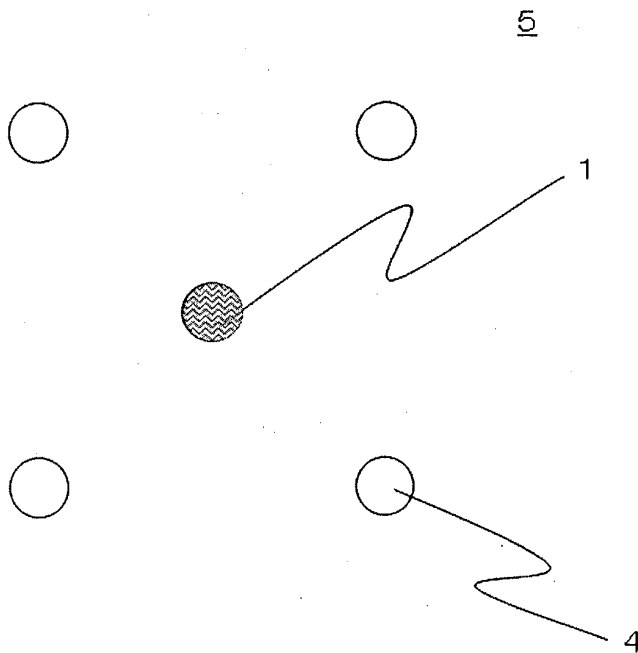


Fig. 13

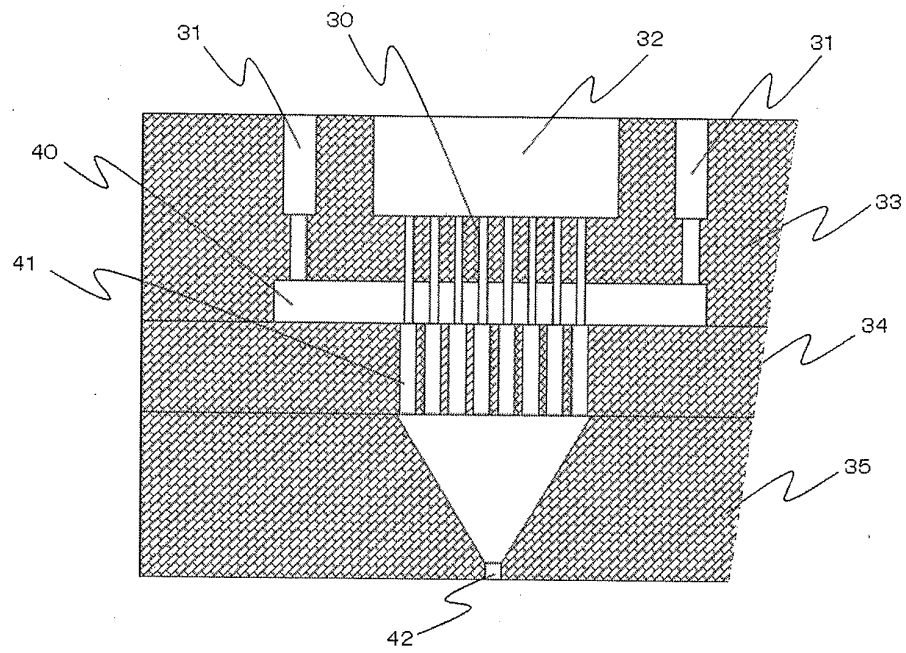
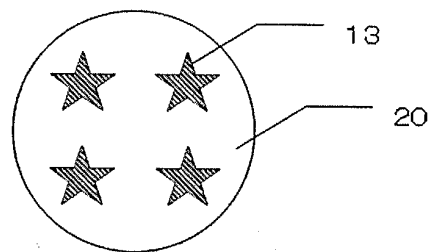
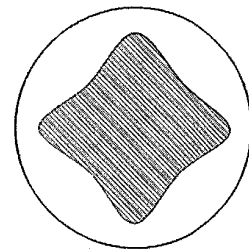


Fig. 14

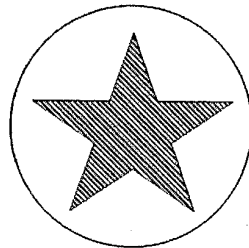
(a)



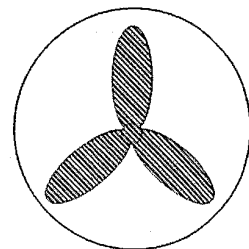
(b)



(c)



(d)



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/054669

A. CLASSIFICATION OF SUBJECT MATTER

D01D5/36(2006.01)i, D01D4/02(2006.01)i

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)
D01D5/36, D01D4/02

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2013
Kokai Jitsuyo Shinan Koho	1971-2013	Toroku Jitsuyo Shinan Koho	1994-2013

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 2011-208313 A (Toray Industries, Inc.), 20 October 2011 (20.10.2011), claims (Family: none)	1-7
A	JP 7-3529 A (BASF Corp.), 06 January 1995 (06.01.1995), claims & US 5405698 A claims & EP 0618316 A1	1-7
A	JP 58-191214 A (Toray Industries, Inc.), 08 November 1983 (08.11.1983), claims (Family: none)	1-7

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

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search
13 May, 2013 (13.05.13)Date of mailing of the international search report
21 May, 2013 (21.05.13)Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/054669

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2011-32611 A (Teijin Fibers Ltd.), 17 February 2011 (17.02.2011), claims (Family: none)	1-7
P, A	WO 2012/090538 A1 (Toray Industries, Inc.), 05 July 2012 (05.07.2012), claims & JP 2012-136804 A	1-7
P, A	JP 2013-14872 A (Toray Industries, Inc.), 24 January 2013 (24.01.2013), claims (Family: none)	1-7

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REFERENCES CITED IN THE DESCRIPTION

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