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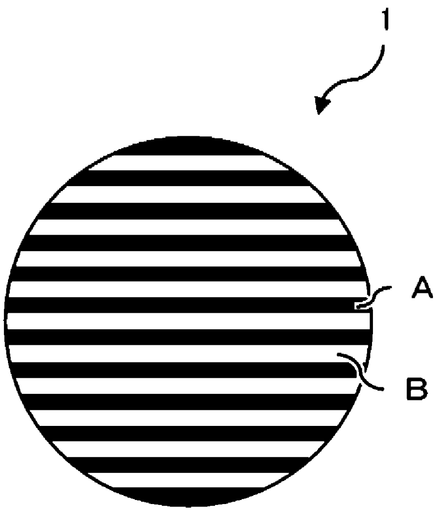
(54) COMPOSITE FIBER AND MULTIFILAMENT

(57) The present invention provides a conjugate fiber wherein the sum of the lengths of interfaces that are formed by two or more kinds of polymers that constitute a fiber cross-section is extremely large. A conjugate fiber according to the present invention has a fiber cross-section which is composed of two or more kinds of polymers that form a plurality of interfaces; the value obtained by dividing the sum of the interface lengths between two kinds of polymers by the area of the fiber cross-section is 0.0010 nm-1 or more; and the interfaces are continuous in the fiber axis direction.

FIG. 1



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Description

TECHNICAL FIELD

[0001] The present invention relates to a conjugate fiber including two or more components, and relates to a multifilament.

BACKGROUND ART

[0002] Synthetic fibers including polyester, polyamide, or the like are excellent in mechanical properties and dimensional stability, and thus are used in a wide range of applications from clothing to industry. In recent years, diversification of applications has been further progressed, and required properties have also become more advanced and multifunctional, and thus fibers including existing polymers may not meet these requirements. It is conceivable to newly design a polymer to achieve the required properties, but from the viewpoint of reducing the cost and period required for the development, a conjugate spinning method in which existing polymers are combined is often selected.

[0003] A fiber formed by the conjugate spinning method, that is, a so-called conjugate fiber, can impart a sensory effect such as appearance and texture, which cannot be achieved by a fiber including a single polymer, by coating a main polymer with the other polymer in a fiber cross section (cross section with respect to an axial direction of the fiber). Even if the conjugate fiber includes a functional polymer that has problems in chemical resistance, heat resistance, and the like and is not practical use when used alone, the conjugate fiber can be put to practical use with dramatically improved chemical resistance, heat resistance, and the like if the functional polymer is coated with the other polymer.

[0004] There are various types of cross-sectional morphologies and objective effects of the conjugate fiber, but in the case where an affinity of polymers to be combined is poor, there is a problem that an interface where two types of polymers are in contact with each other is peeled off when an external force such as an impact is applied to the fiber. Due to the interfacial peeling, not only an originally intended effect is impaired, but also cracks generated by the peeling propagate to a fiber surface to cause frequent fiber breakage in a fiber producing process or a textile processing process, which makes stable production itself difficult.

[0005] Such a problem may be solved by devising a cross-sectional morphology of a conjugate fiber, and for example, Patent Literature 1, Patent Literature 2, and Patent Literature 3 propose cross-sectional morphologies of fibers.

[0006] Patent Literature 1 proposes a fiber having a cross-sectional morphology in which a plurality of a series of laminated structures in which two types of polymers are alternately laminated are joined in a direction perpendicular to a lamination direction thereof. In the technique, a large number of film-like elements constituting a fiber cross section are formed to increase an interface occupied in each film-like element, and a spine-like skeleton that couples the laminated structures acts as a core that supports each film-like element, thereby preventing interfacial peeling and improving processability.

[0007] Patent Literature 2 proposes a fiber having a cross-sectional morphology in which an outer periphery of a laminated structure in which two types of polymers are alternately laminated is coated with a protective layer. As in Patent Literature 1, the technique aims to prevent interfacial peeling of the laminated structure, and aims to improve abrasion resistance by coating the outer periphery of the laminated structure with a high-strength polymer having a specific thickness.

[0008] Patent Literature 3 also proposes a fiber having a cross-sectional morphology in which an entire outer periphery of a laminated structure in which two types of polymers are alternately laminated is coated. The same technical idea as that of Patent Literature 2 is intended to reduce peeling and splitting during the process and improve processability by providing a coating on the outermost periphery of the laminated structure, but the technique is intended to produce an ultrafine fiber by deteriorating the coating on the outermost periphery and promoting the peeling and splitting by treatment under specific conditions.

CITATION LIST

PATENT LITERATURE

[0009]

Patent Literature 1: JPH01-132812A (Pages 1 to 2)
Patent Literature 2: JPH11-181630A (Claims)
Patent Literature 3: JP2000-282333A (Pages 1 to 3)

SUMMARY OF THE INVENTION

TECHNICAL PROBLEM

[0010] Patent Literature 1 describes that the fiber cross section is constituted with a large number of film-like elements, but in fibers actually produced in examples, two structures each laminated with 50 to 65 layers at most are joined adjacent to each other, there is a limit in a length of interface, and it may be insufficient to prevent peeling of each film-like element. Even if a production method is devised to increase the number of laminated layers, it is impossible to stably increase the number of laminated layers due to the principle of the production method.

[0011] In Patent Literatures 2 and 3, there is a possibility that an effect of preventing interfacial peeling against weak friction acting on a fiber surface can be obtained by the presence of a protective layer having abrasion resistance. However, the laminated structure inside the fiber has merely the same number of laminated layers as in Patent Literature 1, and the interfacial peeling may occur when a large external force is applied or due to repeated rubbing. When the interfacial peeling occurs, cracks generated by peeling may propagate to the protective layer on the fiber surface, and in particular, the structure is relatively weak against repeated rubbing or the like. When a multilayer laminated structure is exposed to the surface, the properties of the fiber may be greatly impaired and the quality may be greatly reduced due to exposure to chemicals and heat.

[0012] As described above, in the conjugate spinning method of the related art, it is difficult to prevent interfacial peeling inside the obtained fiber. Even if apparent splitting or the like can be prevented by coating the outer periphery of the laminated structure, the interfacial peeling may occur inside the laminated structure, and the use thereof may be limited from the viewpoint of durability.

[0013] Therefore, a conjugate fiber having improved durability such as abrasion resistance, chemical resistance, and heat resistance has been strongly desired.

SOLUTION TO PROBLEM

[0014] The above object is achieved by the following configurations.

(1) A conjugate fiber including two or more types of polymers, and having a fiber cross section in which a plurality of interfaces is formed, in which

> the conjugate fiber has a value, which is obtained by dividing a sum of lengths of interfaces between two types of the polymers by an area of the fiber cross section, of 0.0010 nm^{-1} or more, and
> each of the interfaces is continuous in a fiber axis direction.

(2) The conjugate fiber according to (1), in which
the value, which is obtained by dividing the sum of lengths of interfaces between the two types of the polymers by the area of the fiber cross section, is 0.0050 nm^{-1} or more.
(3) The conjugate fiber according to (1) or (2), in which
the fiber cross section includes a multilayer laminated structure in which the two types of the polymers are alternately laminated.
(4) The conjugate fiber according to any one of (1) to (3), in which
at least one type of the polymers has a variation (CV value) in layer thickness of 10% or more.
(5) The conjugate fiber according to any one of (1) to (4), in which
at least one type of the polymers has an average layer thickness of 1000 nm or less.
(6) A multifilament consisting of flat ultrafine fibers that each include one type of polymer that is remained by removing another type of polymer among the two types of the polymers constituting the multilayer laminated structure from the conjugate fiber according to (3).
(7) The multifilament according to (6), in which
the flat ultrafine fibers each have a fiber cross section having a flat shape, have a flatness, which is a value obtained by dividing a length of a major axis of the fiber cross section by a length of a minor axis of the fiber cross section, of 15 or more, and have an average thickness of 1000 nm or less.
(8) The multifilament according to (6) or (7), in which
the flat ultrafine fibers have a variation (CV value) in thickness of 10% or more.
(9) The multifilament according to any one of(6) to (8), in which
the polymer constituting the flat ultrafine fibers includes at least one polymer selected from the group consisting of polyester, polyamide, and polyolefin.
(10) The multifilament according to any one of (6) to (9), in which

a functional substance is enclosed in a fiber bundle including the flat ultrafine fibers.

(11) A fiber product at least partially including the conjugate fiber according to any one of (1) to (5) or the multifilament according to any one of (6) to (10).

ADVANTAGEOUS EFFECTS OF INVENTION

[0015] In the conjugate fiber of the present invention, due to an increase in the length of interface between polymers, even when an external force is applied to the fiber, the external force is evenly dispersed at a plurality of interfaces present on the fiber cross section, and a load is prevented from being concentrated on a part of the fiber cross section. Therefore, even in a fiber including a composite of two or more types of polymers, peeling between the components is greatly prevented. Accordingly, it is possible to provide a conjugate fiber and a multifilament excellent in durability such as abrasion resistance, chemical resistance, and heat resistance.

BRIEF DESCRIPTION OF DRAWINGS

[0016]

[FIG. 1] FIG. 1 is a schematic view of a cross section of a unidirectional-laminated fiber according to an aspect of the present invention.

[FIG. 2] FIG. 2 is a partially enlarged view of FIG. 1.

[FIG. 3] FIG. 3 is a schematic view of a cross section of a radial-laminated fiber according to another aspect of the present invention.

[FIG. 4] FIG. 4 is a schematic view of a cross section of a concentric-laminated fiber according to another aspect of the present invention.

[FIG. 5] FIG. 5 is a schematic view of a cross section of a flat ultrafine fiber constituting a multifilament of the present invention.

[FIG. 6] FIG. 6 is a schematic view of a cross section of the multifilament of the present invention.

[FIG. 7] FIG. 7 is a schematic view of a cross section of a multifilament in the case where a functional substance is added to the multifilament of the present invention.

[FIG. 8] FIG. 8 is a cross-sectional view of a composite spinneret for explaining an example of a method for producing a conjugate fiber of the present invention.

[FIG. 9] FIG. 9 is a schematic view of a cross section of a coated unidirectional-laminated fiber in the related art.

[FIG. 10] FIG. 10 is a schematic view of a cross section of a flat fiber in the related art.

[FIG. 11] FIG. 11 is a schematic view of a cross section of a fiber bundle including flat fibers in the related art.

DESCRIPTION OF EMBODIMENTS

[0017] Hereinafter, preferred embodiments of the present invention will be described in detail.

[0018] A conjugate fiber in the present invention means a fiber including two or more types of polymers. The conjugate fiber of the present invention has a cross-sectional morphology in which a sum of lengths (interfacial lengths) of interfaces formed by two types of polymers is extremely larger than that of a conjugate fiber in the related art in a cross section (fiber cross section) of the fiber with respect to an axial direction of the fiber.

[0019] The cross-sectional morphology in which the sum of the interfacial lengths formed by the two types of polymers is extremely large is defined by the sum of the interfacial lengths and an area of the fiber cross section (hereinafter, also referred to as a fiber-cross-sectional area), and refers to a cross-sectional morphology in which a value obtained by dividing the sum of the interfacial lengths by the fiber-cross-sectional area is 0.0010 nm^{-1} or more when a length in the fiber cross section of the interfaces that are formed by the two types of polymers and continuous in a fiber axis direction is defined as the interfacial length.

[0020] The value obtained by dividing the sum of the interfacial lengths by the fiber-cross-sectional area in the present invention is determined as follows.

[0021] That is, a multifilament including the conjugate fiber is embedded with an embedding agent such as an epoxy resin, and the cross sections is imaged with a transmission electron microscopy (TEM) at a magnification at which interfaces of the polymers can be identified. In the case where one entire interface does not fit in one image, a position at which an image is first captured may be set as an imaging start position, and a series of images may be captured along the same interface in the fiber cross section until an imaging position returns to the imaging start position again. In the case where the interface extends to an outer periphery of the fiber cross section, a series of images are captured along the outer periphery until the imaging position returns to the imaging start position again. At this time, in the case where only a specific polymer is subjected to electronic staining, a contrast of the interface becomes clear and measurement to be described later can be efficiently performed, which is preferable.

[0022] Using image analysis software, a measurement start point is freely determined for one interface in the image of the imaging start position, and a length from the measurement start point back to the measurement start point again along the same interface in a series of cross-sectional images is measured. At this time, in the case of reaching the outer periphery of the fiber cross section before returning to the measurement start point, the length is measured without including a length of a portion passing through the outer periphery. The value is taken as an interfacial length of one interface, and is represented by an integer (rounded to the nearest whole number) in units of nm. The same measurement is performed on all interfaces of the fiber cross section, and a value, which is calculated by dividing the sum of the interfacial lengths obtained by adding measured values by the fiber-cross-sectional area, is rounded to the fifth decimal place in units of nm^{-1}. The fiber-cross-sectional area is determined by two-dimensionally imaging the fiber cross section with a stereomicroscope at a magnification at which the entire fiber cross section can be observed, extracting a cross-sectional portion by binarization processing using image analysis software, and rounding an area thereof to a nearest integer in units of nm^2. In the case where the fiber cross section of the conjugate fiber of the present invention includes three or more types of polymers, the sum of the interfacial lengths is a sum of interfacial lengths of not only the interfaces between two specific types of polymers, but also interfaces formed by all polymer combinations.

[0023] The conjugate fiber of the present invention has a cross-sectional morphology in which the sum of the lengths (interfacial lengths) of the interfaces formed by two types of adjacent polymers is extremely large in the fiber cross section. As an index of the cross-sectional morphology, the value obtained by dividing the sum of the interfacial lengths by the fiber-cross-sectional area needs to be 0.0010 nm^{-1} or more, and each of the interfaces should be continuous in the fiber axis direction. The range means that the interfacial length per unit area of the fiber cross section is extremely large, and means that two or more types of polymers forming a cross-sectional morphology are finely divided into a large number of elements. The element as used herein means a polymer separated by being surrounded by different types of polymers in the fiber cross section.

[0024] As described above, the conjugate fiber of the present invention has a cross-sectional morphology in which different types of polymers are finely divided into an extremely large number of elements in the fiber cross section, and the sum of the interfacial lengths formed by the two types of polymers is extremely larger than that in the related art. With the cross-sectional morphology, the following various excellent effects can be exhibited.

[0025] That is, in the conjugate fiber of the present invention, since the sum of the interfacial lengths is extremely large, even when an external force is applied to the fiber, the force is dispersed at a plurality of interfaces present on the fiber cross section, and a load is prevented from being concentrated on a part of the fiber cross section. Therefore, even in a fiber including a composite of two or more types of polymers, peeling between the components can be greatly prevented.

[0026] In the case where the value obtained by dividing the sum of the interfacial lengths by the fiber-cross-sectional area of the conjugate fiber of the present invention is 0.0010 nm^{-1} or more, even when the conjugate fiber includes two types of polymers having poor affinity, the interfacial peeling between the components is less likely to occur, fiber breakage in a fiber producing process or a textile processing process is less likely to be induced, and therefore, not only good operability is maintained, but also a textile can be processed with high quality.

[0027] The larger the value obtained by dividing the sum of the interfacial lengths by the fiber-cross-sectional area, the more preferable from the viewpoint of evenly dispersing the force to the plurality of interfaces present on the fiber cross section. The value obtained by dividing the sum of the interfacial lengths by the cross-sectional area is preferably 0.0050 nm^{-1} or more because the effect of preventing peeling between components can be obtained even in the case where the conjugate fiber includes two types of polymers having poor affinity and is used for applications, such as general clothing, which are subjected to relatively weak rubbing. Proceeding from the above viewpoint, the value obtained by dividing the sum of the interfacial lengths by the cross-sectional area is more preferably 0.0200 nm^{-1} or more because the peeling between components can be effectively prevented even in the case where the conjugate fiber including two types of polymers having poor affinity is used for applications, such as outdoor products, which are subjected to moderate rubbing. In addition, the value obtained by dividing the sum of the interfacial lengths by the cross-sectional area is particularly preferably 0.0500 nm^{-1} or more because the peeling between components is prevented even in the case where the conjugate fiber is used for applications, such as workwear, which are repeatedly subjected to strong rubbing.

[0028] In the conjugate fiber of the present invention, in the case where the value obtained by dividing the sum of the interfacial lengths by the cross-sectional area is 0.0050 nm^{-1} or more, the above mechanical properties are improved, and even when one kind of component constituting the conjugate fiber is a polymer having poor chemical resistance or heat resistance, it is possible to impart excellent chemical resistance and heat resistance by using a polymer having excellent properties as other component. The improvement of the chemical properties and the thermal properties is effective because a layer having the properties of two types of polymers formed in the vicinity of the interface becomes more apparent with a drastic increase in the interfacial length. That is, in a layer in the vicinity of an interface formed by different polymers, molecular chains of different polymers may penetrate into each other, and an interface layer having the properties of two types of polymers may be formed. As in the conjugate fiber of the present invention, in the case where the interfacial length in the fiber cross section is dramatically increased, since the interface layer occupies a large ratio and the properties of the interface layer are apparent, an excellent effect is exhibited from the viewpoint of combining polymer properties.

[0029] In the conjugate fiber of the present invention, the value obtained by dividing the sum of the interfacial lengths by the fiber-cross-sectional area is preferably 0.0050 nm^{-1} or more because a ratio of the interface layer in the fiber cross section is high, and for example, even in the case where a conjugate fiber including an easily soluble polymer and a hardly soluble polymer is subjected to a dissolution treatment, a decrease in weight of the fiber after the treatment is slight and excellent chemical resistance is obtained. The larger the value obtained by dividing the sum of the interfacial lengths by the fiber-cross-sectional area, the more preferable from the viewpoint of increasing the ratio of the interface layer in the fiber cross section. The value obtained by dividing the sum of the interfacial lengths by the cross-sectional area is more preferably 0.0200 nm^{-1} or more because the decrease in fiber weight can be controlled to be extremely slight even in the case where the conjugate fiber is subjected to a chemical treatment for a long time. Proceeding from the above viewpoint, the value obtained by dividing the sum of the interfacial lengths by the cross-sectional area is particularly preferably 0.050 nm^{-1} or more because the deterioration of the fiber properties such as the mechanical properties is also greatly prevented even after the chemical treatment for a long time.

[0030] As described above, in the conjugate fiber of the present invention, as the value obtained by dividing the sum of the interfacial lengths by the fiber-cross-sectional area is larger, the effect exhibited by the characteristic cross-sectional form becomes more remarkable, and a preferable upper limit of the value may be less than 1.000 nm^{-1}. Generally, the interface where different types of polymers are in contact with each other is likely to be hydrodynamically unstable, and in the case where the interfacial length is extremely large as in the present invention, it may be difficult to stably form continuous interfaces. The upper limit of the value obtained by dividing the sum of the interfacial lengths by the fiber-cross-sectional area is preferably less than 1.000 nm^{-1}, because even in the case where polymers having different rheology properties are composited, the interfaces continuous in the fiber axis direction can be relatively easily formed, and thus various combinations of polymers can be applied as the conjugate fiber of the present invention.

[0031] As described above, the conjugate fiber of the present invention has the cross-sectional morphology in which the interfacial length formed by two types of polymers is extremely large, and the cross-sectional morphology not only provides an excellent effect in terms of mechanical properties, but also provides an excellent effect in terms of chemical properties and thermal properties by further increasing the interfacial length. There are various cross-sectional morphologies having an extremely large interfacial length, and from the viewpoint of promoting the effect of the conjugate fiber of the present invention, the cross section of the conjugate fiber of the present invention preferably has a multilayer laminated structure in which two types of polymers are alternately laminated.

[0032] In the case where the conjugate fiber of the present invention has such a structure, different types of polymers are finely divided into an extremely large number of film-like elements (layers) in the fiber cross section, and even in the case where cracks occur due to interfacial peeling in one layer of the large number of layers constituting the cross section, propagation of the cracks can be prevented because the layers are finely constituted. Therefore, it is possible to prevent the progress of breakage in a radial direction of the fiber cross section, and it is possible to effectively prevent fibrillation and splitting even when repeated rubbing is applied.

[0033] From the viewpoint of preventing the propagation of the cracks, as the number of laminated layers in the multilayer laminated structure of the fiber cross section is larger, the cracks can be stopped in a minute range. In the case of being used for applications, such as industrial products, which are repeatedly subjected to strong rubbing, when the number of laminated layers of the two types of polymers is 250 or more, the fibrillation of the fiber surface can be effectively prevented, and thus the above range can be mentioned as a preferable range. In the case of use in applications, such as repeated bending, where cracks are particularly likely to occur, when the number of laminated layers is 500 or more, propagation of the cracks can be stopped in an extremely minute range of the fiber cross section, and thus the above range can be mentioned as a preferable range. Here, the number of laminated layers means the total number of film-like elements of two types of polymers present in the fiber cross section.

[0034] Various lamination forms such as a form in which two types of polymers are alternately laminated in one direction (unidirectional lamination: unidirectional-laminated fiber 1 shown in FIGs. 1 and 2), a form in which two types of polymers are radially laminated (radial lamination: radial-laminated fiber 2 shown in FIG. 3), and a form in which two types of polymers are laminated concentrically (concentric lamination: concentric-laminated fiber 3 shown in FIG. 4) can be applied to the multilayer laminated structure. From the viewpoint of minimizing the propagation of the cracks, the multilayer laminated structure is preferably unidirectional lamination or concentric lamination. The multilayer laminated structure is preferably the unidirectional lamination or concentric lamination, because the size of the film-like element (layer) does not become coarse at the outer periphery of the fiber cross section and even at the outer periphery to which a large load is likely to be applied due to bending deformation, propagation of cracks can be stopped in a minute range.

[0035] As described above, since the cross section of the conjugate fiber of the present invention has a multilayer laminated structure, an effect of improving the mechanical properties can be increased, and further, by making a variation (CV value) in layer thickness of at least one kind of the polymers constituting the multilayer laminated structure relatively large to 10% or more, the interfacial peeling between components can be more effectively prevented.

[0036] Here, the variation in layer thickness is calculated by measuring a thickness of a layer existing on a line that vertically bisects a long side of each layer for 100 layers of one type of the polymers constituting the fiber cross section as an integer in units of nm, dividing a standard deviation of the measured thicknesses by an arithmetic mean to obtain a coefficient of variation, and rounding the coefficient of variation to a nearest integer in units of %. In the case of radial lamination, concentric lamination, or the like in which the layer thickness cannot be measured by the above method, a portion having the largest thickness and a portion having the smallest thickness of each layer are visually selected, an average value thereof is set as the layer thickness, and the variation in layer thickness can be calculated from the arithmetic mean and the standard deviation for 100 layers. In the case where the number of layers in the cross section of one conjugate fiber is less than 100, a total of 100 layers are obtained from cross sections of many conjugate fibers.

[0037] Since the variation in layer thickness of one type of the polymers constituting the multilayer laminated structure is relatively large, there are thin portions of layers and thick portions of layers in the fiber cross section. On the thin portions of layers, the influence of the above interface layer is relatively strong and stress concentration hardly occurs, and on the thick portions of layers, the stress is dispersed by deformation in the vicinity of the interface. Due to the synergistic effect, the generation of stress in the cross section changes in a complicated manner, and stress is relaxed at any place in the fiber, and thus the interfacial peeling between components can be effectively prevented. In the case where the variation in layer thickness of at least one type of the polymers constituting the multilayer laminated structure is 10% or more, the stress is dispersed in a complicated manner in the cross section and fluffing of the conjugate fiber hardly occurs even when compressive deformation is applied in a twisting process or the like, and thus the above range can be mentioned as a preferable range. In the case where the variation in layer thickness of at least one type of the polymers constituting the multilayer laminated structure is 30% or more, even when strong compressive deformation is applied under heating in a false twisting or the like, fluffing due to interfacial peeling hardly occurs and the fiber can be processed as a high-quality textile, and thus the above range can be mentioned as a more preferable range.

[0038] From the viewpoint of further enhancing the effect of improving the mechanical properties of the conjugate fiber of the present invention, an average layer thickness of at least one type of the polymers constituting the multilayer laminated structure is preferably 1000 nm or less. The average layer thickness of the polymer is more preferably 300 nm or less, further preferably 100 nm or less, particularly preferably 50 nm or less, and most preferably 30 nm or less. Here, the average layer thickness is calculated by rounding the arithmetic mean of the layer thicknesses of 100 layers of one type of the polymers constituting the fiber cross section calculated above to a nearest integer in units of nm. In the case where the number of layers in the cross section of one conjugate fiber is less than 100, a total of 100 layers are obtained from cross sections of many conjugate fibers.

[0039] When the layer thickness is relatively small, a proportion of the interface layer per layer is relatively increased, and stress is easily transmitted between adjacent interface layers. Even when the layer is subjected to deformation such as bending deformation in which stress is locally concentrated on the fiber cross section, the stress is dispersed over the entire cross section, and the interface hardly peels off.

[0040] Furthermore, by setting the average layer thickness of at least one kind of the polymers constituting the multilayer laminated structure to 50 nm or less, the effect can be made more remarkable also in terms of chemical properties and thermal properties.

[0041] As described above, in the layer in the vicinity of the interface formed by different types of polymers, the molecular chains of different polymers may penetrate into each other and the interface layer having the properties of two types of polymers may be formed, and a general thickness of the interface layer may be about several nm to ten nm. That is, when the layer thickness of the polymer constituting the multilayer laminated structure is close to the thickness of the interface layer, most of one layer is constituted with the interface layer, and an effect of the interface layer in each layer becomes extremely remarkable, so that an effect of combining the polymer properties becomes remarkable. In the cross section of the conjugate fiber of the present invention, in the case where the average layer thickness of at least one kind of the polymers constituting the multilayer laminated structure is 50 nm or less, most of the layer of the polymer is occupied by the interface layer. Accordingly, also in the case where an easily soluble polymer is used as the polymer, if a hardly soluble polymer is selected as the other polymer, the easily soluble polymer is hardly dissolved and exhibits excellent chemical resistance even when a dissolution treatment is performed, and thus the above range can be mentioned as a preferable range. In the case where a low-melting-point polymer and a high-melting-point polymer are selected, and the respective polymers are alternately laminated so that an average layer thickness of the low-melting-point polymer is 50 nm or less to form a multilayer laminated structure, even when the fiber is exposed to a high temperature equal to or higher than a melting point of the low-melting-point polymer, an effect of preventing fusion bonding between fibers is exhibited. The average layer thickness is preferably smaller because the interface layer becomes more apparent in each layer constituting the fiber cross section. In the case where the average layer thickness of one type of polymer is 30 nm or less, a decrease in weight of the fiber or fusion bonding between the fibers is prevented even in the case where the conjugate fiber including the combination of the above polymers is subjected to a dissolution treatment or heat treatment for a long time, and thus the above range can be mentioned as a most preferable range.

[0042] In the case where the average layer thickness of at least one type of the polymers constituting the multilayer laminated structure is 50 nm or less, the mechanical properties of the conjugate fiber of the present invention may be further improved from the viewpoint of improving dispersibility of an additive. That is, the polymer constituting the conjugate fiber generally contains an additive such as titanium oxide, but the additive is present in an aggregated state, and peeling easily occurs at an interface between a coarse aggregate and the polymer. In the case where the additive contained in the polymer is confined in a thin film of a multilayer laminated structure, the thin film having a size of less than or equal to an aggregation size of the additive, the aggregation state is eliminated by the shearing force, the dispersibility is improved, and an effect of preventing the occurrence of cracks itself can be obtained even when the fiber is repeatedly rubbed. In the case where the average layer thickness of at least one type of polymer is 50 nm or less, since the additive is confined in a layer sufficiently thinner than an aggregation diameter of the general additive, the dispersibility of the additive is improved and the abrasion resistance is excellent, and thus the above range can be mentioned as a most preferable range.

[0043] In the conjugate fiber of the present invention, in the case where a solubility parameter (SP value) difference between the two types of polymers composited in the fiber cross section is set to 3.0 or less, thinning immediately below the spinneret is stabilized, and excellent thickness uniformity in the fiber axis direction is obtained, and thus the range is preferable. Here, the solubility parameter difference means a parameter reflecting the cohesion of a substance defined by (evaporation energy/molar volume)$^{1/2}$, and can be calculated from values described in, for example, "Plastic Data Book", coedited by Asahi Kasei Amidas Co., Ltd./Plastic Editorial Department, page 189 and other pages. An absolute value of a value obtained by subtracting a solubility parameter of one component from a solubility parameter of the other component means the solubility parameter difference in the present invention.

[0044] Generally, in a conjugate fiber including two or more types of polymers, stretching-deformation-behaviors of respective polymers are different, and thus the stretching deformation in the spinning process or the stretching process tends to be unstable. In particular, in the case where the solubility parameter difference between the two types of polymers constituting the conjugate fiber is large, the unstability is aggravated, and the thickness unevenness in the fiber axis direction tends to increase. In the case where the solubility parameter difference between the two types of the polymers constituting the conjugate fiber is 3.0 or less, the stretching deformation in the spinning process or the stretching process becomes stable, and occurrence of excessive thickness unevenness in the fiber axis direction is prevented. As a result, even when an external force such as tension is applied, the stress can be evenly borne by the fiber in the fiber axis direction, and the load is prevented from being concentrated on a part in the fiber axis direction, and thus the occurrence of cracks at the interfaces between the components is more effectively prevented. From the above, in order to further enhance the effect of improving the mechanical properties of the conjugate fiber of the present invention, the solubility parameter difference between the two types of the polymers constituting the conjugate fiber is preferably 3.0 or less.

[0045] Here, the thickness unevenness in the fiber axis direction can be represented by a value of Uster (fineness unevenness) U% which is an index of fineness unevenness, and U% is preferably 1.5% or less. In the case where U% is 1.5% or less, even in the case where an external force such as repeated tension is applied, the load is prevented from being concentrated on a part in the fiber axis direction, and thus it is possible to prevent the occurrence of cracks due to peeling between components constituting the fiber cross section. Also from the viewpoint of chemical properties and thermal properties, in the case where the fineness unevenness is small, the chemical resistance and the heat resistance in the fiber axis direction become homogeneous, and defects caused by an extremely thick or thin portion are also reduced, and thus U% can be preferably controlled to 1.5% or less.

[0046] The conjugate fiber of the present invention not only exhibits an excellent effect in improving mechanical properties by forming a cross-sectional morphology having an extremely large interfacial length which has never been seen before, but also exhibits an excellent effect in chemical properties and thermal properties by appropriately selecting polymers to be combined. Therefore, the conjugate fiber of the present invention can be widely used in general clothing applications such as innerwear and outerwear, interior applications such as curtain and cloth, vehicle interior applications such as car seats, living applications such as wiping cloth and health products, harmful-substance-removal applications such as filters, industrial-material applications such as battery separators, and the like.

[0047] Furthermore, in the conjugate fiber of the present invention, by removing one type of polymer among the two types of the polymers constituting a multilayer laminated cross section, it is possible to obtain a multifilament consisting of flat ultrafine fibers including another type of polymer. That is, in a conjugate fiber having a multilayer laminated cross section in which two types of polymers are alternately connected as a film-like element (layer), when one type of polymer is removed, a large number of layers formed by another type of polymer are separated. Each of these layers forms a flat ultrafine fiber, and a multifilament 5 consisting of flat ultrafine fibers 4 shaped like a layer having a thin cross section is obtained as shown in FIGs. 5 and 6.

[0048] In the multifilament, since the fluffing or the like hardly occurs due to the feature of the conjugate fiber that the interfacial peeling hardly occurs, the multifilament can be processed into a fiber product with high quality, and an extremely large specific surface area is generated due to the feature of the conjugate fiber that the interfacial length is extremely large. Due to the effect of the specific surface area, in the case where the multifilament is subjected to functional processing, a large amount of functional substance is adsorbed, and excellent functionality can be exhibited.

[0049] From the viewpoint of ensuring long-term durability in terms of the functionality and the quality of the fiber material as described above, a cross-sectional shape of the flat ultrafine fiber constituting the multifilament of the present invention is important, and it is important that the fiber cross section has a flat shape, the flatness thereof is extremely high, and the thickness thereof is small.

[0050] Here, the flat shape refers to a shape such as a rectangle or an ellipse in which a length of a major axis and a length of a minor axis are different from each other, and the degree of flatness of the shape is defined as flatness which is a value obtained by dividing the length of the major axis by the length of the minor axis. In the multifilament of the present invention, the flatness of the fiber cross section may need to be 15 or more.

[0051] The flatness in the present invention is determined as follows (see also FIG. 5).

[0052] The multifilament of the present invention is embedded with an embedding agent such as an epoxy resin, a fiber cross section is cut with a microtome equipped with a diamond knife, and the cross section is imaged with a scanning electron microscope (SEM) or the like at a magnification at which the cross section can be identified. With respect to a cross section of a monofilament (flat ultrafine fiber) present in the captured image, a maximum length of the cross section is measured using image analysis software, and the value is rounded to a nearest integer in units of nm and is represented as a length of a major axis of the monofilament. Subsequently, a length at which a line segment orthogonal to a line segment having the maximum length intersects the fiber cross section at a midpoint of the maximum length is measured, and the value is rounded to a nearest integer in units of nm and is represented as a length of a minor axis of the monofilament. Using the length of the major axis and the length of the minor axis, the flatness of the monofilament is calculated by the following equation.

$$\text{Flatness} = \text{length (nm) in major axis direction}/\text{length (nm) in minor axis direction}$$

[0053] The above measurement is carried out for 100 fibers to calculate the flatness of each fiber, and the arithmetic mean of these is defined as the flatness of the present invention.

[0054] A first requirement for the multifilament of the present invention is that the flatness of the fiber cross sections of the flat ultrafine fibers constituting the multifilament is high, and the multifilament of the present invention is required to have the flatness of 15 or more as an index of the cross-sectional shape. Within such a range, the specific surface area of the fiber is increased twice or more as compared with a round cross-sectional fiber having the same fineness, and adsorption efficiency of a functional substance targeted by the present invention can be enhanced.

[0055] In the case where the flatness of the flat ultrafine fiber is 15 or more, as shown in FIG. 6, the multifilament 5 has a specific fiber bundle structure derived from the form of the flat ultrafine fiber 4. That is, a fiber arrangement direction is restricted due to high shape anisotropy of the flat ultrafine fibers, and the flat ultrafine fibers are aligned and overlapped. Due to such a fiber bundle structure, the number of fibers arranged per unit volume is greatly increased, and it is possible to achieve more excellent adsorption efficiency in conjunction with the effect of increasing the specific surface area of one fiber.

[0056] Herein, the fiber bundle is not limited to an aggregation form as long as a plurality of flat ultrafine fibers are aggregated, and includes a bundle in which monofilaments are clearly separated and a bundle in which monofilaments are aggregated to form as if a single coarse fiber.

[0057] Based on the above technical idea, as the flatness is higher, not only the specific surface area of the fiber increases, but also a close-packed arrangement form in which the fiber directions are highly aligned is obtained, which is advantageous in generating a larger fiber area. That is, in the case where the flatness is 30 or more, not only the specific surface area of the fiber is increased three times or more compared to the round cross-sectional fiber having the same fineness, but also a denser arrangement form is obtained, whereby an effect of increasing the surface area is even more conspicuous. In such a case, since the adsorption efficiency of the functional substance is further increased and the function can be effectively exhibited, the flatness is preferably 30 or more.

[0058] In addition, in the case where the flatness is 40 or more, the directions of the fibers are prevented from being disturbed and overlapped in a part of the fiber bundle due to the conspicuous shape anisotropy, and a dense arrangement form in which the fiber directions are uniformly aligned as a whole is obtained. With such an arrangement form, a homogeneous function without unevenness as a whole can be obtained, and thus the flatness is more preferably 40 or more.

[0059] Further, in the case where the flatness is 50 or more, even when the fiber bundle of the flat ultrafine fibers is twisted, an arrangement direction can be freely changed while maintaining the arrangement form in which the fiber directions are aligned, such as the fibers being arranged radially without disturbance with respect to a fiber bundle center. Such a feature exhibits an excellent effect of controlling the strength of the function derived from the functional substance, and when it is desired to change the fiber arrangement direction, the flatness is particularly preferably 50 or more.

[0060] As the flatness of the cross section increases, bending or cracking tends to occur in the major axis direction of the cross section when an external force is applied in the processing process. However, in the case where the flatness is less than 500, the object of the present invention can be achieved without any problem in practical use.

[0061] As described above, in the multifilament of the present invention, due to the extremely high flatness of the fiber cross sections of the flat ultrafine fibers constituting the multifilament, the specific surface area, which is the surface area per weight, increases compared to the normal fibers, and furthermore, the fibers are densely arranged, whereby a very large fiber surface is generated when a fiber aggregate is formed.

[0062] The specific surface area of the monofilament is greatly affected not only by the flatness of the cross section but also by a fiber diameter, and the fiber diameter is also an important requirement to make an effect of increasing the surface area derived from the cross-sectional shape sufficient. As an index of the fiber diameter, a second requirement for the multifilament of the present invention is that a thickness of the flat ultrafine fiber, that is, the length of the minor axis of the fiber cross section is small, and the multifilament of the present invention is required to have an average thickness of 1000 nm or less.

[0063] Here, the average thickness is calculated by rounding an arithmetic mean of the lengths of minor axes of the 100 fibers measured above to a nearest integer in units of nm.

[0064] In the case where the average thickness of the flat ultrafine fibers is 1000 nm or less, a specific surface area equal to or larger than that of ordinary ultrafine fibers can be obtained at least, and high adsorption efficiency is achieved. For this reason, in the multifilament of the present invention, the average thickness of the flat ultrafine fibers may need to be 1000 nm or less.

[0065] As described above, as the average thickness of the flat ultrafine fibers is small, the effect of increasing the specific surface area of the monofilament is promoted, and the thickness also affects flexural rigidity of the fiber, and thus an excellent effect in densification of the fiber bundle is obtained. That is, the flexural rigidity in the minor axis direction decreases in proportion to the cube of the thickness of the fiber, and by reducing the thickness, the fiber can flexibly deform to follow the shape with respect to irregularities or the like, and the fiber bundle structure is easily densified. In the case where the average thickness is 800 nm or less, not only the effect of increasing the specific surface area is further enhanced, but also the fiber is deformed so as to follow the shape, and thus formation of coarse voids between the fibers can be effectively prevented, and a dense structure is easily formed. For this reason, the average thickness is preferably 800 nm or less.

[0066] In the case where the average thickness is 500 nm or less, the flexibility of the fiber becomes extreme, and an intermolecular force such as a van der Waals force acts to form a fiber bundle as if the monofilaments are bonded to each other. In such a case, the voids between the fibers are extremely minute voids of several nm to several hundred nm, and an excellent effect is exhibited from the viewpoint of exhibiting a high durability function to be described later, and thus the average thickness is more preferably 500 nm or less.

[0067] Further, in the case where the average thickness is 300 nm or less, the structure in which the monofilaments are aggregated as described above is homogeneously taken in the entire fiber bundle, and a homogeneous function is exhibited without unevenness throughout when the functional processing is performed. For this reason, the average length of the minor axis is particularly preferably 300 nm or less.

[0068] The multifilament of the present invention tends to be broken in the case where an external force is applied in the processing process as the average thickness of the fiber cross section becomes thinner. However, in the case where the average thickness is 50 nm or more, the object of the present invention can be achieved without any problem in practical use.

[0069] As described above, in the multifilament of the present invention, due to a shape of the cross section having the extremely high flatness of the flat ultrafine fibers constituting the multifilament, the specific surface area of the fiber is greatly increased, and furthermore, dense fiber bundle with aligned directions is formed, whereby a very large fiber surface is formed per unit volume. By utilizing the large fiber surface, not only the adsorption efficiency of the functional substance can be dramatically increased, but also the durability can be dramatically improved with the specific fiber bundle structure. That is, in the case where the multifilament of the present invention is subjected to functional processing, not only a large amount of the functional substance is adsorbed on the fiber surface, but also a functional substance D enters between the flat ultrafine fibers 4 which are aligned and overlapped as shown in FIG. 7. Therefore, while a large amount of the functional substance is enclosed in the fiber bundle, the functional substance is in a distribution state in which the functional substance is hardly exposed on a surface of the fiber bundle, the functional substance is less likely to peel off due to rubbing or the like, and durability in terms of functionality is improved.

[0070] From the viewpoint of utilizing the feature of the multifilament of the present invention to exhibit a function more effectively in functional processing, the ease of impregnation with a functional substance is also important, and the variation in thickness of the flat ultrafine fiber is an indicator to be noted.

[0071] Here, the variation in thickness is determined by calculating an arithmetic mean and a standard deviation using the lengths of the minor axes of the 100 fibers measured as described above, dividing the standard deviation by the arithmetic mean to obtain a coefficient of variation, and rounding the coefficient of variation to a nearest integer in units of %.

[0072] As described above, since the flexural rigidity of the fiber greatly changes depending on the thickness, in the case where there is an appropriate variation in thickness, a behavior becomes heterogeneous for each monofilament, and for example, each monofilament behaves differently in a liquid containing a functional substance and is favorably dispersed. In such a case, the fiber surface is exposed to the liquid without being inhibited by other fibers, and the functional substance can be efficiently adsorbed.

[0073] In the case where the variation in thickness is 10% or more, the monofilaments are easily dispersed well in a liquid or the like and the functional substance is easily impregnated, and thus the variation in thickness is preferably 10% or more.

[0074] Proceeding from the above viewpoint, as the variation in thickness of the fibers increases, the behavior of each monofilament becomes more heterogeneous and the monofilaments are easily dispersed, and in the case where it is desired to effectively expose the surface of the monofilament and complete the functional processing in a short time, the variation in thickness is more preferably 20% or more.

[0075] In the case where the variation in thickness is 40% or more, even in the case of a high-density woven or knitted fabric in which fibers are tightly bound, the liquid easily penetrates the monofilaments, and in the case where it is desired to efficiently perform functional processing with the high-density woven or knitted fabric, the variation in thickness is particularly preferably 40% or more.

[0076] As the variation in thickness increases, breakage is likely to occur in a fiber having a small thickness when an external force is applied in the processing process, but in the case where the variation in thickness is less than 70%, the object of the present invention can be achieved without any problem in actual use.

[0077] Depending on the degree of unevenness of the fiber surface, a dispersion state of the monofilaments during functional processing may be improved, and the degree of unevenness of the cross section is also an indicator to be noted. That is, the presence of appropriate unevenness on the fiber surface results in formation of minute voids of several nm to several hundred nm between the fibers, and the monofilaments are easily effectively dispersed in a liquid containing a functional substance or the like starting from the minute voids.

[0078] Here, the degree of unevenness refers to the degree of unevenness of a monofilament, which is obtained by using the image of the fiber cross section captured to measure lengths at which line segments orthogonal to a line segment having a maximum length intersect the fiber cross section at points obtained by equally dividing a maximum length of the cross section by 10, calculating an arithmetic mean and a standard deviation of the lengths at 10 points, dividing the standard deviation by the arithmetic mean, and rounding a resulting value to a nearest integer in units of%. The same measurement is performed on the cross sections of 10 fibers, and an arithmetic mean of the calculated the degree of unevenness of the 10 fibers is defined as the degree of unevenness of the present invention.

[0079] In the case where the degree of unevenness is 20% or more, the monofilaments are easily dispersed starting from the minute voids between the fibers, and the functional processing can be completed in a short time, and thus the degree of unevenness is preferably 20% or more.

[0080] As the degree of unevenness increases, a load is concentrated on a part of the cross section and cracking tends to occur, but in the case where the degree of unevenness is less than 60%, the object of the present invention can be achieved without any problem in practical use.

[0081] Since the multifilament of the present invention can greatly increase the specific surface area while maintaining the cross-sectional area of the fiber due to the specific cross-sectional shape of the fiber cross section, the monofilament has the same tenacity as that of a normal fiber, and the multifilament is excellent in handleability without problems such as unnecessarily lowering the quality of a fiber product. In addition, the flat ultrafine fiber of the present invention has a continuous form in the fiber axis direction, and the number of fiber ends in the fiber bundle is reduced, and thus the quality of the fiber product is hardly impaired and the handleability is excellent. The polymer constituting the flat ultrafine fiber is preferably a crystalline polymer in view of the processability in a normal textile processing process and practical use, and the polymer constituting the flat ultrafine fiber preferably contains at least one polymer selected from the group consisting of polyester, polyamide, and polyolefin. In addition to the above advantages, since these polymers are thermoplastic, the multifilament of the present invention can be produced not only by a melt spinning method with high productivity, but also these polymers are preferable from the viewpoint of adjusting mechanical properties and the like such as highly oriented crystallization in the stretching process.

[0082] In the multifilament of the present invention, in view of practical use, the strength of the fiber is preferably 1 cN/dtex or more, and in the case where the multifilament is used as a woven fabric or a sheet material used in a relatively harsh atmosphere, the strength suitably has a strength of 2 cN/dtex or more, and thus the range can be mentioned as a more preferable range.

[0083] By utilizing the features of the multifilament of the present invention, not only the function can be effectively exhibited by adsorbing a larger amount of the functional substance by functional processing, but also the functional substance is enclosed in the fiber bundle by the specific fiber bundle structure, and thus the functional substance hardly peels off and excellent durability can be exhibited. By utilizing the features, it is also possible to obtain a sustained release effect in which the functional substance is gradually released by diffusing the functional substance inside the fiber bundle or deforming the fiber bundle by an external force. Therefore, in the case where the multifilament of the present invention is used as a functional material in combination with a functional substance, the multifilament is preferably processed into a state in which the functional substance is enclosed in a fiber bundle consisting of flat ultrafine fibers

[0084] Here, the functional substance refers to a substance that actively imparts functionality to fibers, and is not particularly limited as long as the functional substance is a compound having a function. The functional substance may be an organic compound or an inorganic compound. Examples of the functionality include, but are not limited to, ultraviolet cut, fragrance, deodorization, antibacterial, pest control, moisture absorption, antistatic effect, flame retarding, antifouling, beauty, and health care.

[0085] In addition, various forms are conceivable as a state in which the functional substance is present in the fibers, and examples of the form include carrying, exhaustion, and physical adsorption by chemical bonding. In order to dramatically improve the functionality and improve durability and texture, it is preferable to process the functional substance using the properties of the flat ultrafine fiber of the present invention well. For example, after a specific functional substance is enclosed in the fiber bundle by functional processing in a general solution, a coating film is formed on the surface of the fiber bundle using the other functional substance by a pad dry method or the like, and thus two or more kinds of functions may be combined, or a limit of a function based on a mutual effect of different functional substances may be investigated.

[0086] As described above, when the features of the multifilament of the present invention are utilized, a functional material efficiently containing a functional substance and having excellent durability can be obtained, and thus the multifilament of the present invention can be widely used in general clothing applications such as innerwear and outerwear, interior applications such as curtain and cloth, vehicle interior applications such as car seats, living applications such as wiping cloth and health products, harmful-substance-removal applications such as filters, industrial-material applications such as battery separators, and the like.

[0087] Hereinafter, an example of a method for producing a conjugate fiber and a multifilament of the present invention will be described in detail.

[0088] The conjugate fiber and the multifilament of the present invention can be produced by a fiber producing process using a composite spinneret as described later, and melt spinning is preferably adopted from the viewpoint of high productivity.

[0089] As the composite spinneret used in the present invention, for example, it is preferable to use a composite spinneret 10 in which three kinds of members, that is, a measuring plate E, a composite plate F, and a discharge plate G, are laminated as shown in FIG. 8. Incidentally, FIG. 8 is an example in which two types of polymers, that is, a component A and a component B, are used, and if necessary, three or more types of polymers may be used for fiber production. In the composite spinneret 10, the measuring plate E measures the amount of polymer per hole of the composite plate F, the composite plate F merges the measured different types of polymer flows to form a composite flow having an interface, and divides and remerges the composite flow to increase the interface in a transverse cross section of the composite flow, and the discharge plate G compresses and discharges the composite flow formed by the composite plate F. Here, the composite flow means a fluid in which a cross section perpendicular to a flow direction is composed of two or more types of polymers.

[0090] In the composite plate F, the number of fine flow paths H each having a merging portion and a branch portion is equal to or larger than the number of discharge holes of the discharge plate G, and installation of the merging portion and the branch portion can be appropriately adjusted so as to form a desired cross section. Here, the merging portion means a portion where two or more flows merge, and the branch portion means a portion where the flow is divided into two or more. With such a configuration, when different types of polymers pass through the composite plate F, the polymers flowing from respective flow path holes merge at the merging portion to form a composite flow, and the composite flow is divided at the branch portion, and by repeating the processes, a cross-sectional morphology, which is required for the conjugate fiber of the present invention, characterized in that the sum of lengths interfaces between two types of polymers is extremely large with respect to the fiber-cross-sectional area is formed. Regarding to the merging and dividing, it is unnecessary to repeat the merging and dividing, and the merging may be performed again after merging, or the dividing may be performed again after dividing. Two types of polymers may be blended in advance in the fluid supplied to the fine flow path of the composite plate F, or a composite flow formed by other method or the like may be used.

[0091] The fine flow path used in the production of the present invention can produce the conjugate fiber of the present invention by employing a flow path configuration that minimizes turbulence of the flow in the flow path. Incidentally, it can be said that the above-described fine flow path has the same feature as a static mixer of the related art in that the fluid is merged or divided in the flow path. However, a general static mixer has a flow path design for the purpose of mixing two types of polymers, and the flow of the inserted polymer is disturbed, and thus it is difficult even for those skilled in the art to produce the conjugate fiber of the present invention. Incidentally, by precisely designing the flow path configuration of the fine flow path of the present invention, the form such as the thickness of respective layers constituting a laminated composite flow formed in the flow path can be controlled, and a fiber cross section of any cross-sectional morphology can be formed.

[0092] In order to avoid complication of the description of the composite spinneret, although not shown, a member forming a flow path may be used in accordance with a spinning machine and a spin pack as a member stacked on the measuring plate E. By designing the measuring plate E in accordance with the existing flow path member, the existing spin pack and the member thereof can be utilized as they are. Therefore, it is unnecessary to exclusively use a spinning machine for the spinneret. Actually, a plurality of flow path plates may be stacked between the flow path and the measuring plate E or between the measuring plate E and the composite plate F. The purpose of this is to provide a flow path through which the polymer is efficiently transferred in a cross-sectional direction of the spinneret and a cross-sectional direction of the monofilament, and to provide a configuration of introducing the polymer into the composite plate F. A composite polymer flow discharged from the discharge plate G is cooled and solidified, then applied with an oil agent and taken up by a roller having a specified peripheral speed to thereby form a conjugate fiber.

[0093] The conjugate fiber of the present invention can be produced using the composite spinneret as described above. Incidentally, the conjugate fiber of the present invention can be produced using the composite spinneret even by a spinning method using a solvent, such as solution spinning.

[0094] In the case where the melt spinning is selected, the polymer constituting the conjugate fiber of the present invention is as described above. Examples thereof include melt-moldable polymers such as polyethylene terephthalate or a copolymer thereof, polyethylene naphthalate, polybutylene terephthalate, polytrimethylene terephthalate, polypropylene, polyolefin, polycarbonate, polyacrylate, polyamide, polylactic acid, and thermoplastic polyurethane. In particular, a polycondensation polymer represented by polyester or polyamide has a high melting point and is more preferable. The polymer may contain various additives such as inorganic materials such as titanium oxide, silica, and barium oxide, coloring agents such as carbon black, dyes, and pigments, a flame retardant, a fluorescent whitening agent, an antioxidant, and an ultraviolet absorbent. In the case where the polymer containing these additives is selected, unevenness corresponding to the particle size of fine particles as the additive occur in each layer of the multilayer laminated fiber, and based on this, any unevenness can be imparted to the flat ultrafine fiber generated.

[0095] Two or more types of these polymers are combined to form a multilayer laminated fiber, and from the viewpoint of improving a laminated structure, a combination of polymers is also important.

[0096] That is, as the solubility parameter (SP value) difference between the polymers to be combined is smaller, a good laminated structure without interlaminar merging is formed, and the polymer is preferably selected such that the solubility parameter difference between two types of polymers forming an interface is 3.0 or less. The solubility parameter herein is as described above.

[0097] From the viewpoint of making an interface layer having properties of two types of polymers formed in the vicinity of the interface, which is a feature of the conjugate fiber of the present invention, apparent, the polymer is preferably polyester because the interface layer is formed in a wider area at one interface. In particular, in the case where an easily soluble polyester in which a metal sulfonate group is copolymerized is used as one polymer, it is preferable to use a hardly soluble polyester as the other polymer because excellent chemical resistance can be imparted even in a fiber containing the easily soluble polyester. In particular, in the case where a polyester copolymerized with sodium sulfoisophthalic acid or polyethylene glycol alone or in combination is used as the polyester copolymerized with the metal sulfonate group, not only excellent chemical resistance but also good color developability after dyeing is obtained, which is preferable. An example of a combination of polymers is to use polyethylene terephthalate copolymerized with 5 mol% to 15 mol% of 5-sodium sulfoisophthalic acid and polyethylene terephthalate copolymerized with 5 wt% to 15 wt% of polyethylene glycol having a weight-average molecular weight of 500 to 3000 in addition to the above 5-sodium sulfoisophthalic acid as one polymer, and polyethylene terephthalate as the other polymer from the viewpoint of melting point.

[0098] A spinning temperature at the time of spinning the conjugate fiber of the present invention is a temperature at which a polymer having a high melting point or high viscosity mainly exhibits fluidity among two or more polymers. The temperature at which the polymer exhibits fluidity may vary depending on the molecular weight, but may be set within a range from a melting point of the polymer to melting point + 60°C or less. The temperature is preferably less than or equal to the above range because the polymer is not thermally decomposed in a spinning head or a spin pack and a decrease in molecular weight is prevented. The conjugate fiber of the present invention can be stably produced by setting the discharge amount in spinning to 0.1 g/min·hole to 20.0 g/min hole. In particular, a single hole discharge amount such that the monofilament fineness after stretching is less than 4 dtex is preferable because a soft texture can be obtained when the woven fabric is formed due to the thinness thereof.

[0099] A ratio of the component A to the component B when spinning the conjugate fiber of the present invention can be selected in a range of 5/95 to 95/5 as the ratio of the component A/component B based on the discharge amount. Even when a polymer inferior in chemical resistance and heat resistance is used, in the case where it is desired to impart excellent chemical resistance and heat resistance by increasing the interface between components, it is preferable to use a polymer excellent in chemical resistance and heat resistance as the other polymer to form a composite and increase the ratio thereof. For example, when the component A is a high-chemical-resistant polymer and the component B is a low-chemical-resistant polymer, the ratio of the component A/component B is preferably 99/1 to 70/30 because the weight of the fiber is slightly reduced even when the dissolution treatment is performed for a long time.

[0100] The polymer flow discharged in this manner is cooled and solidified, applied with an oil agent, and taken up by a roller having a specified peripheral speed to thereby form a conjugate fiber. Here, a take-up speed may be determined by the discharge amount and a target fiber diameter, and is preferably in a range of 100 m/min to 7000 m/min in order to stably produce the conjugate fiber used in the present invention. The conjugate fiber may be stretched from the viewpoint of achieving high orientation and improving mechanical properties. The stretching may be performed after being once wound in the spinning process, or may be continuously performed without being once wound.

[0101] As a stretching condition, for example, in a stretching machine including one or more pairs of rollers, a fiber including a polymer having generally melt-spinnable thermoplastic is easily stretched in the fiber axis direction and heat-set and wound at a peripheral speed ratio between a first roller set at a temperature equal to and more than a glass transition temperature and equal to and less than the melting point and a second roller at a temperature corresponding to a crystallization temperature, and it is possible to obtain a conjugate fiber having a cross-sectional morphology as shown in FIG. 1. The upper limit of the temperature of the first roller is preferably set to a temperature at which a fiber path of the fiber is not disturbed in a preheating process, and for example, in the case of polyethylene terephthalate having a glass transition temperature of about 70°C, a preheating temperature is usually set to about 80°C to 95°C.

[0102] As described above, the method for producing a conjugate fiber of the present invention has been described based on a general melt spinning method, but it is needless to say that the conjugate fiber can be produced by a melt blow method and a spunbond method, and further, the conjugate fiber can be produced by a solution spinning method such as wet and dry-wet methods.

[0103] In order to obtain the multifilament of the present invention from the conjugate fiber having a multilayer laminated structure obtained as described above, by immersing the multilayer laminated fiber in a solvent or the like in which the easily soluble polymer is soluble to remove the easily soluble polymer, it is possible to obtain a flat ultrafine fiber including a hardly soluble polymer, and a fiber bundle thereof. In the case where the easily soluble polymer is the copolymerized polyethylene terephthalate obtained by being copolymerized with 5-sodium sulfoisophthalic acid or the like, an alkaline aqueous solution such as sodium hydroxide aqueous solution can be used. As the method therefor, for example, the multilayer laminated fiber or a textile made of the multilayer laminated fiber may be used and then immersed in an alkaline aqueous solution. At this time, the alkaline aqueous solution is preferably heated to 50°C or higher because the progress of hydrolysis can be accelerated. The method for generating the multifilament from the multilayer laminated fiber is not limited to the above dissolution treatment, but by dissolving and removing the easily soluble polymer, the fiber can be reliably separated into monofilaments of the flat ultrafine fiber including the hardly soluble polymer, damage of the fiber can be controlled to the minimum, and the multifilament of the present invention can be successfully generated.

EXAMPLES

[0104] Hereinafter, the conjugate fiber of the present invention will be specifically described with reference to Examples.

[0105] Examples and Comparative Examples were evaluated as follows.

A. Melt Viscosity

[0106] A chip-shaped polymer was dried with a vacuum dryer so that a moisture content was 200 ppm or less, and the melt viscosity was measured by changing a strain rate in stages with Capillograph manufactured by Toyo Seiki Seisaku-sho, Ltd. The measurement temperature was the same as the spinning temperature, and the melt viscosity at a shear rate of 1216 s^{-1} is described in Examples and Comparative Examples. The measurement was performed under a nitrogen atmosphere and the time from the time a sample was put into a heating furnace until the start of the measurement was 5 minutes.

B. Melting Point

[0107] About 5 mg of the chip-shaped polymer dried with the vacuum dryer so that the moisture content was 200 ppm or less was weighed out, and was heated from 25°C to 300°C at a heating rate of 16 °C/min using a differential scanning calorimetry (DSC) Q2000 manufactured by TA Instruments Japan Inc., and then held at 300°C for 5 minutes to perform DSC measurement. The melting point was calculated based on a melting peak observed during the heating process. The measurement was performed three times for one sample, and an average value thereof was defined as the melting point. In the case where a plurality of melting peaks was observed, the melting peak top on the highest temperature side was defined as the melting point.

C. Solubility Parameter Difference

[0108] A solubility parameter (SP value) is a parameter reflecting the cohesion of a substance defined by the square root of (evaporation energy/molar volume), and was calculated by immersing the polymer in various solvents and setting a value of (evaporation energy/molar volume) of a solvent with a maximum swelling pressure as (evaporation energy/molar volume) of the polymer. The SP value calculated in this manner is described in, for example, "Plastic Data Book", coedited by Asahi Kasei Amidas Co., Ltd./Plastic Editorial Department, page 189 and other pages, and the value can be used. The solubility parameter difference between the polymers to be combined was calculated as an absolute value of (SP value of component A - SP value of component B).

D. Fineness

[0109] A weight of 100 m of the conjugate fiber was measured, and a value calculated by multiplying a value of the weight by 100 was calculated. The measurement was repeated 10 times, and an average value thereof was defined as fineness (dtex). A value calculated by dividing the fineness by the number of filaments was defined as the monofilament fineness (dtex).

E. Uster U%

[0110] The Uster U% (H) of the conjugate fiber was measured using a fineness unevenness measuring apparatus (UT-4) manufactured by Zellweger under the conditions of a fiber feeding speed of 100 m/min, a twister rotation speed of 6000 rpm, and a measurement length of 100 m.

F. Sum of Interfacial Lengths/Fiber-Cross-Sectional Area (nm^{-1})

[0111] The conjugate fiber was embedded with an embedding agent such as an epoxy resin, frozen in a FC-4E cryosectioning system manufactured by Reichert, and cut with a Reichert-Nissei ultracut N (ultramicrotome) equipped with a diamond knife. Thereafter, the cut surface was imaged with a H-7100FA transmission electron microscope (TEM) manufactured by Hitachi, Ltd. at a magnification at which an interface formed by two types of polymers could be identified. Using image analysis software (WINROOF), a length of one interface from a measurement start point freely determined back to the measurement start point again was measured and rounded to a nearest integer in units of nm to thereby obtain the length (interfacial length) of one interface. In the case of reaching the outer periphery of the fiber cross section before returning to the measurement start position, the length was measured without including a length of a portion passing through the outer periphery in the length from the measurement start point back to the measurement start position again along the interface and the outer periphery. The same measurement was performed on all the interfaces present in fiber cross section, and all the interfacial lengths were added to thereby calculate the sum of the interfacial lengths. By dividing the calculated sum of the interfacial lengths by the fiber-cross-sectional area, a value of the sum of interfacial lengths/fiber-cross-sectional area was calculated by rounding the obtained value to the fifth decimal place in units of nm^{-1}. In order to calculate the fiber-cross-sectional area, the conjugate fiber was cut perpendicularly to the fiber axis direction at any position in the fiber axis direction, the cut surface was two-dimensionally imaged with an optical microscope manufactured by OLYMPUS Corporation at a magnification at which an entire cross section of one filament could be observed, the cross section of one filament was extracted using the image analysis software (WINROOF), and then the fiber cross section was calculated by rounding the cross-sectional parameters obtained by the binarization processing to a nearest integer in units of nm.

G. Variation in Layer Thickness (Conjugate fiber)

[0112] A length of a layer existing on a straight line vertically bisecting a long side of one layer (film-like element) constituting the fiber cross section was defined as the layer thickness, and 100 elements of the component B were randomly extracted from the cross section image of the conjugate fiber imaged by the same method as the above method of measuring the sum of the interfacial lengths, and the layer thickness thereof was measured and rounded to a nearest integer in units of nm. In the case where the number of layers in the cross section of one conjugate fiber was less than 100, a total of 100 layers were obtained from cross sections of many conjugate fibers. The variation in thickness was calculated by calculating an arithmetic mean and a standard deviation of the obtained values, dividing the standard deviation by the arithmetic mean to obtain a coefficient of variation, and rounding the coefficient of variation to a nearest integer in units of %. In the case of radial lamination and concentric lamination in which the layer thickness could not be measured by the above method, a portion having the largest thickness and a portion having the smallest thickness of each layer were visually selected, the average value thereof was set as the thickness of each layer, and the coefficient of variation obtained by dividing the standard deviation by the arithmetic mean in the same manner as described above was calculated as the variation in layer thickness.

H. Average Layer Thickness (Conjugate fiber)

[0113] A length of a layer existing on a straight line vertically bisecting a long side of one layer constituting the fiber cross section was defined as the layer thickness, and 100 elements of the component B were randomly extracted from the cross section image of the conjugate fiber imaged by the same method as the above method of measuring the sum of the interfacial lengths, and the layer thickness thereof was measured and rounded to a nearest integer in units of nm. In the case where the number of layers in the cross section of one conjugate fiber was less than 100, a total of 100 layers were obtained from cross sections of many conjugate fibers. An arithmetic mean of the obtained values was rounded to a nearest integer in units of nm to calculate the average layer thickness. In the case of radial lamination and concentric lamination in which the layer thickness could not be measured by the above method, a portion having the largest thickness and a portion having the smallest thickness of each layer were visually selected, the average value thereof was set as the thickness of each layer, and the arithmetic mean thereof was calculated as the average layer thickness in the same manner as described above.

I. Abrasion Resistance

[0114] The number of conjugate fibers was adjusted so that the weave density was 180 fibers/2.54 cm, and a plain weave fabric was produced. A plain weave fabric cut to have a diameter of 10 cm was set in a sample holder of an appearance retention tester (ART type tester) manufactured by Daiei Kagaku Seiki Mfg. Co., Ltd., a pressing load was set to 3.9 N, the plain weave fabric was rubbed with a silicon carbide friction plate (3K), the friction was stopped every time the friction plate rotated once, the number of times of friction at which the generation of fibril on the fiber surface was confirmed was measured, and an average value of five measurements was calculated. Here, the number of times of friction was obtained by rounding off decimal places, and the abrasion resistance of the fiber was evaluated according to the following four levels.

(Evaluation Criteria)

[0115]

A (excellent): The number of times of friction was 100 times or more.
B (good): The number of times of friction was 50 times or more and less than 100 times.
C (fair): The number of times of friction was 20 times or more and less than 50 times.
D (poor): The number of times of friction was less than 20 times.

J. Chemical Resistance

[0116] A tubular knitted fabric of the conjugate fiber was prepared, treated with a 1% sodium hydroxide aqueous solution at 90°C for 30 minutes, washed with water, and sufficiently dried at 60°C, and a weight loss rate was calculated based on weights before and after the treatment. Here, a value of the weight loss rate is a value rounded to the second decimal place, and the chemical resistance was evaluated according to the following four levels.

(Evaluation Criteria)

[0117]

A (excellent): The weight loss rate was 0.0% or more and less than 2.0%.
B (good): The weight loss rate was 2.0% or more and less than 5.0%.
C (fair): The weight loss rate was 5.0% or more and less than 10.0%.
D (poor): The weight loss rate was 10.0% or more.

K. Heat Resistance

[0118] A skein was collected by winding the conjugate fiber 10 times using a measuring machine with a frame circumference of 1.0 m, and a skein length before treatment was measured under a load of 0.0294 cN/dtex. The skein was placed in a hot air dryer at 160°C in a load-free state and treated for 15 minutes, a load of 0.0294 cN/dtex was again applied to the skein taken out, and the skein length after the treatment was measured. A dry heat shrinkage ratio was calculated from the skein length before the treatment and the skein length after the treatment by the equation [dry heat shrinkage ratio (%) = (skein length before treatment - skein length after treatment)/skein length before treatment x 100].

The dry heat shrinkage ratios were determined from five measurements, and an arithmetic mean thereof was calculated and rounded to the second decimal place. A fiber surface of the treated skein was observed with an optical microscope manufactured by Olympus Corporation to confirm whether fusion bonding occurred between the fibers, and the heat resistance was evaluated according to the following three levels.

(Evaluation Criteria)

[0119]

A (good): The dry heat shrinkage ratio was less than 15.0%, and there was no fusion bonding between fibers.
B (fair): The dry heat shrinkage ratio was 15.0% or more, and there was no fusion bonding between fibers.
C (poor): There was fusion bonding between fibers.

L. Flatness

[0120] The multifilament consisting of flat ultrafine fibers was embedded with an embedding agent such as an epoxy resin, frozen in a FC-4E cryosectioning system manufactured by Reichert, and cut with a Reichert-Nissei ultracut N (ultramicrotome) equipped with a diamond knife, and then the cut surface was imaged with a H-7100FA transmission electron microscope (TEM) manufactured by Hitachi, Ltd. at a magnification at which a cross section could be identified. A maximum length of the cross section of the monofilament was measured using the image analysis software (WINROOF), and the value was rounded to a nearest integer in units of nm to thereby obtain a length of a major axis of the monofilament. Next, a length at which a line segment orthogonal to a line segment having the maximum length intersects the fiber cross section at a midpoint of the maximum length was measured, and the value was rounded to a nearest integer in units of nm to thereby obtain a length of a minor axis of the monofilament. Using the length of the major axis and the length of the minor axis, the flatness of the monofilament was calculated by the following equation.

$$\text{Flatness} = \text{length (nm) in major axis direction}/\text{length (nm) in minor axis direction}$$

[0121] The above measurement was carried out for 100 fibers to calculate the flatness of each fiber, and the flatness of the flat ultrafine fiber was calculated by rounding an arithmetic mean of the flatness to a nearest integer.

M. Average thickness of Fiber (Flat Ultrafine Fiber)

[0122] The average thickness of the flat ultrafine fibers was calculated by rounding an arithmetic mean of the lengths of minor axes of the 100 fibers measured above to a nearest integer in units of nm.

N. Variation in Thickness of Fiber (Flat Ultrafine Fiber)

[0123] The variation in thickness of the flat ultrafine fibers was determined by calculating an arithmetic mean and a standard deviation using the lengths of the minor axes of the 100 fibers measured as described above, dividing the standard deviation by the arithmetic mean to obtain a coefficient of variation, and rounding the coefficient of variation to a nearest integer in units of %.

O. Degree of unevenness

[0124] The degree of unevenness of the monofilament was calculated by using the image of the fiber cross section imaged above to measure lengths at which line segments orthogonal to a line segment having a maximum length intersected the fiber cross section at points obtained by equally dividing a maximum length of the cross section by 10, calculating an arithmetic mean and a standard deviation of the lengths at 10 points, dividing the standard deviation by the arithmetic mean, and rounding a resulting value to a nearest integer in units of%. The same measurement was performed on the cross sections of 10 fibers, and an arithmetic mean of the calculated the degree of unevenness of the 10 monofilaments was defined as the degree of unevenness of the flat ultrafine fiber.

P. Distribution State of Functional Substance

[0125] In order to perform model evaluation on a distribution state of a functional substance when a fiber bundle was treated with the functional substance, a woven fabric was treated at a bath ratio of 1: 50, a treatment temperature of

30°C, and a treatment time of 30 minutes using a dye solution prepared by adjusting an acid dye telon Black LD02 manufactured by Dystar, which is non-staining to polyester, to 10 %owf, and then a surface and a cross section of the woven fabric were observed with a digital microscope VHX-6000 manufactured by Keyence Corporation. The distribution state at this time was determined based on the following criteria.

(Evaluation Criteria)

[0126] Inside the fiber bundle: A dye (colored substance) was present between fibers in a cross section of the fiber bundle.

[0127] None: No dye (colored substance) was present between fibers in the cross section of the fiber bundle.

Q. Functional Processing (Deodorizing)

[0128] Using a 10% aqueous solution of dodecanedioic acid dihydrazide having an adsorption ability to acetaldehyde, a woven fabric was treated at a solid content of 20 %owf, a bath ratio of 1: 20, a treatment temperature of 130°C, and a treatment time of 1 hour.

R. Deodorizing Property (Acetaldehyde Concentration)

[0129] Under a humidified environment with a temperature of 20°C and a humidity of 65 %RH, 1g of the woven fabric functionally processed in the above Q was put into a 5L tetrabag, 3L of acetaldehyde with a concentration of 30 ppm was injected into the tetrabag, and a gas concentration (ppm) in the tetrabag after 10 minutes was measured using a gas detector tube (manufactured by Gastec Corporation).

S. Content of Functional Substance

[0130] The woven fabric before the processing was dried at 110°C for 2 hours, and a weight thereof was measured (W1). The woven fabric functionally processed in the above Q was dried at 110°C for 2 hours, and a weight thereof was measured (W2). From the weights before and after the processing, the content (%) of the functional substance was calculated by the following equation.

$$\text{Content (\%) of functional substance} = (W2 - W1)/W1 \times 100$$

T. Content of Functional Substance after Washing

[0131] The woven fabric functionally processed in the above Q was subjected to 50 cycles of washing (15 minutes) → dewatering (1 minute) → rinsing (6 minutes) → dewatering (1 minute) → drying in this order. Washing conditions used were a water temperature of 40°C, a bath ratio of 1: 30, and 0.5 g/l of detergent "Top" (manufactured by Lion Corporation). Rinsing conditions were a water temperature of 20°C and a bath ratio of overflow.

[0132] The washed woven fabric was dried at 110°C for 2 hours, and a weight thereof was measured (W3). From the weights before the processing and after the washing, the content (%) of the functional substance was calculated by the following equation.

$$\text{Content (\%) of functional substance after washing} = (W3 - W1)/W1 \times 100$$

[Example1]

[0133] Polyethylene terephthalate (PET, melt viscosity: 120 Pa·s, melting point: 254°C, SP value: 21.4 $\text{MPa}^{1/2}$) as the component A and polyethylene terephthalate (SSIA-PEG-copolymerized PET, melt viscosity: 95 Pa·s, melting point: 233°C, SP value: 22.9 $\text{MPa}^{1/2}$), which was obtained by copolymerizing 8.0 mol% of 5-sodium sulfoisophthalic acid and 9 wt% of polyethylene glycol, as the component B were prepared.

[0134] The component A and the component B were separately melted at 290°C, a composite ratio of the component A/component B was set to 90/10, and the melted component A and the melted component B flowed into the spin pack in which the composite spinneret 10 shown in FIG. 8 was incorporated, and a composite polymer flow was discharged from the discharge holes. The composite plate F was provided with the fine flow paths H that can alternately laminate both components into 1024 layers, and two types of polymers shown in FIG. 1 were discharged in a cross-sectional morphology in which the two types of polymers were alternately laminated in one direction in multiple layers. The discharged composite polymer flow was cooled and solidified, applied with an oil agent, and wound at a spinning speed of 1000 m/min to collect an undrawn fiber of 200 dtex-24 filament (total discharge amount: 20 g/min). The wound undrawn fiber was drawn 3.6 times between rollers heated to 90°C and 130°C to thereby obtain a drawn fiber of 56 dtex-24 filament. The U% (H) which is an index of fineness unevenness was 0.6%, and the thickness uniformity in the fiber axis direction was excellent.

[0135] When a cross section of the obtained conjugate fiber was observed, the sum of interfacial lengths/fiber-cross-sectional area was 0.0557 nm^{-1}, the sum of the interfacial lengths with respect to the fiber-cross-sectional area was extremely large, and the same interface was continuous in the fiber axis direction. In addition, an average layer thickness of the component B was 4 nm, and a variation in layer thickness was as relatively large as 32%, and the cross section was divided into extremely thin film-like elements.

[0136] As a result of evaluating peeling resistance of a woven fabric formed by weaving the obtained conjugate fibers, generation of fibrils was not observed even when the number of times of friction was set to 100 times or more. Incidentally, when the cross section of the conjugate fiber after the abrasion resistance evaluation was observed with the scanning electron microscope (SEM) manufactured by Hitachi, Ltd., no peeling between components was observed.

[0137] When a tubular knitted fabric of the obtained conjugate fiber was immersed for 30 minutes in a sodium hydroxide aqueous solution (bath ratio: 1: 50) with a concentration of 1% heated to 90°C, the weight loss rate was 0.6%.

[0138] The results are shown in Table 1.

[Examples 2, 3, 4, 5, 6]

[0139] Examples 2, 3, 4, 5, and 6 were carried out in the same manner as in Example 1 except that the composite plate of Example 1 was changed to a composite plate provided with fine flow paths in which the total number of layers of the component A and the component B was laminated to 512 layers (Example 2), 256 layers (Example 3), 128 layers (Example 4), 64 layers (Example 5), and 32 layers (Example 6) in the method described in Example 1. The evaluation results of the conjugate fibers are shown in Table 1.

[0140] The conjugate fibers of Examples 2 to 6 each had a composite structure as shown in FIG. 1 in which two types of polymers were laminated alternately in one direction in multiple layers, and the same interface was continuous in the fiber axis direction. In Example 2, generation of fibrils was not observed even when the number of times of friction was set to 100 times or more. However, in Examples 3 to 6, a value of the sum of interfacial lengths/fiber-cross-sectional area decreased as the number of laminated layers of the two types of polymers in the fiber cross section decreased compared to Example 2, and thus fibrils were observed in several monofilaments when the number of times of friction was 50 or more. When a cross section of the fibrillated conjugate fiber was observed by the same method as described above, it was presumed that the fiber was split in a direction in which the two types of polymers were bonded, which may be caused by peeling between the components. In Examples 2 and 3, as the value of the sum of interfacial lengths/fiber-cross-sectional area decreased, the weight loss rate slightly increased but was less than 2.0%, and the chemical resistance was excellent. In Examples 5 and 6 in which the value of the sum of interfacial lengths/fiber-cross-sectional area was further decreased, the weight loss rate was increased to 5.0% or more, and the chemical resistance was reduced compared to Examples 1 to 3.

[Comparative Example 1]

[0141] Comparative Example 1 was carried out in the same manner as in Example 1 except that the composite plate of Example 1 was changed to a composite plate provided with fine flow paths in which the total number of layers of the component A and the component B was laminated to 8 layers (Comparative Example 1) in the method described in Example 1. The evaluation results of the conjugate fibers are shown in Table 1.

[0142] The conjugate fiber of Comparative Example 1 had a composite structure as shown in FIG. 1 in which two types of polymers were alternately laminated in one direction in multiple layers, but the number of divisions (the number of laminated layers) was significantly smaller than that of the conjugate fiber of the present invention, and the value of the sum of interfacial lengths/fiber-cross-sectional area was small. Therefore, when the number of times of friction was 20 or more, fibrils were observed in a large number of monofilaments, and the abrasion resistance was inferior. In addition, when the chemical resistance of the tubular knitted fabric of the obtained conjugate fiber was evaluated, the weight loss rate was 10.0% or more, and the chemical resistance was inferior. Incidentally, when the tubular knitted fabric after the chemical resistance evaluation was dyed under the same conditions as described above, the tubular knitted fabric was not dyed, and it was presumed that almost all of the easily soluble SSIA-PEG-copolymerized PET constituting the conjugate fiber was dissolved by the chemical resistance evaluation.

[Example 7]

[0143] Example 7 was carried out in the same manner as in Example 1 except that polyethylene terephthalate (SPG-CHDC-copolymerized PET, melt viscosity: 75 Pa·s, melting point: none [glass transition temperature: 76°C], SP value: 23.0 MPa$^{1/2}$), which was obtained by copolymerizing 21 mol% of spiroglycol and 29 mol% of cyclohexanedicarboxylic acid, was used as the component B, and the component B was melted at 285°C so that a composite ratio of the component A/component B was 50/50 in the method described in Example 1. The evaluation results of the conjugate fiber are shown in Table 2.

[0144] The conjugate fiber of Example 7 had a composite structure as shown in FIG. 1 in which two types of polymers were laminated alternately in one direction in multiple layers, and the same interface was continuous in the fiber axis direction. As a result of evaluating peeling resistance of a woven fabric made of the obtained conjugate fiber, generation of fibrils was not observed even when the number of times of friction was set to 100 times or more. When a skein of the obtained conjugate fiber was treated with a hot air dryer at 160°C for 15 minutes, a dry heat shrinkage ratio was less than 15.0%, and the thermal dimensional stability was excellent, and fusion bonding between fibers was not observed even though the SPG-CHDC-copolymerized PET which is amorphous and has a glass transition temperature equal to or lower than the treatment temperature of the hot air dryer was used.

[Examples 8, 9]

[0145] Examples 8 and 9 were carried out in the same manner as in Example 7 except that the composite plate of Example 7 was changed to a composite plate provided with fine flow paths in which the total number of layers of the component A and the component B was laminated to 512 layers (Example 8) and 256 layers (Example 9) in the method described in Example 7. The evaluation results of the conjugate fibers are shown in Table 2.

[0146] In Example 8, generation of fibrils was not observed even when the number of times of friction was set to 100 times or more. However, in Example 9, the value of the sum of interfacial lengths/fiber-cross-sectional area decreased as the number of laminated layers of the two types of polymers in the fiber cross section decreased compared to Example 8, and thus fibrils were observed in several monofilaments when the number of times of friction was 50 or more. Since a composite ratio of the SPG-CHDC-copolymerized PET having inferior heat resistance was increased, the dry heat shrinkage ratio was increased, and the heat resistance was decreased although the heat resistance was at an unproblematic level in Example 9. In Example 9, since two types of polymers having different properties were alternately laminated with a layer thickness such that thin-film interference of visible light occurred, the obtained conjugate fiber was structurally colored in blue.

[Comparative Example 2]

[0147] Comparative Example 2 was carried out in the same manner as in Example 7 except that a composite plate provided with fine flow paths in which the total number of layers of the component A and the component B was laminated to 8 layers was used in the method described in Example 7. The evaluation results of the conjugate fibers are shown in Table 2.

[0148] The conjugate fiber of Comparative Example 2 had a composite structure shown in FIG. 1 in which two types of polymers were alternately laminated in one direction in multiple layers, but the number of divisions (the number of laminated layers) was significantly smaller than that of the conjugate fiber of the present invention, and the value of the sum of interfacial lengths/fiber-cross-sectional area was small. Therefore, when the number of times of friction was 20 or more, fibrils were observed in a large number of monofilaments, and the abrasion resistance was inferior. In addition, when the heat resistance of the tubular knitted fabric made of the obtained conjugate fiber was evaluated, the dry heat shrinkage ratio was 20.0% or more, the fusion bonding between the fibers was significant, and the texture of the skein was very hard.

[Examples 10, 11, 12]

[0149] Examples 10, 11, and 12 were carried out in the same manner as in Example 7 except that the component B was changed to polyamide-6 (N6, melt viscosity of 100 Pa·s, melting point: 225°C, SP value: 23.7 MPa$^{1/2}$) and melted at 280°C and a composite plate provided with fine flow paths in which both components were laminated to 1024 layers (Example 10), 512 layers (Example 11), and 256 layers (Example 12) was used in the method described in Example 7. The evaluation results of the conjugate fibers are shown in Table 3.

[0150] In Examples 10 to 12, since polymers having a large solubility parameter difference were composited to form a conjugate fiber, fibrils were observed in several monofilaments when the number of times of friction was 50 times or more, but the abrasion resistance was generally good.

[Examples 13, 14]

[0151] Examples 13 and 14 were carried out in the same manner as in Example 10 except that the composite plate of Example 10 was changed to a composite plate provided with fine flow paths in which the total number of layers of the component A and the component B was laminated to 256 layers, and the flow path arrangement was changed to have a concentric laminated structure (Example 13) and a radial laminated structure (Example 14) in the method described in Example 10. The evaluation results of the conjugate fibers are shown in Table 3.

[0152] In Example 13, a composite structure as shown in FIG. 4 in which two types of polymers were alternately laminated concentrically in multiple layers was formed, and in Example 14, a composite structure as shown in FIG. 3 in which two types of polymers were alternately laminated radially in multiple layers was formed, and the same interface was continuous in the fiber axis direction in both Examples. Since polymers having a large solubility parameter difference were composited to form a conjugate fiber, fibrils were observed in several monofilaments when the number of times of friction was 50 times or more, but the abrasion resistance was generally good.

[Comparative Example 3]

[0153] Comparative Example 3 was carried out in the same manner as in Example 10 except that a composite plate provided with fine flow paths in which the total number of layers of the component A and the component B was laminated to 8 layers was used in the method described in Example 10. The evaluation results of the conjugate fiber are shown in Table 3.

[0154] The conjugate fiber of Comparative Example 3 had a composite structure as shown in FIG. 1 in which two types of polymers were alternately laminated in one direction in multiple layers, but the number of divisions (the number of laminated layers) was significantly smaller than that of the conjugate fiber of the present invention, and the value of the sum of interfacial lengths/fiber-cross-sectional area was small. Therefore, even when the number of times of friction was 20 or less, fibrils were generated in a large number of monofilaments, and the abrasion resistance was inferior. In addition, fibrillation also occurs in a weaving process, and fiber breakage frequently occurs, resulting in a problem in textile processing passability.

[Comparative Example 4]

[0155] Comparative Example 4 was carried out in the same manner as in Comparative Example 3 except that a composite plate provided with a flow path for discharging only the component A around fine flow paths in which both components were laminated to 8 layers was used in the method described in Comparative Example 3. The evaluation results of the conjugate fiber are as shown in Table 3. The multilayer laminated structure was a composite structure (coated unidirectional-laminated fiber 6) coated with the component A as shown in FIG. 9, but the number of laminated layers was significantly smaller than that of the conjugate fiber of the present invention, and the value of the sum of interfacial lengths/fiber-cross-sectional area was small. Therefore, even in the case where the coating was provided on the fiber surface, when the number of times of friction was 20 times or less, a large number of monofilaments were fibrillated, and the abrasion resistance was inferior.

[Example 15]

[0156] Polyethylene terephthalate (PET, melt viscosity: 120 Pa·s, melting point: 254°C, SP value: 21.4 MPa$^{1/2}$) as the component A and polyethylene terephthalate (SSIA-PEG-copolymerized PET, melt viscosity: 95 Pa·s, melting point: 233°C, SP value: 22.9 MPa$^{1/2}$), which was obtained by copolymerizing 8.0 mol% of 5-sodium sulfoisophthalic acid and 9 wt% of polyethylene glycol, as the component B were prepared. The solubility parameter difference between these polymers is 1.5 MPa$^{1/2}$.

[0157] The component A and the component B were separately melted at 290°C, a composite ratio of the component A/component B was set to 80/20, and the melted component A and the melted component B flowed into the spin pack in which the composite spinneret 10 shown in FIG. 8 was incorporated, and a composite polymer flow was discharged from the discharge holes. The composite plate F was provided with the fine flow paths H that can alternately laminate both components into 128 layers, and two types of polymers shown in FIG. 1 were discharged in a cross-sectional morphology in which the two types of polymers were alternately laminated in one direction in multiple layers. The discharged composite polymer flow was cooled and solidified, applied with an oil agent, and wound at a spinning speed of 1000 m/min to collect an undrawn fiber of 300 dtex-24 filament (total discharge amount: 30 g/min). The wound undrawn fiber was drawn 3.6 times between rollers heated to 90°C and 130°C to obtain a drawn fiber of 84 dtex-24 filament. The U% (H) which is an index of fineness unevenness was 0.6%, and the thickness uniformity in the fiber axis direction was excellent.

[0158] When a cross-sectional shape of the obtained conjugate fiber was observed, it was confirmed that the conjugate fiber had a plate-like laminated structure in which lamination directions were aligned as shown in FIG. 1 and was a multilayer laminated fiber.

[0159] As a result of evaluating peeling resistance of a woven fabric formed by weaving the obtained conjugate fibers, generation of fibrils was not observed even when the number of times of friction was set to 50 times or more. Incidentally, when the cross section of the conjugate fiber after the abrasion resistance evaluation was observed with the scanning electron microscope (SEM) manufactured by Hitachi, Ltd., no peeling between components was observed, and the conjugate fiber had excellent abrasion resistance.

[0160] By immersing the conjugate fiber for 30 minutes or more in a sodium hydroxide aqueous solution (bath ratio: 1: 50) with a concentration of 1% heated to 90°C, 99% or more of SSIA-PEG-copolymerized PET as the component B was removed to thereby obtain a multifilament consisting of flat ultrafine fibers. The woven fabric formed by weaving the conjugate fiber was treated in the same manner to thereby obtain a woven fabric consisting of flat ultrafine fibers.

[0161] When the cross section of the obtained flat ultrafine fibers was observed, the cross section was a ribbon-like cross section in which the lengths of the major axis and the minor axis were significantly different, and had the flatness of 80 and an average thickness of 225 nm. The cross section had a variation in thickness of 36% and the degree of unevenness of 30%, and the flat ultrafine fibers had an appropriate variation in thickness and appropriate unevenness on the surface.

[0162] When the cross section of the woven fabric made of the obtained flat ultrafine fibers was also observed, a large number of flat ultrafine fibers were overlapped with the minor axis directions aligned to form a dense fiber bundle structure. In addition, respective flat ultrafine fibers were aggregated as if adhered, and extremely fine voids of several nm to several hundred nm were present between the fibers.

[0163] When the woven fabric consisting of the flat ultrafine fibers was immersed in a dye solution prepared by adjusting a non-staining dye (acidic black dye) to 10 %owf and treated at a bath ratio of 1: 50, a treatment temperature of 30°C, and a treatment time of 30 minutes, in the cross section, spaces between the flat ultrafine fibers was colored black, the dye was enclosed in the fiber bundle, and the surface of the woven fabric was also colored black.

[0164] The woven fabric consisting of the flat ultrafine fibers was treated at a solid content of 20 %owf, a bath ratio of 1: 20, a treatment temperature of 130°C, and a treatment time of 1 hour using a 10% aqueous solution of dodecanedioic acid dihydrazide, and subjected to a deodorizing functional processing. When the acetaldehyde removal ability was evaluated, the concentration decreased from an initial concentration of 30 ppm to 2 ppm in 10 minutes, and thus the deodorizing property was high. In addition, a content of a functional substance was 5.0%, a content after washing was 4.2%, which was not greatly reduced, a large amount of the functional substance was adsorbed, and the functional substance was hard to fall off and had high durability.

[0165] The results are shown in Table 4.

[Examples 16, 17]

[0166] Examples 16 and 17 were carried out in the same manner as in Example 15 except that the composite plate of Example 15 was changed to a composite plate provided with fine flow paths in which the total number of layers of the component A and the component B was laminated to 64 layers (Example 16) and 32 layers (Example 17) in the method described in Example 15. The conjugate fibers were dissolved in the same manner as described above to thereby produce flat ultrafine fibers. The evaluation results of the conjugate fibers and the flat ultrafine fibers are shown in Table 4.

[0167] In Examples 16 and 17, although the degrees are different, the flat ultrafine fibers had extremely thin cross-sectional shapes with high flatness, and had appropriate variations in lengths of minor axes and the degree of unevenness. As in Example 15, the woven fabric had a dense fiber bundle structure in which the flat ultrafine fibers were aligned and overlapped, but since the flatness was decreased and the average layer thickness was increased compared to Example 15, the voids between the fibers of the fiber bundle were coarse and aggregated portions of the monofilaments were small. When the woven fabric was immersed in the non-staining dye, the dye was distributed so as to be enclosed in the fiber bundle. Since a specific surface area was reduced compared to Example 15, a content of the functional substance was slightly reduced, but the content was maintained at a high value, and a sufficient deodorizing property was exhibited. Even after washing, a high content of the functional substance was maintained, and the functional substance was hard to fall off.

[Examples 18, 19]

[0168] Examples 18 and 19 were carried out in the same manner as in Example 15 except that the composite plate of Example 15 was changed to a composite plate provided with fine flow paths in which the total number of layers of the component A and the component B was laminated to 256 layers (Example 18) and 512 layers (Example 19) in the method described in Example 15. The conjugate fibers were dissolved in the same manner as described above to thereby produce flat ultrafine fibers. The evaluation results of the conjugate fibers and the flat ultrafine fibers are shown in Table 4.

[0169] In Example 18 and Example 19, the flat ultrafine fibers had extremely thin ribbon-like cross sections with extremely high flatness, and had appropriate variations in lengths of minor axes and the degree of unevenness. As in Example 15, the woven fabric had a dense fiber bundle structure in which the flat ultrafine fibers were aligned and overlapped, but since the flatness was increased and the average length of the minor axes was decreased compared to Example 15, the voids between the fibers of the fiber bundle were extremely minute, ranging from several nm to several tens of nm, and the monofilaments were aggregated as if adhered in the entire fiber bundle. When the woven fabric was immersed in the non-staining dye, the dye was distributed so as to be enclosed in the fiber bundle. In the functional processing, since the average length of the minor axes was extremely small, the woven fabric was excessively soft and had poor handleability. Since the specific surface area was increased compared to Example 15, the content of the functional substance was increased, and thus the deodorizing property was excellent. Since the fiber bundle has a strong aggregation structure enclosing the functional substance, the content of the functional substance is hardly decreased even after washing, and the functional substance can be held with high durability.

[Comparative Example 5]

[0170] Comparative Example 5 was carried out in the same manner as in Example 15 except that polyethylene terephthalate (PET, melt viscosity: 120 Pa·s, melting point: 254°C, SP value: 21.4 MPa$^{1/2}$) was used, melted at 290°C, and then flowed into a single spin pack to be discharged from the discharge holes. The evaluation results of a single fiber are shown in Table 4.

[0171] In Comparative Example 5, the single fiber had a round cross-sectional fiber having a general fiber diameter, a small specific surface area, and a sparse structure in which a distance between monofilaments was large even in a fiber bundle. Even when the woven fabric was immersed in the non-staining dye, adhesion of the dye was not observed. Since the specific surface area was small, the content of the functional substance was small, and the deodorizing property was poor. By washing, the content of the functional substance decreased to near 0, and the functional substance attached to the fiber surface easily fell off.

[Comparative Example 6]

[0172] Comparative Example 6 was carried out in the same manner as in Example 15 except that a spin pack incorporating an 8-island type sea-island composite spinneret in which the component A was an island component and the component B was a sea component was used. The sea-island conjugate fiber was dissolved in the same manner as described above to thereby produce ultrafine fibers. The evaluation results of the ultrafine fibers are shown in Table 4.

[0173] In Comparative Example 6, the ultrafine fiber had a significantly reduced fiber diameter and a large specific surface area. In the fiber bundle, the distance between the monofilaments was small. When immersed in the non-staining dye, the woven fabric was not colored, and adhesion of the dye between fibers was not observed. When the functional processing was performed, the functional substance adhered to a moderate extent due to an increase in specific surface area because of ultra-thinness, but the fiber did not exhibit a high deodorizing property, and the adsorption amount of the functional substance was significantly reduced by washing.

[Comparative Example 7]

[0174] Comparative Example 7 was carried out in the same manner as in Example 15 except that the composite plate of Example 15 was changed to a composite plate provided with fine flow paths in which the total number of layers of the component A and the component B was laminated to 8 layers in the method described in Example 15. The conjugate fiber was dissolved in the same manner as described above to thereby produce flat fibers. The evaluation results of the conjugate fiber and the flat fibers are shown in Table 4.

[0175] As shown in FIG. 10, a flat fiber 7 of Comparative Example 7 had a cross-sectional shape with low flatness. Since the flatness was low, in the multifilament, directions of the flat fibers 7 were not aligned as shown in FIG. 11, and a fiber bundle structure in which the distance between the monofilaments was large was obtained. Even when the woven fabric was immersed in the non-staining dye, adhesion of the dye was not observed. Since the specific surface area was small, the content of the functional substance was small, and the deodorizing property was poor. By washing, the content of the functional substance decreased to near 0, and the functional substance attached to the fiber surface easily fell off.

[Example 20]

[0176] Example 20 was carried out in the same manner as in Example 15 except that a composite plate having a flow path diameter different from the fine flow path having the merging portion and the branch portion was used in the method described in Example 15. The conjugate fiber was dissolved in the same manner as described above to thereby produce flat ultrafine fibers. The evaluation results of the conjugate fiber and the flat ultrafine fibers are shown in Table 5.

[0177] In Example 20, the flat ultrafine fibers had an extremely thin cross-sectional shape with high flatness as in Example 15, but were homogeneous with a small variation in lengths of minor axes and a small degree of unevenness due to the change in the flow path design of the composite plate. The woven fabric had a dense fiber bundle structure in which the flat ultrafine fibers were aligned and overlapped as in Example 15, but since the degree of unevenness was small, a proportion of fine voids of several nm to several hundred nm between the fibers of the fiber bundle was large compared to Example 15. When the woven fabric was immersed in the non-staining dye, the dye was enclosed in the fiber bundle, but was not uniformly distributed as a whole, and a portion in which the dye was not enclose was observed. Compared to Example 15, the dispersibility of the monofilament was low, and thus the content of the functional substance was slightly inferior, but the functional substance was hard to fall off by washing.

[Example 21]

[0178] Example 21 was carried out in the same manner as in Example 15 except that polyamide-6 (N6, melt viscosity: 100 Pa·s, melting point: 225°C, SP value: 23.7 MPa$^{1/2}$) as the component A and polyethylene terephthalate (SSIA-PEG-copolymerized PET, melt viscosity: 95 Pa·s, melting point: 233°C, SP value: 22.9 MPa$^{1/2}$) obtained by copolymerizing 8.0 mol% of 5-sodium sulfoisophthalic acid and 9 wt% of polyethylene glycol as the component B were used for spinning at 280°C in the method described in Example 1. The solubility parameter difference between the combined polymers is 0.8 MP$^{1/2}$. The conjugate fiber was dissolved in the same manner as described above to thereby produce flat ultrafine fibers. The evaluation results of the conjugate fiber and the flat ultrafine fibers are shown in Table 5.

[0179] In Example 21, the flat ultrafine fibers had an extremely thin cross-sectional shape with high flatness as in Example 15, but since hydrogen bonds acted between the fibers, the fiber bundle thereof had a more densely aggregated structure than in Example 15. When the functional processing was performed, since the fibers, which showed the same content of the functional substance as in Example 15, were connected by hydrogen bonds, the woven fabric swelled during washing and was easily redispersed into monofilaments, and the functional substance was more likely to fall off during washing than in Example 15.

[Example 22]

[0180] Example 22 was carried out in the same manner as in Example 15 except that polypropylene (PP, melt viscosity: 70 Pa·s, melting point: 165°C, SP value: 16.8 MPa$^{1/2}$) as the component A and polyethylene terephthalate (SSIA-PEG-copolymerized PET, melt viscosity: 95 Pa·s, melting point: 233°C, SP value: 22.9 MPa$^{1/2}$) obtained by copolymerizing 8.0 mol% of 5-sodium sulfoisophthalic acid and 9 wt% of polyethylene glycol as the component B were used for spinning at 280°C in the method described in Example 15. The solubility parameter difference between the combined polymers is 6.1 MPa$^{1/2}$. When a cross-sectional shape of the conjugate fiber was observed, the cross section formability was unstable due to a large solubility parameter difference, and the conjugate fiber had an irregular laminated structure in which a lamination direction changed locally in the cross section, which was different from Example 15. The conjugate fiber was dissolved in the same manner as described above to thereby produce flat ultrafine fibers. The evaluation results of the conjugate fiber and the flat ultrafine fibers are shown in Table 5.

[0181] In Example 22, since the flatness was low and the specific surface area was reduced, and the content of the functional substance was reduced compared to Example 15, but the content was high, and the functional substance was hard to fall off by washing.

[Table1]

		Example 1	Example 2	Example 3	Example 4
Polymer	Component A	PET	PET	PET	PET
	Component B	SSIA-PEG-copolymerized PET	SSIA-PEG-copolymerized PET	SSIA-PEG-copolymerized PET	SSIA-PEG-copolymerized PET
Composite ratio A/B (wt%)		90/10	90/10	90/10	90/10
Solubility parameter difference (MPa$^{1/2}$)		1.5	1.5	1.5	1.5
Composite fiber	Composite structure	Unidirectional lamination	Unidirectional lamination	Unidirectional lamination	Unidirectional lamination
	Sum of interfacial lengths/fiber-cross-sectional area (nm^{-1})	0.0557	0.0278	0.0149	0.0080
	Component B Variation in layer thickness (%)	32	30	38	36
	Component B Average layer thickness (nm)	4	8	15	28
	The number of laminated layers	1024	512	256	128
U% (H)		0.6	0.4	0.4	0.5
Abrasion resistance		A	A	B	B
Chemical resistance	Evaluation	A	A	A	B
	Weight loss rate (%)	0.6	0.9	1.7	4.8
		Example 5	Example 6	Comparative Example 1	
Polymer	Component A	PET	PET	PET	
	Component B	SSIA-PEG-copolymerized PET	SSIA-PEG-copolymerized PET	SSIA-PEG-copolymerized PET	
Composite ratio A/B (wt%)		90/10	90/10	90/10	
Solubility parameter difference (MPa$^{1/2}$)		1.5	1.5	1.5	

(continued)

		Example 5	Example 6	Comparative Example 1
Polymer	Component A	PET	PET	PET
	Component B	SSIA-PEG-copolymerized PET	SSIA-PEG-copolymerized PET	SSIA-PEG-copolymerized PET
Conjugate fiber	Composite structure	Unidirectional lamination	Unidirectional lamination	Unidirectional lamination
	Sum of interfacial lengths/fiber-cross-sectional area (nm^{-1})	0.0043	0.0023	0.0005
	Component B Variation in layer thickness (%)	41	39	5
	Component B Average layer thickness (nm)	51	92	369
	The number of laminated layers	64	32	8
U% (H)		0.6	0.6	0.4
Abrasion resistance		B	B	C
Chemical resistance	Evaluation	C	C	D
	Weight loss rate (%)	8.8	9.7	10.5
PET: polyethylene terephthalate, SSIA: 5-sodium sulfoisophthalic acid, PEG: polyethylene glycol				

[Table2]

		Example 7	Example 8	Example 9	Comparative Example 2
Polymer	Component A	PET	PET	PET	PET
	Component B	SPG-CHDC-copolymerized PET	SPG-CHDC-copolymerized PET	SPG-CHDC-copolymerized PET	SPG-CHDC-copolymerized PET
Composite ratio A/B (wt%)		50/50	50/50	50/50	50/50
Solubility parameter difference ($MPa^{1/2}$)		1.6	1.6	1.6	1.6

(continued)

		Example 7	Example 8	Example 9	Comparative Example 2
Polymer	Component A	PET	PET	PET	PET
	Component B	SPG-CHDC-copolymerized PET	SPG-CHDC-copolymerized PET	SPG-CHDC-copolymerized PET	SPG-CHDC-copolymerized PET
Conjugate fiber	Composite structure	Unidirectional lamination	Unidirectional lamination	Unidirectional lamination	Unidirectional lamination
	Sum of interfacial lengths/fiber-cross-sectional area (nm^{-1})	0.0520	0.0278	0.0139	0.0057
	Component B Variation in layer thickness (%)	32	30	38	8
	Component B Average layer thickness (nm)	21	40	81	1847
	The number of laminated layers	1024	512	256	8
U% (H)		0.6	0.6	0.4	0.6
Abrasion resistance		A	A	B	D
Heat resistance	Evaluation	A	A	B	C
	Dry heat shrinkage ratio (%)	14.1	14.8	15.5	28.2
	Fusion bonding between fibers	None	None	None	Present
PET: polyethylene terephthalate, SPG: spiroglycol, CHDC: cyclohexanedicarboxylic acid					

[Table3]

		Example 10	Example 11	Example 12
Polymer	Component A	PET	PET	PET
	Component B	N6	N6	N6
Composite ratio A/B (wt%)		50/50	50/50	50/50
Solubility parameter difference ($MPa^{1/2}$)		2.3	2.3	2.3

(continued)

		Example 10	Example 11		Example 12
Polymer	Component A	PET	PET		PET
	Component B	N6	N6		N6
Conjugate fiber	Composite structure	Unidirectional lamination	Unidirectional lamination		Unidirectional lamination
	Sum of interfacial lengths/ fiber-cross-sectional area (nm^{-1})	0.0433	0.0216		0.0114
	Component B Variation in layer thickness (%)	48	42		50
	Component B Average layer thickness (nm)	26	51		98
	The number of laminated layers	1024	512		256
U% (H)		1.3	0.9		0.8
Abrasion resistance		B	B		B
		Example 13	Example 14	Comparative Example 3	Comparative Example 4
Polymer	Component A	PET	PET	PET	PET
	Component B	N6	N6	N6	N6
Composite ratio A/B (wt%)		50/50	50/50	50/50	50/50
Solubility parameter difference ($MPa^{1/2}$)		2.3	2.3	2.3	2.3
Conjugate fiber	Composite structure	Concentric lamination	Radial lamination	Unidirectional lamination	Coated unidirectional lamination
	Sum of interfacial lengths/ fiber-cross-sectional area (nm^{-1})	0.0160	0.0156	0.0004	0.0003
	Component B Variation in layer thickness (%)	49	41	12	11
	Component B Average layer thickness (nm)	72	88	2215	1530
	The number of laminated layers	256	256	8	8
U% (H)		0.7	0.7	0.6	0.6
Abrasion resistance		B	B	D	D
PET: polyethylene terephthalate, N6: Nylon 6					

[Table4]

		Example 15	Example 16	Example 17	Example 18
Polymer	Component A	PET	PET	PET	PET
	Component B	SSIA-PEG-copolymerized PET	SSIA-PEG-copolymerized PET	SSIA-PEG-copolymerized PET	SSIA-PEG-copolymerized PET
Composite ratio A/B (wt%)		80/20	80/20	80/20	80/20
Solubility parameter difference (MPa$^{1/2}$)		1.5	1.5	1.5	1.5
Conjugate fiber	Composite structure	Unidirectional lamination	Unidirectional lamination	Unidirectional lamination	Unidirectional lamination
	Sum of interfacial lengths/fiber-cross-sectional area (nm^{-1})	0.0079	0.0039	0.0020	0.0158
	Component B Variation in layer thickness (%)	38	43	29	50
	Component B Average layer thickness (nm)	57	113	231	30
	The number of laminated layers	128	64	32	256
U% (H)		0.5	0.6	0.6	0.4
Abrasion resistance		B	B	B	A
Flat ultrafine fiber	Flatness	80	40	20	160
	Average thickness (nm)	225	450	900	113
	Variation in thickness (%)	36	41	39	48
	Degree of unevenness (%)	30	25	26	26
Fabric properties	Distribution state of functional substance	In fiber bundle	In fiber bundle	In fiber bundle	In fiber bundle
	Content of functional substance (%)	5.2	3.9	2.9	6.1
	Content of functional substance after washing (%)	4.4	2.8	1.4	5.8
	Acetaldehyde concentration (ppm)	2	4	6	1
		Example 19	Comparative Example 5	Comparative Example 6	Comparative Example 7
Polymer	Component A	PET	PET	PET	PET
	Component B	SSIA-PEG-copolymerized PET	-	SSIA-PEG-copolymerized PET	SSIA-PEG-copolymerized PET
Composite ratio A/B (wt%)		80/20	100	80/20	80/20

(continued)

		Example 19	Comparative Example 5	Comparative Example 6	Comparative Example 7
Polymer	Component A	PET	PET	PET	PET
	Component B	SSIA-PEG-copolymerized PET	-	SSIA-PEG-copolymerized PET	SSIA-PEG-copolymerized PET
Solubility parameter difference ($MPa^{1/2}$)		1.5	-	1.5	1.5
Conjugate fiber	Composite structure	Unidirectional lamination	Monocomponent	Sea-island	Plate-like lamination
	Sum of interfacial lengths/fiber-cross-sectional area (nm^{-1})	0.0318	-	0.0006	0.0004
	Component B Variation in layer thickness (%)	48			30
	Component B Average layer thickness (nm)	16	-	-	920
	The number of laminated layers	512	-	8 (the number of islands)	8
U% (H)		0.4	0.4	0.4	0.4
Abrasion resistance		A	A	C	C
Flat ultrafine fiber	Flatness	320	1 (round cross section)	1 (round cross section)	5
	Average thickness (nm)	56	18000 (diameter)	5620 (diameter)	3600
	Variation in thickness (%)	48	-	-	32
	Degree of unevenness (%)	26	-	-	25
Fabric properties	Distribution state of functional substance	In fiber bundle	None	None	None
	Content of functional substance (%)	7.5	0.7	1.1	1.0
	Content of functional substance after washing (%)	7.2	0.1	0.2	0.1
	Acetaldehyde concentration (ppm)	1	23	19	21

[Table5]

		Example 20	Example 21	Example 22
Polymer	Component A	PET	N6	PP
	Component B	SSIA-PEG-copolymerized PET	SSIA-PEG-copolymerized PET	SSIA-PEG-copolymerized PET
Composite ratio A/B (wt%)		80/20	80/20	80/20

(continued)

		Example 20	Example 21	Example 22
Polymer	Component A	PET	N6	PP
	Component B	SSIA-PEG-copolymerized PET	SSIA-PEG-copolymerized PET	SSIA-PEG-copolymerized PET
Solubility parameter difference (MPa$^{1/2}$)		1.5	0.8	6.1
Conjugate fiber	Composite structure	Unidirectional lamination	Unidirectional lamination	Irregular lamination
	Sum of interfacial lengths/ fiber-cross-sectional area (nm^{-1})	0.0081	0.0076	0.0039
	Component B Variation in layer thickness (%)	7	41	33
	Component B Average layer thickness (nm)	55	53	231
	The number of laminated layers	128	128	32
U% (H)		0.5	0.4	1.2
Abrasion resistance		B	A	D
Flat ultrafine fiber	Flatness	80	83	18
	Average thickness (nm)	225	217	403
	Variation in thickness (%)	8	39	60
	Degree of unevenness (%)	5	30	38
Fabric properties	Distribution state of functional substance	In fiber bundle	In fiber bundle	In fiber bundle
	Content of functional substance (%)	3.5	5.3	2.7
	Content of functional substance after washing (%)	2.8	3.8	1.9
	Acetaldehyde concentration (ppm)	5	2	6

[0182] Although the present invention has been described in detail with reference to specific embodiments, it is apparent to those skilled in the art that various changes and modifications may be made without departing from the spirit and scope of the present invention. The present application is based on Japanese Patent Application No. 2020-210112 filed on December 18, 2020, and the content thereof is incorporated herein as reference.

REFERENCE SIGNS LIST

[0183]

1: unidirectional-laminated fiber

2: radial-laminated fiber

3: concentric-laminated fiber

4: flat ultrafine fiber

5: multifilament

6: coated unidirectional-laminated fiber

7: flat fiber

10: composite spinneret

A: component A

B: component B

D: functional substance

E: measuring plate

F: composite plate

G: discharge plate

H: fine flow path

Claims

1. A conjugate fiber comprising two or more types of polymers, and having a fiber cross section in which a plurality of interfaces is formed, wherein

    the conjugate fiber has a value, which is obtained by dividing a sum of lengths of interfaces between two types of the polymers by an area of the fiber cross section, of 0.0010 nm^{-1} or more, and
    each of the interfaces is continuous in a fiber axis direction.

2. The conjugate fiber according to claim 1, wherein
the value, which is obtained by dividing the sum of the lengths of interfaces between the two types of the polymers by the area of the fiber cross section, is 0.0050 nm^{-1} or more.

3. The conjugate fiber according to claim 1 or 2, wherein
the fiber cross section comprises a multilayer laminated structure in which the two types of the polymers are alternately laminated.

4. The conjugate fiber according to any one of claims 1 to 3, wherein
at least one type of the polymers has a variation (CV value) in layer thickness of 10% or more.

5. The conjugate fiber according to any one of claims 1 to 4, wherein
at least one type of the polymers has an average layer thickness of 1000 nm or less.

6. A multifilament consisting of flat ultrafine fibers that each comprise one type of polymer that is remained by removing another type of polymer among the two types of the polymers constituting the multilayer laminated structure from the conjugate fiber according to claim 3.

7. The multifilament according to claim 6, wherein
the flat ultrafine fibers each have a fiber cross section having a flat shape, have a flatness, which is a value obtained by dividing a length of a major axis of the fiber cross section by a length of a minor axis of the fiber cross section, of 15 or more, and have an average thickness of 1000 nm or less.

8. The multifilament according to claim 6 or 7, wherein
the flat ultrafine fibers have a variation (CV value) in thickness of 10% or more.

9. The multifilament according to any one of claims 6 to 8, wherein the polymer constituting the flat ultrafine fibers comprises at least one polymer selected from the group consisting of polyester, polyamide, and polyolefin.

10. The multifilament according to any one of claims 6 to 9, wherein a functional substance is enclosed in a fiber bundle comprising the flat ultrafine fibers

11. A fiber product at least partially comprising the conjugate fiber according to any one of claims 1 to 5 or the multifilament according to any one of claims 6 to 10.

FIG. 1

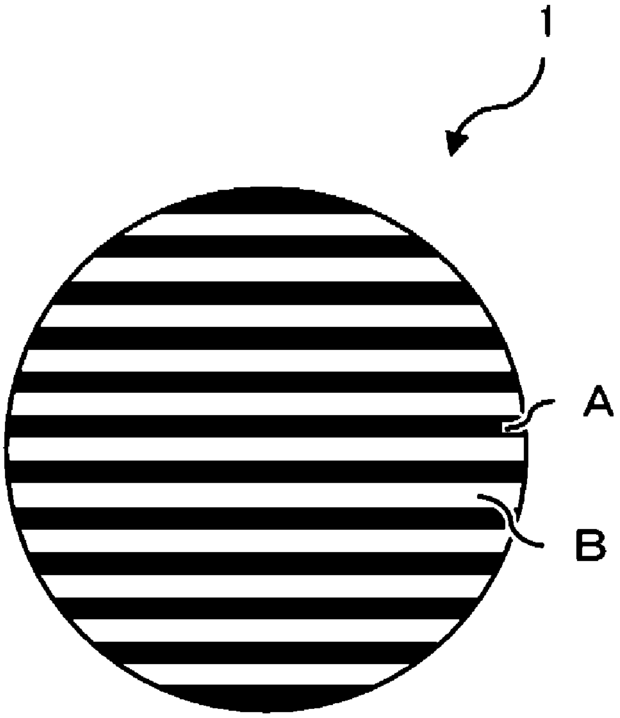


FIG. 2

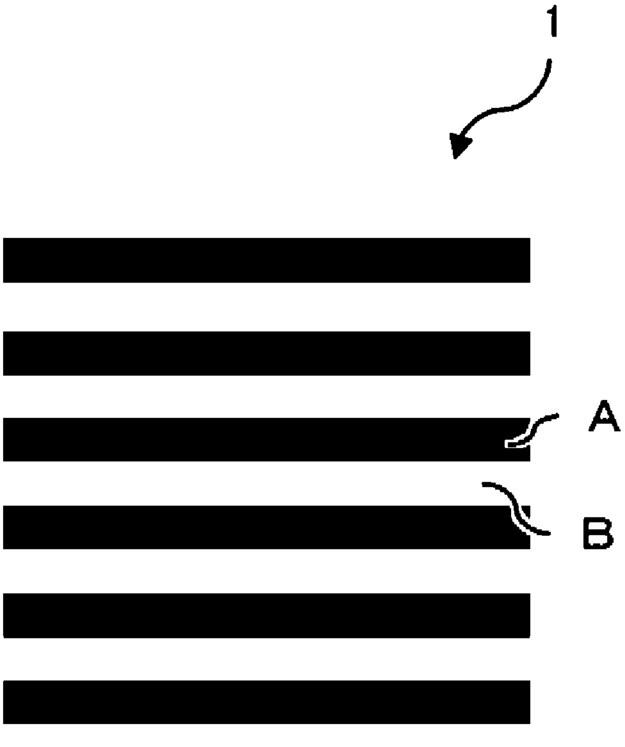


FIG. 3

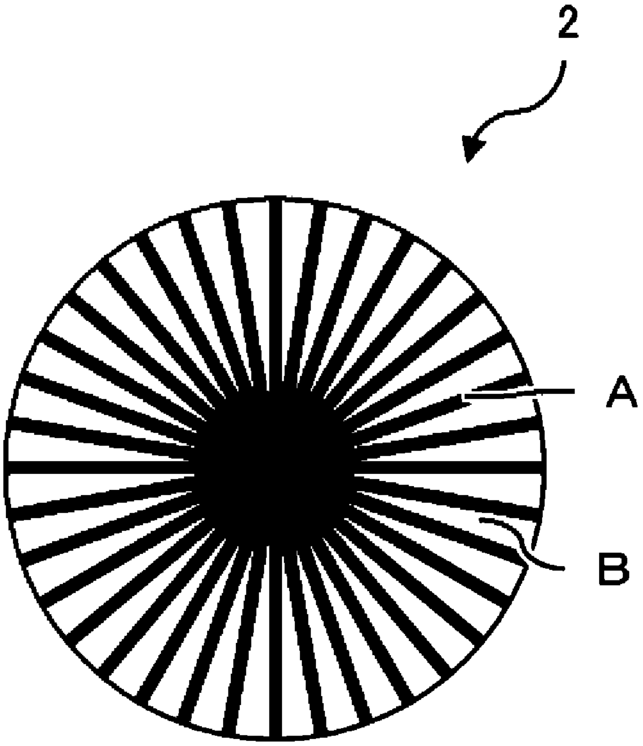


FIG. 4

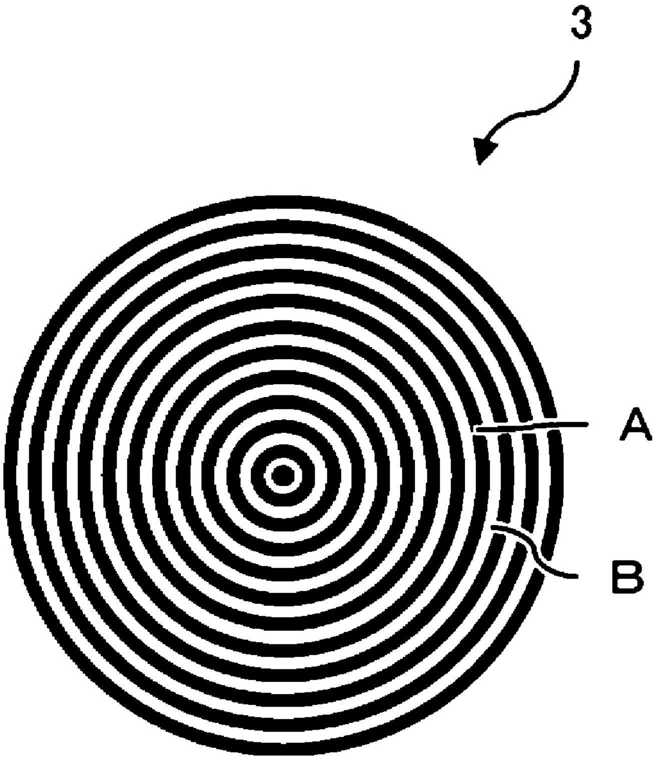


FIG. 5

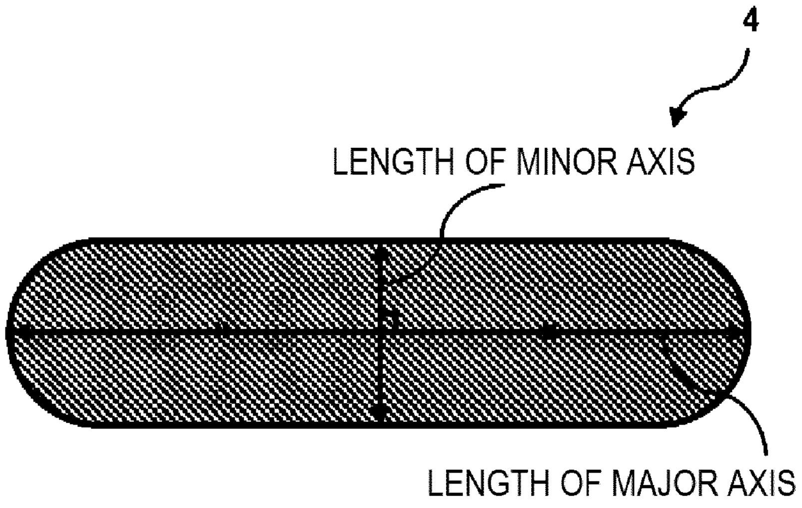


FIG. 6

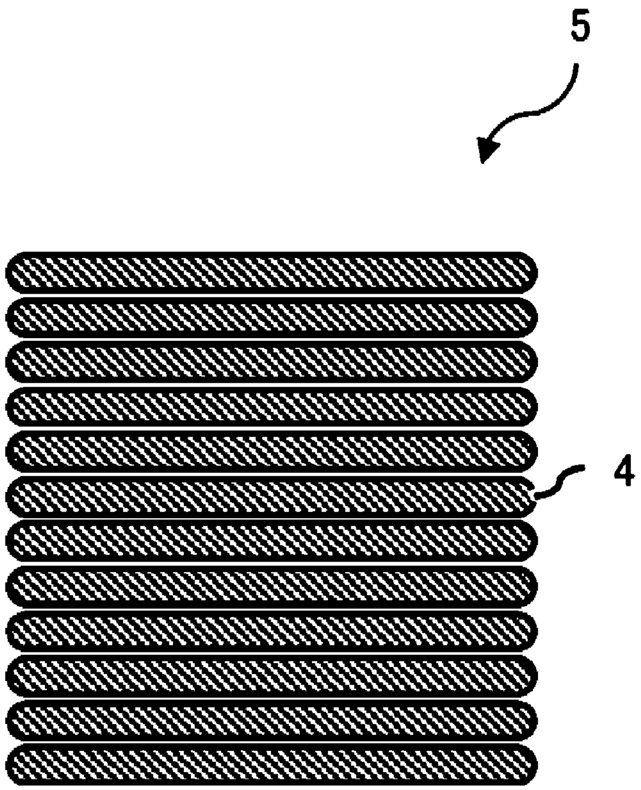


FIG. 7

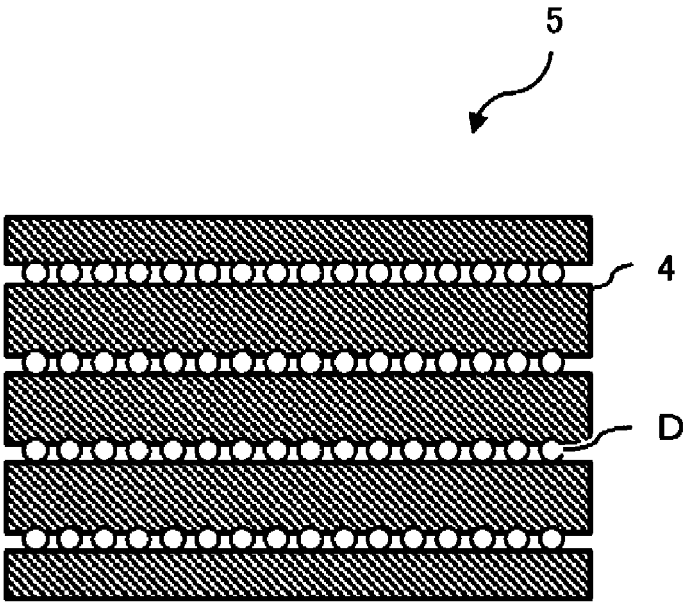


FIG. 8

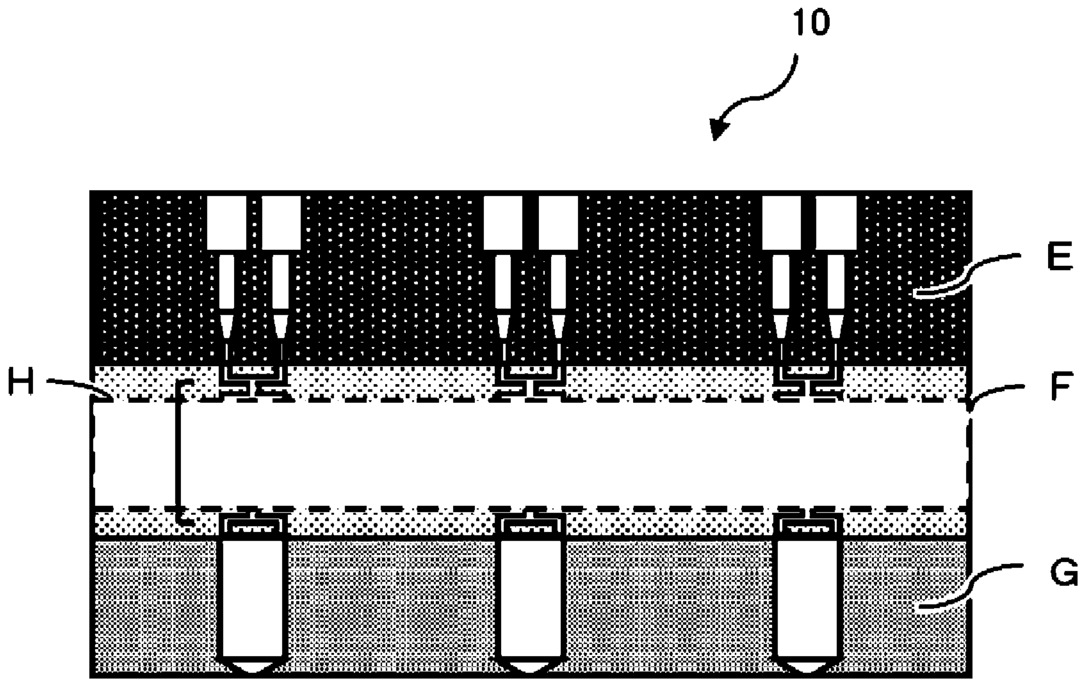


FIG. 9

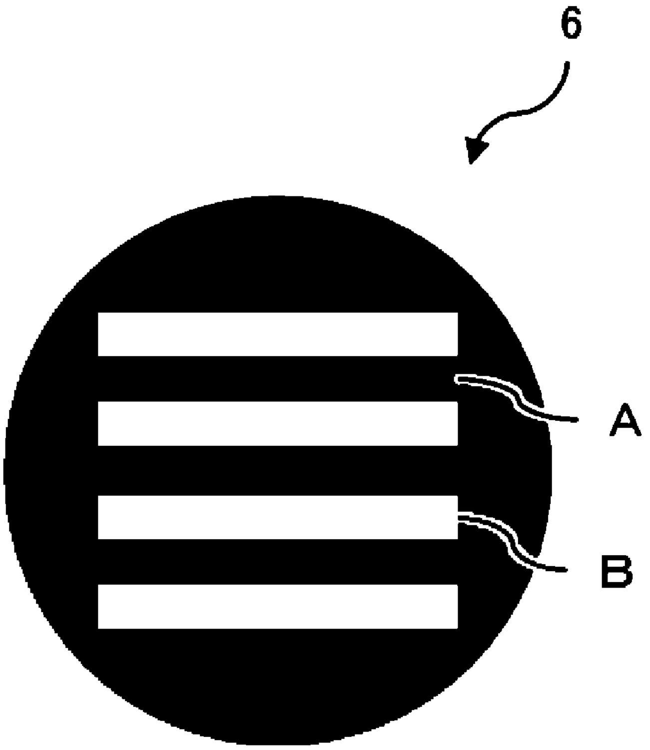


FIG. 10

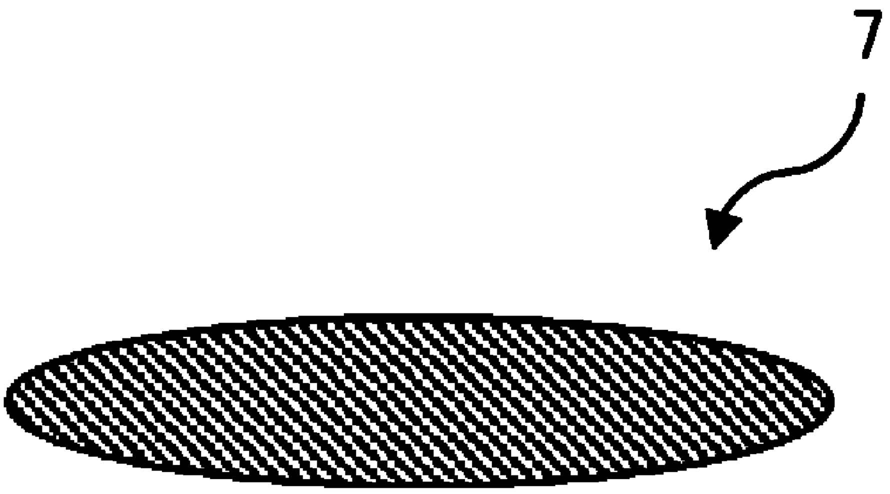
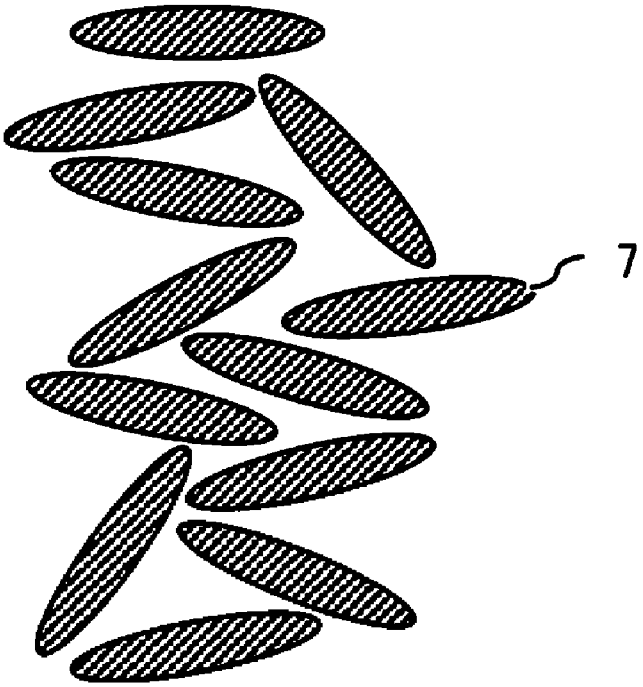


FIG. 11



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2021/046396

A. CLASSIFICATION OF SUBJECT MATTER

D01F 8/04(2006.01)i; ***D01F 8/14***(2006.01)i
FI: D01F8/04 B; D01F8/14 B; D01F8/14 D

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

D01F8/00-8/18

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2022
Registered utility model specifications of Japan 1996-2022
Published registered utility model applications of Japan 1994-2022

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

JSTPlus/JMEDPlus/JST7580 (JDreamIII)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2017-115254 A (TORAY INDUSTRIES, INC.) 29 June 2017 (2017-06-29) claims, paragraph [0023], example 1	1-5, 11
X	JP 07-195603 A (NISSAN MOTOR CO., LTD.) 01 August 1995 (1995-08-01) claims, paragraphs [0001], [0032], [0043], [0106]-[0108]	1-3, 5-7, 9-11
Y	claims	4, 8
Y	JP 11-189911 A (NISSAN MOTOR CO., LTD.) 13 July 1999 (1999-07-13) claims, paragraphs [0011]-[0020]	4, 8
X	JP 08-246337 A (KANEBO LTD.) 24 September 1996 (1996-09-24) claims, paragraphs [0019], [0029], fig. 1	1-11
A	JP 60-246725 A (KANEBO LTD.) 06 December 1985 (1985-12-06)	1-11
A	JP 07-026433 A (TOYO BOSEKI KABUSHIKI KAISHA) 27 January 1995 (1995-01-27)	1-11

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

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"O" document referring to an oral disclosure, use, exhibition or other means
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Date of the actual completion of the international search **02 February 2022**	Date of mailing of the international search report **22 February 2022**
Name and mailing address of the ISA/JP **Japan Patent Office (ISA/JP)** **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2021/046396

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2017-115254 A	29 June 2017	(Family: none)	
JP 07-195603 A	01 August 1995	(Family: none)	
JP 11-189911 A	13 July 1999	(Family: none)	
JP 08-246337 A	24 September 1996	(Family: none)	
JP 60-246725 A	06 December 1985	(Family: none)	
JP 07-026433 A	27 January 1995	(Family: none)	

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- JP H11181630 A **[0009]**
- JP 2000282333 A **[0009]**
- JP 2020210112 A **[0182]**