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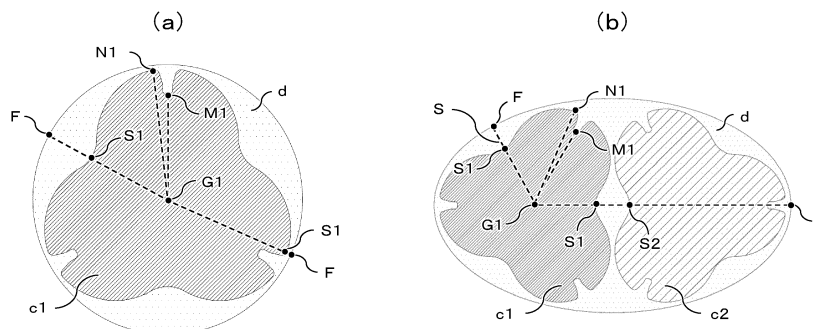
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(54) **SHEATH-CORE COMPOSITE FIBER AND MULTIFILAMENT**

(57) A sheath-core composite fiber which is composed of two or more polymers, wherein a core component having a multifoliate shape with three or more projections is completely covered by a sheath component in a fiber cross-section of the sheath-core composite fiber, while having a ratio of the maximum thickness S_{max} of the sheath component to the minimum thickness S_{min}

of the sheath component, namely S_{max}/S_{min} of 5.0 or more; and a multifilament which is composed of the core component of this sheath-core composite fiber. The present invention provides a sheath-core composite fiber and a multifilament, which are suitable for the achievement of a good textile that is comparable to natural silk.

Figure 5



Description

TECHNICAL FIELD

5 **[0001]** The present invention relates to a core-sheath composite fiber and a multifilament that are suitable for producing a light, flexible, and resilient textile having a natural silk-like luxurious gloss.

BACKGROUND ART

10 **[0002]** Synthetic fibers made of polyester, polyamide, etc. have excellent mechanical properties and high dimensional stability, and accordingly they are used in various fields ranging from clothing to non-clothing. However, in recent years when people's lives have diversified and people are demanding a better life, many industries including clothing production are requiring advanced textures and functions that are not realized with conventional synthetic fibers.

15 **[0003]** In view of the history of technological development in the field of synthetic fibers, it is no exaggeration to say that various elemental technologies have evolved with the motivation of imitating good characteristics of natural materials. This is because natural fibers such as hemp, wool, cotton, and silk have excellent textures and functions, and humans feel that the complex gloss and textures realized by them are attractive and luxurious.

20 **[0004]** In the history of the development of synthetic fibers performed by imitating natural materials as described above, there have been proposals of a wide range of fiber technologies aiming to achieve the characteristics of silk (hereinafter referred to as natural silk), which is the highest level natural material. They include polymer techniques for designing of fibers with special cross-sectional shapes and spinning techniques that use mixtures of different types of fibers.

25 **[0005]** For example, it has been known that if polyester fibers, which can reflect light relatively strongly, have an irregular cross section of a multilobar shape, they can give amplified light reflection due to the irregularity of the multilobar shape, resulting in a mild gloss in combination with high brightness to imitate natural silk. Such fibers are now produced in large quantities as a typical silky material. With only the simple use of an irregular cross section, however, it is sometimes difficult to realize the good textural features (dry touch, lightness, flexibility, resilience, etc.) of natural silk, excluding gloss. A variety of fiber techniques have been disclosed with the aim of producing composite fibers that have more complicated cross-sectional shapes to realize natural silk-like textures.

30 **[0006]** Patent document 1 proposes a composite fiber that is characterized of a multilobar fiber cross section in which an easily dissolvable component is located at each apex of the multilobar shape in a tapered manner toward the interior of the fiber. For this composite fiber, the easily dissolvable component is subjected to dissolution treatment to produce grooves in the apex portions of the multilobar shape, thereby enhancing the light reflection by the multilobar shape and also increasing the frictional force by the groove portions. This document insists that this serves to realize not only luxurious gloss and dry touch of natural silk, but also scroop, which is characteristic feature of textiles made of natural silk.

35 **[0007]** Patent document 2 proposes a composite fiber that has a fiber cross section in which several hardly dissolvable components are separated by an easily dissolvable component. As the composite fiber is subjected to dissolution treatment to dissolve out the easily dissolvable component, the single composite fiber is divided into a plurality of fibers having irregular cross sections and the combined effect of the decreased fiber diameter and the irregular cross-sectional shape acts to give a soft texture in addition to natural silk-like luxurious gloss and dry touch.

40 **[0008]** Furthermore, it is known that silky woven and knitted fabrics can be produced from multifilaments that contain a mixture of fibers that differ in shrinkage rate. Patent document 3 proposes a shrinkage-varying combined-fiber multifilament containing at least two types of fibers with different thermal shrinkage rates produced by the spinning-combining method. The shrinkage-varying combined-fiber multifilament contains a fiber of copolymer polyester as a component. When it is heated, there occur differences in length among the groups of fibers that differ in shrinkage rate, and this serves to produce cloth with fluffiness, resulting in a silky material.

PRIOR ART DOCUMENTS

PATENT DOCUMENTS

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[0009]

Patent document 1: Japanese Unexamined Patent Publication (Kokai) No. SHO 57-5912

Patent document 2: Japanese Unexamined Patent Publication (Kokai) No. 2010-222771

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Patent document 3: Japanese Unexamined Patent Publication (Kokai) No. HEI 2-19528

SUMMARY OF INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0010] As described in Patent document 1, the formation of a special cross-sectional shape using a dissolvable component to control light reflection and frictional force serves to some extent to develop a luxurious gloss and dry touch peculiar to natural silk as well as unique scroop. In the case of Patent document 1, however, interfiber spaces are not formed sufficiently in some cases, and the resulting fabric is likely to be in the form of closely packed single fibers. As a result, when worn as clothes, it sometimes fails to have a sufficiently light and flexible texture that ensures comfortability.

[0011] Compared to this, the approach of forming flexible cloth by performing a fiber thinning technique such as dissolution and division to decrease the bending rigidity of each single fiber as described in Patent document 2 is effective in terms of flexibility enhancement. In the case of Patent document 2, however, only a limited space is formed in each multifilament in some cases and this, in combination with the thinning of fiber diameters, can easily lead to the closest packing of single fibers, depending on the tissue of the cloth. Therefore, this approach may impose limits on material development activities due to, for example, the necessity of precise fabric design to obtain a light texture peculiar to natural silk.

[0012] In addition, the approach of mixing fibers having different shrinkage rates to produce cloth with fluffiness, such as proposed in Patent document 3, is actually effective in terms of the formation of cloth having lightness brought about by the fluffiness, but the fibers cannot be mixed uniformly in some cases because the mixing of different types of fibers occurs during the take-up step or the yarn processing step. If such uneven fiber mixing occurs, the cloth may fail to develop a sufficiently flexible texture because, for example, it suffers clogging in portions where fibers with higher shrinkage rates are localized densely.

[0013] As described above, various technical proposals have been made so far in an effort to provide a silky material by making effective use of synthetic fibers, but it is difficult to say that there exists a technique that serves to allow a light, flexible, and resilient texture having a natural silk-like luxurious gloss to be developed in a good balance. Thus, the main object of the present invention is to solve the above problems with the prior art technology and to provide a core-sheath composite fiber and a multifilament that are suitable for producing a good textile that can be a match for natural silk.

MEANS OF SOLVING THE PROBLEMS

[0014] This object of the present invention can be achieved by the following approach. Specifically, it provides:

a core-sheath composite fiber including two or more types of polymers and having a cross section in which a core component possesses a multilobar shape with three or more convex portions and a sheath component surrounds it completely, wherein the maximum thickness $S_{\max}$ and the minimum thickness $S_{\min}$ of the sheath component have a $S_{\max}/S_{\min}$ ratio of 5.0 or more,

a multifilament formed of the core component of a core-sheath composite fiber as described above,

a multifilament having a space structure in which the average interfiber space distance is 5 to 30 μm and the spaces with an interfiber space distance of less than 5 μm account for 10% to 50%, and

fiber products partly including a core-sheath composite fiber or a multifilament as described above.

ADVANTAGEOUS EFFECTS OF THE INVENTION

[0015] The use of the core-sheath composite fiber or multifilament according to the present invention serves to form a unique space structure in which fine interfiber spaces with fiber-to-fiber distances of less than 5 μm and coarse interfiber spaces with fiber-to-fiber distances of 10 μm or more coexist uniformly in a multifilament as in natural silk, and this serves to produce a light, flexible, and resilient textile having a natural silk-like luxurious gloss.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016]

[Fig. 1] This gives a schematic diagram of a cross-sectional structure of raw silk that is prepared from silkworm cocoons and used to produce natural silk.

[Fig. 2](a)(b) This gives schematic diagrams of typical cross-sectional structures of core-sheath composite fibers according to the present invention.

[Fig. 3](a)(b)(c) This gives schematic diagrams of typical cross-sectional structures of composite fibers produced

by conventional techniques.

[Fig. 4](a)(b)(c) This gives schematic diagrams of typical cross-sectional structures of core-sheath composite fibers according to the present invention.

[Fig. 5](a)(b) This gives schematic diagrams of typical cross-sectional structures of core-sheath composite fibers according to the present invention.

[Fig. 6](a)(b) This gives schematic diagrams of typical cross-sectional structures of composite fibers produced by conventional techniques.

[Fig. 7] This shows a typical crimp structure of crimped fibers contained in a multifilament according to the present invention.

[Fig. 8] This gives schematic diagrams of typical cross-sectional structures of multifilaments according to the present invention. Diagram (a) is intended to explain the state of "uniform coexistence" and Diagram (b) is intended to explain the method for measuring the average interfiber space distance.

[Fig. 9](a)(b) This gives schematic diagrams of typical cross-sectional structures of crimped fibers contained in multifilaments according to the present invention.

[Fig. 10](a)(b) This gives schematic diagrams of typical cross-sectional structures of core-sheath composite fibers that can be processed into multifilaments according to the present invention.

[Fig. 11] This gives schematic diagrams of typical cross-sectional structures of composite fibers that can be processed into multifilaments by conventional techniques.

[Fig. 12] This gives a cross-sectional view of a composite spinneret to illustrate the production method for the core-sheath composite fiber and multifilament according to the present invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

[0017] The invention is described in more detail below with reference to preferred embodiments.

[0018] In investigating the mechanism of the development of the texture of natural silk, a review of the spinning process of natural silk showed that raw silk as produced from silkworm cocoons, which is to be processed into natural silk, has a cross section containing two triangular regions containing fibroin (a in Fig. 1), which is a hardly dissolvable component, surrounded by sericin (b in Fig. 1), which is an easily dissolvable component. Natural silk is formed through a special spinning step in which sericin is dissolved out of this raw silk, and interfiber spaces are left after the dissolution of sericin to create the light and flexible texture peculiar to natural silk.

[0019] Conventional silky material production processes, too, have often used techniques designed to form interfiber spaces by thinning fibers with chemicals such as alkali, but the present inventors, who focused attention on the process of the interfiber space formation, made detailed observations of woven natural silk fabrics and silky materials produced by conventional techniques and found that there are significant differences in the size and distribution of the resulting interfiber spaces between natural silk and conventional materials.

[0020] Specifically, it was found that natural silk contains fine interfiber spaces with fiber-to-fiber distances of less than 5 μm and coarse interfiber spaces with fiber-to-fiber distances of 10 μm or more coexist uniformly between single fibers whereas in conventional materials, only either interfiber spaces of less than 5 μm or those of 10 μm or more can be formed, and this difference in space formation has significant influence on the characteristics of the resulting woven and knitted fabrics.

[0021] In this connection, as the size of interfiber spaces increases up to 10 μm or more, fibers fixed at tying points in the woven or knitted fabric become movable, the fabric increases in flexibility and it also enhances in lightness as a result of a decrease in apparent density brought about by an increase in space proportion, whereas interfiber spaces with sizes of 5 μm or more cause a decrease in bending rigidity and, in turn, a decrease in resilience. Accordingly, there occurs a trade-off relation between lightness/flexibility and resilience in the case of conventional materials in which only either interfiber spaces of less than 5 μm or interfiber spaces of 10 μm or more can be formed. In the case of natural silk, on the other hand, coarse interfiber spaces of 10 μm or more that work to realize lightness and flexibility and fine interfiber spaces of less than 5 μm that work to realize resilience coexist uniformly, and the above trade-off relation is eliminated to allow a light, flexible, and resilient texture to be developed in a good balance.

[0022] The present invention is constructed based on this idea. To produce such unique interfiber spaces characteristic of natural silk as described above, it is important for the composite fiber according to the present invention to be a core-sheath composite fiber including two or more types of polymers and having a cross section in which the core component possesses a multilobar shape with three or more convex portions and the sheath component surrounds it completely, which is the first requirement of the present invention.

[0023] A core-sheath composite fiber as referred to for the present invention is one including two or more types of polymers and having a cross section perpendicular to the fiber axis in which the sheath component is arranged so that it surrounds the core component.

[0024] The core-sheath composite fiber according to the present invention will be high in processability if both the core

component and the sheath component included therein are thermoplastic polymers, and accordingly, the polymers to use to form the fiber are preferably selected from the groups of, for example, polyester based, polyethylene based, polypropylene based, polystyrene based, polyamide based, polycarbonate based, polymethyl methacrylate based, and polyphenylene sulfide based polymers, as well as copolymers thereof. In particular, from the viewpoint of developing a high interfacial affinity and obtaining a fiber free of abnormalities in the composite cross section, it is preferable for all thermoplastic polymers contained in the core-sheath composite fiber to be polymers belonging to the same polymer group or copolymers thereof. Furthermore, from the viewpoint of achieving a bending rigidity close to that of natural silk and allowing good color development property to be demonstrated in a dyeing step, it is particularly preferable to adopt a combination of polyester based polymers. In addition, the polymers may contain inorganic substances such as titanium oxide, silica, and barium oxide; coloring agents such as carbon black and other dyes and pigments; and other various additives such as flame retardant, fluorescent brightening agent, antioxidant, and ultraviolet absorber.

[0025] Moreover, as attention is focused on environmental problems, the use of plant derived biopolymers and recycled polymers is desirable for the present invention as well from the viewpoint of reducing the environmental load. The polymers listed above that serve for the present invention may be recycled polymers that are recycled by any of useful techniques including chemical recycling, material recycling, and thermal recycling. When biopolymers or recycled polymers are adopted, too, polyester based resins show suitable polymer characteristics to allow the features of the present invention to be realized in a noticeable manner and, as described above, they serve to achieve a bending rigidity close to that of natural silk and good color development. From this viewpoint, the use of recycled polyesters is preferred for the present invention.

[0026] Here, the core-sheath composite fiber according to the present invention is designed to provide a multifilament formed of the core component, which is produced by subjecting the fiber to high-order processing such as weaving and knitting and then dissolving out the sheath component. To this end, it is preferable that the core component and the sheath component are hardly dissolvable and easily dissolvable, respectively, in the solvent used to dissolve out the sheath component, and therefore, a good approach is to first select a core component suitable for the purpose and then identify a sheath component from among the above polymers in consideration of useful solvents. Here, it is desirable for the ratio in the rate of dissolution in the solvent between the hardly dissolvable component (core component) and the easily dissolvable component (sheath component) adopted for use in combination to be as high as possible, and it is favorable to adopt polymers having a ratio in dissolution rate of up to about 3,000.

[0027] As the sheath component, it is preferable to select a polymer from among those which are melt-moldable and higher in solubility than the other components, such as polyester and copolymers thereof, polylactic acid, polyamide, polystyrene and copolymers thereof, polyethylene, and polyvinyl alcohol. In addition, from the viewpoint of simplifying the step of dissolving out the sheath component, it is preferable for the sheath component to be a copolymer polyester, polylactic acid, polyvinyl alcohol, etc., that are easily dissolvable in aqueous solvents, hot water, etc., and in particular, a polyester copolymerized with 5 mol% to 15 mol% of 5-sodium sulfoisophthalic acid or a polyester copolymerized not only with the above 5-sodium sulfoisophthalic acid but also with 5 wt% to 15 wt% of a polyethylene glycol with a weight average molecular weight of 500 to 3,000 can be cited as particularly preferred polymers because they show solubility in aqueous solvents such aqueous alkali solutions while maintaining crystallinity and fusion bonding etc. between composite fibers can be prevented in the false-twisting step etc. in which the polymer suffers abrasion while being heated, thereby ensuring high-order processability.

[0028] In general, as the size of interfiber spaces increases, fibers fixed at tying points in the woven or knitted fabric become movable to ensure higher flexibility, and the increase in space proportion can cause a decrease in apparent density to ensure higher lightness whereas bending rigidity can be decreased to cause a decrease in resilience. To eliminate this trade-off relation, it is important that coarse interfiber spaces of 10 μm or more that work to improve the lightness and fine interfiber spaces of less than 5 μm that realize both flexibility and resilience coexist uniformly, and in order to achieve this, it is necessary that in the core-sheath composite fiber according to the present invention, the core component having a multilobar shape with three or more convex portions is surrounded completely by the sheath component.

[0029] If the core component having a multilobar shape with three or more convex portions is surrounded completely by the sheath component, coarse interfiber spaces of 10 μm or more can be formed by the dissolution of the sheath in the concave portions of the multilobar shape where the sheath has a larger thickness while fine interfiber spaces of less than 5 μm are formed in the convex portions where the sheath has a smaller thickness. This serves to achieve resilience in addition to a light and flexible texture peculiar to natural silk. Furthermore, the formation of concave and convex portions along the fiber surface also acts to amplify the reflection of light and this serves to allow the fiber surface to have dry touch due to the concave and convex portions formed along the fiber surface in addition to the luxurious gloss such as bright, mild gloss like natural silk. In view of this, since a larger number of convex portions works to form more interfiber spaces and develop better gloss and dry touch, it is preferable to adopt, for example, a trefoil shape that has three convex portions as shown in Fig. 2(a) or a quatrefoil shape that has four convex portions as shown in Fig. 2(b). As the number of concave and convex portions is increased excessively, however, the distances between the concave

and convex portions become shorter to cause the cross section to gradually become rounder. In the multilobar shape of the core component according to the present invention, therefore, the substantial upper limit of the number of convex portions contained is six.

[0030] For the composite fiber according to the present invention, in order to allow the dissolution of the sheath component to serve to produce fine interfiber spaces of less than 5 μm where mutually adjacent single fibers can move, it is preferable that the ratio of $S_{\min}/D$ between the minimum thickness $S_{\min}$ of the sheath component and the fiber diameter D of the composite fiber be 0.01 or more.

[0031] To measure the fiber diameter D for the present invention, a multifilament of the core-sheath composite fiber according to the present invention is embedded in an embedding material such as epoxy resin, and its cross section perpendicular to the fiber axis is photographed by transmission electron microscopy (TEM) at a magnification where 10 or more fibers can be observed. In this observation, metal dyeing will serve to dye the different polymers to different degrees, thereby enhancing contrast at the boundaries between the core and sheath components. Fibers were selected at random in each image of the photographed images, and their diameters were measured in μm to the first decimal place. This procedure was repeated to measure the diameters of 10 randomly selected fibers, and the arithmetic number average of the measurements was calculated and rounded off to a whole number to give a value to represent the fiber diameter D (μm). Here, when the fiber's cross section perpendicular to the fiber axis was not a perfect circle, its area was measured, and the diameter calculated therefrom assuming a circle was adopted.

[0032] To determine the minimum thickness $S_{\min}$ of the sheath component referred to for the present invention, a straight line is drawn from the center of gravity $G1$ of the core component 1, which exists in the fiber cross section, to an arbitrary fiber surface as described in, for example, Fig. 2(a) and Fig. 5(a), and the distance $S1-F$ from the intersection $S1$ of the perimeter of the core component 1 and the straight line to the intersection F of the fiber surface and the straight line is measured to the first decimal place, and the minimum among the measurements taken is determined. This procedure was repeated to take measurements from 10 randomly selected fibers, and the arithmetic number average of the results was calculated and rounded off to a whole number to give a value to represent the minimum thickness $S_{\min}$ (μm) of the sheath component. Here, as shown in Fig. 4(a) and Fig. 5(b) for example, if there existed another core component 2, in addition to the core component 1 which has the center of gravity $G1$, on the straight line drawn from the center of gravity $G1$ of the core component 1 toward an arbitrary fiber surface, the distance $S1-S2$ measured from the intersection $S1$ of the perimeter of the core component 1 and the straight line to the intersection $S2$, which is the nearest to the intersection $S1$ among all intersections of the perimeter of the core component 2 and the straight line, was adopted. With regard to the symbols in the figures, it is noted that, for example, $G1$ refers to the center of gravity of the core component 1 and $G2$ refers to the center of gravity of the core component 2, with G referring to them collectively. This applies to other symbols.

[0033] Then, from the fiber diameter D and the minimum thickness $S_{\min}$ of the sheath component measured above, the arithmetic number average of the ratio of $S_{\min}/D$ was calculated and rounded off to the second decimal place to give a value to represent the ratio of $S_{\min}/D$.

[0034] If the sheath component is arranged in such a manner that the ratio of $S_{\min}/D$ between the minimum thickness $S_{\min}$ of the sheath component and the fiber diameter D is 0.01 or more, this is preferable because a woven or knitted fabric that has fine interfiber spaces of less than 5 μm to permit movements of fibers fixed at tying points can be produced by dissolving out the sheath component, thereby allowing a flexible texture to be developed. From this viewpoint, a larger $S_{\min}/D$ ratio allows fine interfiber spaces of less than 5 μm to increase in size to make fibers more movable, and accordingly a $S_{\min}/D$ ratio of 0.03 or more causes a larger increase in flexibility to develop better natural silk-like drape property peculiar to natural silk. Therefore, this range can be cited as a more preferable range. If the size of the interfiber spaces is increased excessively, on the other hand, bending recovery will decrease, and resilience, which represents an important part of the texture of natural silk, deteriorates. Accordingly, the upper limit is substantially 0.1 for the present invention.

[0035] In order to eliminate the trade-off relation in which an improvement in flexibility and lightness achieved by an increased size of interfiber spaces causes a deterioration in resilience, it is important for the core component to have a multilobar shape in which the concave portions of the multilobar shape, where the sheath thickness is large, contain coarse interfiber spaces of 10 μm or more that are formed by dissolving out the sheath component whereas the convex portions, where the sheath thickness is small, contain fine interfiber spaces of less than 5 μm , and it is also important to control the maximum and minimum sizes of the interfiber spaces. Therefore, the present inventors made intensive studies, and as a result, it was found that if the ratio between the maximum and minimum interfiber space sizes is increased to above a certain level, there will be a sufficient difference between the two groups of interfiber spaces to develop a texture having such a prominently light, flexible, and resilient texture as is peculiar to natural silk. Thus, the second requirement is that the ratio of $S_{\max}/S_{\min}$ between the maximum thickness $S_{\max}$ and the minimum thickness $S_{\min}$ of the sheath component should be 5.0 or more.

[0036] For the present invention, to determine the maximum thickness $S_{\max}$ of the sheath component, a straight line is drawn from the center of gravity $G1$ of the core component 1, which exists in the fiber cross section, to an arbitrary

fiber surface as described in, for example, Fig. 2(a) and Fig. 5(a), and the distance S1-F from the intersection S1 of the perimeter of the core component 1 and the straight line to the intersection F of the fiber surface and the straight line is measured to the first decimal place, and the maximum among the measurements taken is determined. This procedure was repeated to take measurements from 10 randomly selected fibers, and the arithmetic number average of the results was calculated and rounded off to a whole number to give a value to represent the minimum thickness $S_{\max}$ (μm) of the sheath component. Here, as shown in Fig. 4(a) and Fig. 5(b) for example, if there existed another core component 2, in addition to the core component 1 which has the center of gravity G1, on the straight line drawn from the center of gravity G1 of the core component 1 toward an arbitrary fiber surface, the distance S1-S2 measured from the intersection S1 of the perimeter of the core component 1 and the straight line to the intersection S2, which is the nearest to the intersection S1 among all intersections of the perimeter of the core component 2 and the straight line, was adopted.

[0037] Then, from the maximum thickness $S_{\max}$ of the sheath component and the minimum thickness $S_{\min}$ of the sheath component measured above, the arithmetic number average of the ratio of $S_{\max}/S_{\min}$ was calculated and rounded off to the first decimal place to give a value to represent the ratio of $S_{\max}/S_{\min}$.

[0038] For the core-sheath composite fiber according to the present invention, a texture having such a prominently light, flexible, and resilient texture as is peculiar to natural silk can be developed sufficiently if the ratio of $S_{\max}/S_{\min}$ between the maximum thickness $S_{\max}$ of the sheath component, which is related with the coarse interfiber spaces of 10 μm or more, and the minimum thickness $S_{\min}$ which is related with the fine interfiber spaces of less than 5 μm , is 5.0 or more. If the ratio of $S_{\max}/S_{\min}$ is increased to 10.0 or more, furthermore, interfiber spaces with a size peculiar to natural silk can be formed to achieve natural silk-like lightness, and therefore, this can be cited as a more preferable range. Therefore, a larger value of $S_{\max}/S_{\min}$ is more desirable from the viewpoint of such lightness, but if the value of $S_{\max}/S_{\min}$ is too large, the irregular cross-sectional shape of the fiber formed by the dissolution of the sheath component will increase in the degree of shape irregularity so largely that cloth produced therefrom may suffer high-order problems such as glare and stripes. Thus, the upper limit of $S_{\max}/S_{\min}$ is substantially 30.0.

[0039] The area proportion of the sheath component in the core-sheath composite fiber according to the present invention is preferably 10% to 50%. As the proportion of the area occupied by the sheath component increases, the dissolution of the sheath component works more effectively in forming interfiber spaces, and it is preferably 10% or more, and more preferably 20% or more. On the other hand, although a higher area proportion of the sheath component is more preferred from the viewpoint of interfiber spaces, excessive dissolution of the sheath component can occur to cause a decrease in strength or lengthening of the dissolution treatment step, and therefore, the upper limit is substantially 50%.

[0040] For the core-sheath composite fiber according to the present invention, the fiber cross section should be a perfect circle or an ellipse, and it is preferable that the relation of $1.0 \leq R_B/R_A \leq 2.5$ hold wherein R_A is the diameter of the inscribed circle of the fiber (diameter of A in Fig. 4(a)) and R_B is the diameter of the circumscribed circle (diameter of B in Fig. 4(a)). It is noted that the ratio of R_B/R_A represents the degree of shape irregularity of the fiber.

[0041] For the core-sheath composite fiber according to the present invention, it is important that different interfiber spaces coexist as a result of the formation of a multilobar shape by the dissolution of the sheath component and it is preferable that the core-sheath composite fiber is perfectly circular as illustrated in Fig. 2(a) and (b), Fig. 4(b) and (c), and Fig. 5(a) or elliptical as illustrated in Fig. 4(a) and Fig. 5(b) and contains a multilobar shaped core component, rather than such core-sheath composite fibers as shown in Fig. 3(a) and (b) that change in size while maintaining a similar same shape between before and after the dissolution of the sheath component, because this allows interfiber spaces of 10 μm or more and interfiber spaces of less than 5 μm to coexist. Furthermore, the ratio of R_B/R_A that represents the degree of shape irregularity preferably satisfies the relation of $1.0 \leq R_B/R_A \leq 2.5$ because when the core-sheath composite fiber according to the present invention is in the form of a multifilament, closest packing can be achieved easily and interfiber spaces can be formed uniformly without unevenness by the dissolution of the sheath component, which is preferable from the viewpoint of quality control.

[0042] For the core-sheath composite fiber according to the present invention, from the viewpoint of ensuring enhanced dry touch after the dissolution of the sheath component, it is preferable that a groove extending toward the center of gravity of the core component be formed at the apex of each convex portion in the multilobar shaped core component and that the ratio of GN/GM between the distance GM from the center of gravity G of the core component to the bottom M of the groove and the distance GN from the center of gravity G of the core component to the apex N of the convex portion be 1.1 to 1.5.

[0043] As illustrated in Fig. 5(a) for example, the distance GM referred to for the present invention, which is measured from the center of gravity G of the core component to the bottom M of the groove, is determined by calculating the distance from the center of gravity G1 of the core component, which is the intersection of two arbitrary straight lines each dividing the area of the core component into halves, to the bottom M1 of the groove, which is the point on the groove surface located nearest to the center of gravity G1 of the core component. In this instance, if there were two or more core component regions, the largest value among these core component regions was adopted. This procedure was repeated to take measurements from 10 randomly selected fibers, and the arithmetic number average of the results

was calculated and rounded off to a whole number to give a value to represent the distance GM (μm) from the center of gravity G of the core component to the bottom M of the groove.

[0044] As illustrated in Fig. 5(a) for example, furthermore, the distance GN referred to for the present invention, which is measured from the center of gravity G of the core component to the apex N of a convex portion, is determined by calculating the distance from the center of gravity G1 of the core component to the apex N1 of the convex portion, which is the point on the groove surface located farthest from the center of gravity G1 of the core component. In this instance, if there were two or more core components, the largest value among these core components was adopted. This procedure was repeated to take measurements from 10 randomly selected fibers, and the arithmetic number average of the results was calculated and rounded off to a whole number to give a value to represent the distance GN (μm) from the center of gravity G of the core component to the apex N of the convex portion.

[0045] Then, from the distance GM from the center of gravity G of the core component to the bottom M of a groove and the distance GN from the center of gravity G of the core component to the apex N of the convex portion measured above, the arithmetic number average of the ratio of GN/GM was calculated and rounded off to the second decimal place to give a value to represent the ratio of GN/GM. In this instance, if there was no groove at the apex of the convex portion in the core component, the relation of GN/GM = 1.0 was adopted.

[0046] For the present invention, it is preferable that a groove extending toward the center of gravity of the core component and having a depth that gives a GN/GM ratio of 1.1 or more be formed at the apex of each convex portion by dissolving out the sheath component because the surface of the groove can come in point contact with the skin, thereby serving to increase the friction force and enhance the dry touch. Furthermore, if the groove has a depth that gives a GN/GM ratio of 1.3 or more, diffused reflection of light occurs to develop a mild gloss in addition to dry touch and this also acts to suppress the fading that may be caused by regular reflection of light, leading to improved color development in the dyeing step. Therefore, this can be cited as a more preferable range. If the depth of the groove is increased excessively, however, the friction force will become too large, possibly leading to fibrillation etc. that can cause a deterioration in wear resistance. Accordingly, the upper limit of the GN/GM ratio is substantially 1.5.

[0047] From the viewpoint of close imitation of the texture of natural silk through precise production of such interfiber spaces as are peculiar to natural silk, it is preferable that in the core-sheath composite fiber according to the present invention, there are two or more regions of the core component separated from each other by the sheath component and that each separated region of the core components has a multilobar shape as described above.

[0048] Raw silk as produced from silkworm cocoons, which is to be processed into natural silk, has a cross section containing two triangular regions containing fibroin (a in Fig. 1), which is the hardly dissolvable component, surrounded by sericin (b in Fig. 1), which is the easily dissolvable components. This means that the spaces between mutually adjacent ones of the separated fibers is always controlled only by the proportion of the dissolution of sericin regardless of the arrangement of the single fibers in the multifilament, and this is considered to be the reason for the state peculiar to natural silk in which fine interfiber spaces with fiber-to-fiber distances of less than 5 μm exist stably between these single fibers. For the core-sheath composite fiber according to the present invention, it is preferable that there are two or more regions of the core component separated from each other by the sheath component and that each separated region of the core component has a multilobar shape. The number of separated regions is not particularly limited as long as it is two or more, and for example, there may be six separated core component regions as illustrated in Fig. 4(c). However, as the number of separated regions increases, not only the size of interfiber spaces that can be formed will decrease, but also precise control of the cross section will become more difficult. Therefore, the upper limit of the number of separated regions is substantially 10.

[0049] To produce coarser interfiber spaces for the present invention, it is preferable that polymers with different melting points are located next to each other in the fiber cross section so that the difference in melting point causes a difference in shrinkage rate during heat treatment to develop crimps in the core-sheath composite fiber or causes a difference in fiber length after dissolving out the sheath component from the core-sheath composite fiber. If coarser interfiber spaces can be formed, not only diffused reflection of light will occur more intensely to bring about a luxurious gloss and high-grade color development, but also the space proportion will increase to cause a decrease in apparent density, thereby realizing enhancement in lightness.

[0050] Therefore, in the core-sheath composite fiber according to the present invention, it is preferable that among the core component regions separated by the sheath component, the core component region 1 (for example c1 in Fig. 4(a), (b), and (c)) and the core component region 2 (for example c2 in Fig. 4(a), (b), and (c)), which are located adjacent to each other, be formed of polymers having different melting points.

[0051] For the present invention, polymers having different melting points mean a combination of polymers that are selected from melt-moldable polymers including polyester based, polyethylene based, polypropylene based, polystyrene based, polyamide based, polycarbonate based, polymethyl methacrylate based, polyphenylene sulfide based, and other similar polymers as well as copolymers thereof, and that differ in melting point by 10°C or more. For the core-sheath composite fiber according to the present invention, furthermore, a difference in shrinkage rate among core components is utilized with the aim of forming a core-sheath composite fiber having crimps or developing a difference in fiber length

after dissolving out the sheath component from the core-sheath composite fiber, and therefore, a good combination of core-component polymers with different melting points can be formed by adopting a polymer with a higher shrinkage rate and a lower melting point as the a core component 1 and a polymer with a lower shrinkage rate and a higher melting point as the core component 2. There are various such combinations of polymers with low melting points and polymers with high melting points including, for example, polyester based ones such as copolymer polyethylene terephthalate/polyethylene terephthalate, polybutylene terephthalate/polyethylene terephthalate, polytrimethylene terephthalate/polyethylene terephthalate, thermoplastic polyurethane/polyethylene terephthalate, polyester based elastomer/polyethylene terephthalate, and polyester based elastomer/polybutylene terephthalate; polyamide based ones such as nylon 66/nylon 610, nylon 6-nylon 66 copolymer/nylon 6 or 610, PEG copolymerized nylon 6/nylon 6 or 610, and thermoplastic polyurethane/nylon 6 or 610; and polyolefin based ones such as ethylene-propylene-rubber-finely-dispersed polypropylene/polypropylene, and propylene- α -olefin copolymer/polypropylene. For the core-sheath composite fiber according to the present invention, the use of a combination of polyester based polymers for the separated core components is particularly preferable from the viewpoint of realizing not only a bending rigidity close to that of natural silk but also high-grade color development in the dyeing step. Here, good copolymerization components for the copolymer polyethylene terephthalate include, for example, succinic acid, adipic acid, azelaic acid, sebacic acid, 1,4-cyclohexanedicarboxylic acid, maleic acid, phthalic acid, isophthalic acid, and 5-sodium sulfoisophthalic acid, and it is preferable to use a polyethylene terephthalate copolymerized with 5 mol% to 15 mol% of isophthalic acid from the viewpoint of maximizing the difference in shrinkage rate compared to polyethylene terephthalate.

[0052] With regard to the area ratio between the core component 1, i.e., the polymer with a lower melting point, and the core component 2, i.e., the polymer with a higher melting point, to use for the core-sheath composite fiber according to the present invention, it is preferable for the ratio of the core component 1 to the core component 2 to be in the range of 70%/30% to 30%/70%. If the ratio is in this range, it will be possible to form crimps in the core-sheath composite fiber by making use of the difference in shrinkage rate or develop a difference in fiber length by dissolving out the sheath component from the core-sheath composite fiber, while preventing the hardening of the texture from being caused by an influence of clogging that may occur when the polymer with a lower melting point is shrunk to a high degree in the heat treatment step. This brings about the development of coarser interfiber spaces.

[0053] The core-sheath composite fiber according to the present invention is processed first into a sheet-like fiber structure such as woven or knitted fabric, nonfabric, paper, or other various forms, and then the sheath component is dissolved out to produce a multifilament mainly containing the core component. The multifilament has natural silk-like textural features such as luxurious gloss, dry touch, lightness, flexibility, and resilience that result from the unique fiber's cross-sectional shape and interfiber spaces.

[0054] To maximize the aforementioned natural silk-like textural features such as luxurious gloss, lightness, flexibility, and resilience, the key point is that a space structure in which fine interfiber spaces with fiber-to-fiber distances of less than 5 μm and coarse interfiber spaces with fiber-to-fiber distances of 10 μm or more coexist uniformly as seen in natural silk are formed in the multifilament. To this end, it is important for the multifilament according to the present invention to have a space structure in which the average interfiber space distance is 5 to 30 μm , with the spaces with an interfiber space distance of less than 5 μm accounting for 10% to 50%.

[0055] To determine the interfiber space distance referred to for the present invention, a specimen of multifilament cloth is observed by scanning electron microscopy (SEM) to photograph the cloth's cross section perpendicular to the length direction of the cloth and also perpendicular to the fiber axis direction of the multifilament at a magnification where 10 or more fibers can be observed. In each photograph taken, a perfect circle that contains 10 fibers is drawn as illustrated in Fig. 8(b), and a fiber is selected arbitrarily from the 10 fibers existing in the perfect circle. Then, a straight line connecting between the center of gravity of the fiber and that of an adjacent fiber is drawn and the intersections between the straight line and the surfaces of the fibers are identified, followed by measuring the distance between the intersections in μm to the first decimal place. Subsequently, the measured value was rounded off to a whole number to give a value to represent the interfiber space distance (μm). The term "adjacent" used herein means that no other fiber exists on the straight line connecting between the centers of gravity of the two arbitrarily selected fibers. This procedure was performed to take measurements from all the 10 fibers existing in the perfect circle, and the arithmetic number average of the distances between all mutually-adjacent fibers was calculated as illustrated in Fig. 8(b) and rounded off to a whole number to give the average interfiber space distance (μm). The proportion of the spaces with interfiber space distances of less than 5 μm was also calculated.

[0056] A longer average interfiber space distance brings about larger spaces in which fibers fixed on the tying points of woven or knitted fabrics can move to achieve higher flexibility, and accordingly, it is necessary for the average interfiber space distance to be 5 μm or more. If the average interfiber space distance is 10 μm or more, furthermore, the fiber improves in bulkiness and can form cloth with a decreased apparent density, which leads to improved lightness as well. Accordingly, a natural silk-like light, flexible texture can be developed, indicating that the above range can be cited as a more preferable range. Although this works to improve lightness and flexibility as described above, it has less effect in preventing a decrease in bending rigidity in the interfiber spaces of less than 5 μm that coexist uniformly in the

multifilament and it tends to lead to a decreased resilience. Thus, the upper limit of the average interfiber space distance is substantially 30 μm .

[0057] In addition to the above requirement, it is necessary for the interfiber spaces with interfiber space distances of less than 5 μm to account for 10% or more so that a longer average space distance serves to prevent a decrease in bending rigidity and maintain a required resilience. If the interfiber spaces with interfiber space distances of less than 5 μm account for 20% or more, furthermore, the trade-off relation between lightness/flexibility and resilience can be eliminated, and a light, flexible, and resilient texture can be developed in a good balance, indicating that the above range can be cited as a more preferable range. Although resilience can be improved by increasing the proportion of spaces with interfiber space distances of less than 5 μm as described above, this tends to cause a decrease in lightness and flexibility and accordingly, the upper limit of the proportion of spaces with interfiber space distances of less than 5 μm is substantially 50%.

[0058] It is preferable for the multifilament according to the present invention to have a space structure in which the space proportion is 30 to 80%.

[0059] To determine space proportion referred to for the present invention, a specimen of multifilament cloth is observed by scanning electron microscopy (SEM) to photograph the cloth's cross section perpendicular to the length direction of the cloth and also perpendicular to the fiber axis direction of the multifilament at a magnification where 10 or more fibers can be observed. In each photograph taken, a perfect circle that contains 10 fibers was drawn as illustrated in Fig. 8(b), and the total cross-sectional area of the 10 fibers existing in the perfect circle was subtracted from the cross-sectional area of the perfect circle. In this instance, a fiber was included in the calculation if 1/2 or more of its area existed inside the perfect circle, and the area of each cross section was measured in μm^2 to the first decimal place. Subsequently, the calculated value was divided by the cross section of the perfect circle, multiplied by 100, and rounded off to a whole number to give a value to represent the space proportion (%).

[0060] It is preferable for the multifilament to have a space structure with a space proportion of 30% or more because it brings about larger spaces in which fibers fixed to the tying points in woven or knitted fabrics can move to achieve higher flexibility.

[0061] If the space structure has a space proportion of 50% or more, furthermore, the fiber with such a high space proportion can form cloth with a decreased apparent density, which leads to improved lightness as well. Accordingly, a natural silk-like light, flexible texture can be developed, indicating that the above range can be cited as a more preferable range. Although lightness and flexibility improve as the average interfiber space distance and space proportion increase as described above, it has less effect in preventing a decrease in bending rigidity in the interfiber spaces of less than 5 μm that coexist uniformly in the multifilament and it tends to lead to a decreased resilience. Thus, the upper limit of the space proportion in the space structure is substantially 80%.

[0062] It is preferable that the multifilament according to the present invention contains two or more types of crimped fibers that are formed of polymers having different melting points and that these crimped fibers coexist uniformly. A crimped fiber as referred to for the present invention means a fiber having curled crimps as illustrated in Fig. 7.

[0063] The expression "crimped fibers coexist uniformly" used for the present invention means that for a crimped fiber X selected arbitrarily in a multifilament as illustrated in Fig. 8(a), at least one crimped fiber Y that is formed of a polymer different from that of the crimped fiber X exists among all crimped fibers located adjacent to the crimped fiber X. The term "adjacent" used for the present invention implies that no other crimped fiber exists on the straight line connecting between the center of gravity of the crimped fiber X and that of an arbitrary crimped fiber. There are various methods that serve to produce a space structure as existing in the multifilament according to the present invention. For example, two or more core-sheath composite fibers as illustrated in Fig. 2(a) and Fig. 5(a) are bound together, followed by dissolving out the sheath component, or two or more mutually adjacent core-sheath composite fibers each containing core component regions of polymers with different melting points as illustrated in Fig. 4(a), (b), and (c) are bound together, followed by dissolving out the sheath component to divide them and then developing a difference in fiber length by heat treatment. From the viewpoint of forming fine interfiber spaces of less than 5 μm and coarse interfiber spaces of 10 μm or more that coexist more uniformly in a multifilament, it is preferable that two or more core-sheath composite fibers each containing two core component regions c1 and c2 formed of polymers with different melting points as illustrated in Fig. 10(a) and (b), which are divided by the sheath component d in the fiber's cross section, are bound together and subjected heat treatment to develop crimps, followed by dissolving the sheath component so that the crimps of polymers are separated from each other. This allows crimped fibers formed of different polymers to coexist uniformly.

[0064] If this method is used, crimps are formed by heat-treating core-sheath composite fibers, thereby forming coarse interfiber spaces of 10 μm or more. Furthermore, the sheath component exists between the core component regions, and by dissolving out the sheath component, interfiber spaces of less than 5 μm can be formed more stably between mutually adjacent crimped fibers formed of polymers with different melting points. Consequently, the resulting multifilament can contain fine interfiber spaces of less than 5 μm and coarse interfiber spaces of 10 μm or more that coexist uniformly. Thus, it is preferable for the multifilament according to the present invention to contain two or more types of crimped fibers formed of polymers with different melting points, with these crimped fibers coexisting uniformly, which

serves to realize enhanced natural silk-like textural features such as luxurious gloss, dry touch, lightness, flexibility, and resilience that result from the fiber's unique cross-sectional shape and space structure.

[0065] It is preferable for the multifilament according to the present invention to contain crimped fibers having five or more crimps per centimeter.

[0066] If the rate is in this range, the interfiber excluded volume effect is achieved sufficiently to form coarse interfiber spaces of several tens of micrometers. If the rate is 10 crimps/cm or more, furthermore, the interfiber excluded volume effect is enhanced to further increase the size of the interfiber spaces, thereby developing a natural silk-like light and flexible texture, indicating that this range can be cited as a more preferable range. On the other hand, as the number of crimps is increased, the steric hindrance effect of the crimps exceeds the excluded volume effect, possibly causing interfiber entanglement and a decrease in flexibility. Thus, the upper limit of the number of crimps is 100 crimps/cm.

[0067] It is preferable that for the multifilament according to the present invention, the two or more types of crimped fibers formed of different polymers have a fiber length difference of 3% or more. If the fiber length difference is 3% or more, the crimped fiber formed of polymers with different melting points, which is in a crimped form, can develop 10 crimps/cm or more. If the fiber length difference is too large, however, the number of crimps increases accordingly. As a result, the steric hindrance effect of the crimps can exceed the excluded volume effect, possibly causing interfiber entanglement and a decrease in flexibility. Thus, the upper limit of the fiber length difference is 20%.

[0068] For the multifilament according to the present invention, it is preferable for the crimped fiber to be formed of homopolymers. If the crimped fiber is formed of homopolymers, mutually adjacent crimped fibers can be synchronized in phase as a core-sheath composite fiber containing mutually adjacent polymers with different melting points is heat-treated to develop crimps, making it possible to form fine interfiber spaces of less than 5 μm . If it is formed of two or more different polymers, on the other hand, the center of gravity in the cross section of the polymer differs in different composite cross sections and accordingly, mutually adjacent fibers formed of polymers with different melting points form crimped fibers having crimps of different shapes after dissolving out the sheath component. As a result, their crimp phases are not synchronized, making stable production of fine interfiber spaces of less than 5 μm difficult.

[0069] Each fiber contained in the multifilament according to the present invention preferably has a fiber cross section of a multilobar shape with three or more convex portions.

[0070] If it has a fiber cross section of a multilobar shape with three or more convex portions, the fiber surface will have concave and convex portions along the fiber surface that act to amplify the reflection of light. Along with the existence of large and small interfiber spaces, they cause complicated light reflection, thereby leading to luxurious gloss such as bright and mild gloss like natural silk. In addition, the formation of an irregular fiber surface acts to increase friction, leading to dry touch. The above argument suggests that better gloss and dry touch can be developed by increasing the number of convex portions, but as the number of concave and convex portions is increased excessively, the distances between the concave and convex portions become shorter to cause the cross section to gradually become rounder. In the multifilament according to the present invention, therefore, the upper limit of the number of convex portions contained in a fiber is substantially six.

[0071] For a fiber contained in the multifilament according to the present invention, it is preferable that the relation of $1.5 \leq R_D/R_C \leq 2.0$ hold wherein R_C is the diameter of the inscribed circle (diameter of C in Fig. 9(a)) and R_D is the diameter of the circumscribed circle (diameter of D in Fig. 9(a)). It is noted that the ratio of R_D/R_C represents the degree of shape irregularity of the fiber. A value in this range is preferable from the viewpoint of quality control because the light that undergoes amplified reflection on the concave and convex portions of the multilobar shape is reflected uniformly without glare.

[0072] For the fiber contained in the multifilament according to the present invention, it is preferable from the viewpoint of enhancing dry touch that a groove exist at the apex of each convex portion in the fiber cross section and that the ratio MN/D between the distance MN from the bottom M of the groove to the apex N of the convex portion and the fiber diameter D be 0.04 to 0.20.

[0073] To determine the ratio MN/D between the distance MN from the bottom M of the groove to the apex N of the convex portion and the fiber diameter D , the multifilament according to the present invention is embedded in an embedding material such as epoxy resin, and its cross section perpendicular to the fiber axis is photographed by scanning electron microscopy (SEM) at a magnification where 10 or more fibers can be observed. For fibers randomly selected from each photographed image, the distance MN measured from the bottom M of a groove, which is the point on the groove surface located nearest to the center of gravity G , i.e., the intersection of two arbitrary straight lines each dividing the cross-sectional area of the crimped fiber into halves in the fiber cross section, to the apex N of the convex portion, which is the point located farthest therefrom, as illustrated in Fig. 9, was calculated.

[0074] The diameter of the fiber was also determined in μm to the first decimal place. In this instance, if the fiber cross section perpendicular to the fiber axis was not a perfect circle, its area was measured, and the diameter calculated therefrom assuming a circle was adopted.

[0075] From these measurements of the distance MN from the bottom M of the groove to the apex N of the convex portion and the fiber diameter D , the ratio of MN/D was calculated to the fourth decimal place. This procedure was

performed for 10 randomly selected fibers and the arithmetic number average of the results was calculated and rounded off to the second decimal place to give a value to represent the ratio of MN/D. In this instance, if there was no groove at the apex of the convex portion in the crimped fiber, the relation of MN/D = 0 was adopted.

[0076] It is preferable for a fiber contained in the multifilament according to the present invention to have a groove with a depth that gives a MN/D ratio of 0.04 or more because the surface of the groove can come in point contact with the skin and this serves to increase the friction and enhance dry touch. Furthermore, if the groove has a depth that gives a MN/D ratio of 0.10 or more, diffused reflection of light occurs to develop a mild gloss in addition to dry touch and this acts to suppress the fading that may be caused by regular reflection of light, leading to improved color development in the dyeing step. Therefore, this can be cited as a more preferable range. If the depth of the groove is increased excessively, however, the friction will become too large, possibly leading to fibrillation etc. that can cause a deterioration in wear resistance. Accordingly, the upper limit of the MN/D ratio is substantially 0.20.

[0077] For a fiber contained in the multifilament according to the present invention, it is preferable for the fiber diameter to be 15 μm or less from the viewpoint of further enhancing the flexibility of the texture. If the fiber diameter is 12 μm or less, the single fiber fineness comes closer to that of natural silk, i.e., about 10 μm , to realize more natural silk-like touch. Thus, this can be cited as a preferable range for the production of general clothing such as inner wear, shirts, and blouses that are used in contact with the skin. On the other hand, the fiber diameter is preferably 8 μm or more because if the fiber diameter is too small, bending recovery will decrease, possibly leading not only to a decrease in resilience, which represents a feature of the texture of natural silk, but also to a deterioration in color development.

[0078] In the core-sheath composite fiber and the multifilament according to the present invention, it is possible to form a unique space structure in which fine interfiber spaces with fiber-to-fiber distances of less than 5 μm and coarse interfiber spaces with fiber-to-fiber distances of several tens of micrometers coexist uniformly as seen in natural silk. Therefore, fiber materials formed at least partially of the core-sheath composite fiber or the multifilament according to the present invention will have various natural silk-like textural features. Thus, with high handleability peculiar to synthetic fibers, they can be used suitably for the production of a wide range of textile products including jackets, skirts, pants, underwear, other general clothing, sportswear, clothing materials, carpets, sofas, curtains, other interior products, car seats, other vehicle interiors, cosmetics, cosmetic masks, wiping cloth, and health products, not to mention conventional Western and Japanese style clothing in which natural silk has been mainly used.

[0079] Typical production methods for the core-sheath composite fiber and the multifilament according to the present invention are described in detail below.

[0080] Useful methods to produce the core-sheath composite fiber according to the present invention that contains two or more polymers include the melting spinning method designed for production of long fibers, solution spinning methods such as for wet and dry-jet wet spinning, melt-blowing method, which is suitable for producing sheet-like fiber structures, and spun-bonding method, of which the melting spinning method is preferred from the viewpoint of high productivity. For their production, the melting spinning method may be used with a composite spinneret as described later, and spinning should be performed at a temperature at which mainly the high melting point one or high viscosity one among all polymer species used show flowability. Depending on the molecular weight, the temperature where such a polymer show flowability may be set between its melting point and a temperature 60°C above the melting point to ensure stable production.

[0081] The spinning speed may be set at about 500 to 6,000 m/min and adjusted according to the physical properties of the polymer or purposes of the fiber. From the viewpoint of ensuring a high degree of orientation and improved mechanical characteristics, in particular, it is preferable to perform spinning at 500 to 4,000 m/min, followed by stretching, to produce a fiber that is strongly oriented uniaxially. In the stretching step, it is preferable to set an appropriate preheating temperature on the basis of the temperature at which the polymer can soften, such as its glass transition temperature. The upper limit of preheating temperature is preferably set at a temperature where unstable thread passage is not caused by spontaneous stretching of the fiber during preheating. In the case of PET, for example, which has a glass transition temperature of about 70°C, the preheating temperature is commonly set at about 80°C to 95°C.

[0082] Furthermore, stable production of the core-sheath composite fiber according to the present invention can be performed if the discharge rate per single hole of the spinneret is about 0.1 to 10 g/min•hole. The polymer flow discharged is cooled for solidification, supplied with a lubricant, and taken up on a roller with a prescribed circumferential speed. Subsequently, it is stretched by heated rollers to form an intended core-sheath composite fiber.

[0083] For the core-sheath composite fiber according to the present invention that contains two or more polymers, furthermore, it is preferable to use polymers with a melt viscosity ratio of less than 5.0 and a solubility parameter difference of less than 2.0 because a composite polymer flow can be formed stably and a fiber having a desirable composite cross section can be produced.

[0084] The composite spinneret used to produce the core-sheath composite fiber according to the present invention that contains two or more polymers is preferably a composite spinneret as described in Japanese Unexamined Patent Publication (Kokai) No. 2011-208313. The composite spinneret illustrated in Fig. 12 in the present Application is composed mainly of the three members of a measuring plate 1, a distribution plate 2, and a discharge plate 3, from top to bottom,

to constitute a layered structure which is built into a spinning pack to be used for spinning. Here, Fig. 12 shows an example in which three polymers, that is, polymer A, polymer B, and polymer C, are used. It is difficult for conventional composite spinnerets to form a composite flow containing three or more polymers, and therefore, it is preferable to use a composite spinneret having fine flow channels as illustrated in Fig. 12.

[0085] With regard to the spinneret members illustrated in Fig. 12, the measuring plate 1 feeds polymers while measuring the polymer feeding rate for each discharge hole and distribution hole, and the distribution plate 2 controls the composite cross section and the cross-sectional shape of each single fiber. Then, the discharge plate 3 compresses and discharges the composite polymer flow formed by the distribution plate 2.

[0086] The members located above the measuring plate 1 are not shown in the figure to avoid complexity in explaining the composite spinneret, but any appropriate ones may be used if they have flow channels that are suitable for use with the spinning machine and spinning pack. For example, a conventional spinning pack and its members may serve effectively without any modifications if the measuring plate 1 is tailored to the existing flow channel members. It is not necessary, therefore, to prepare a specially designed spinning machine for use with this spinneret. In actual cases, furthermore, it may be desirable to provide a plurality of flow channel plates between the flow channels and the measuring plate or between the measuring plate 1 and the distribution plate 2. This intends to provide flow channels that work to allow the polymers to be efficiently transported in the cross-sectional direction of the spinneret and the cross-sectional direction of the single fibers to ensure their smooth introduction to the distribution plate 2. The composite polymer flow discharged through the discharge plate 3 is then processed by the aforementioned production method in which it is cooled for solidification, supplied with a lubricant, and taken up on a roller with a prescribed circumferential speed. Subsequently, it is stretched by heated rollers to form an intended core-sheath composite fiber.

[0087] To allow a multifilament formed of the core component to be produced by removing the sheath component from the core-sheath composite fiber according to the present invention, it is necessary to dissolve out the sheath component to form a fiber formed of the core component. This can be achieved by removing the sheath component by immersing the core-sheath composite fiber in a solvent etc. that can dissolve the easily dissolvable component. An aqueous alkali solution such as aqueous solution of sodium hydroxide can be used when the easily dissolvable component is, for example, polylactic acid, copolymer polyethylene terephthalate copolymerized with 5-sodium sulfoisophthalic acid, polyethylene glycol, etc. Here, it is preferable to heat the aqueous alkali solution at 50°C or more because its hydrolysis can be accelerated. Furthermore, the use of a fluid dyeing machine etc. is preferable from an industrial viewpoint because a large batch can be processed at a time.

EXAMPLES

[0088] The core-sheath composite fiber and the multifilament according to the present invention will now be illustrated in detail below with reference to examples.

[0089] For the examples and comparative examples, evaluations were made as described below.

A. Melt viscosity of polymers

[0090] Chips of a polymer were dried in a vacuum dryer to a moisture content of 200 ppm or less and subjected to melt viscosity measurement using a Capilograph, manufactured by Toyo Seiki Co., Ltd., in which the strain rate was changed stepwise. Here, the measuring temperature used was the same as the spinning temperature, and measurement was started in 5 minutes after putting a sample into a nitrogen atmosphere in a heating furnace. A melt viscosity measurement taken at a shear rate of $1,216 \text{ s}^{-1}$ was adopted for evaluation of the polymer.

B. Melting point of polymers

[0091] Chips of a polymer were dried in a vacuum dryer to a moisture content of 200 ppm or less and a sample of about 5 mg was weighed and heated from 0°C to 300°C in a differential scanning calorimeter (DSC) (Q2000, manufactured by TA Instruments) at a heating rate of 16°C/min. It was maintained at 300°C for 5 minutes and then subjected to DSC measurement. The melting point was calculated from the melting peak observed during the heating step. Three measurements were taken from a sample, and their average was adopted as its melting point. Here, in the case where two or more melting peaks were observed, the melting peak appearing at the highest temperature was adopted to determine the melting point.

C. Fineness

[0092] The weight of a multifilament sample with a length of 100 m was measured and the measured value was multiplied by 100. This procedure was repeated 10 times, and the average was rounded off to the first decimal place to

give value to represent the fineness (dtex) of the multifilament.

D. Cross section parameter (R_B/R_A)

[0093] A core-sheath composite fiber was embedded in an embedding material such as epoxy resin, and its cross section perpendicular to the fiber axis was photographed using a HITACHI scanning electron microscope (SEM) at a magnification where 10 or more fibers could be observed. The image obtained was analyzed using WinROOF (computer software supplied by Mitani Shoji Co., Ltd.) to determine the value of R_B/R_A , i.e., the ratio between the diameter R_B of the circumscribed circle of the fiber (for example, the diameter of B in Fig. 4A(a)) and the diameter R_A of the inscribed circle of the fiber (for example, the diameter of A in Fig. 4(a)). For the present invention, three measurements were taken from each filament and the arithmetic number average of the measurements taken from 10 filaments were calculated and rounded off to the second decimal place to give a value to represent R_B/R_A .

E. Cross section parameters (S_{min}/D , S_{max}/S_{min})

[0094] A core-sheath composite fiber was embedded in an embedding material such as epoxy resin, and its cross section perpendicular to the fiber axis was photographed by transmission electron microscopy (TEM) at a magnification where 10 or more fibers could be observed. In this observation, metal dyeing can serve to dye different polymers to different degrees, thereby enhancing contrast at the boundaries between the composite components. From the photographed image, the ratio of S_{min}/D between the minimum thickness S_{min} of the sheath component and the fiber diameter D and the ratio of S_{max}/S_{min} between the maximum thickness S_{max} of the sheath component and the minimum thickness S_{min} of the sheath component were calculated.

[0095] For the present invention, fibers were selected at random in each image of the photographed images, and their diameters were measured in μm to the first decimal place. This procedure was repeated to measure the diameters of 10 randomly selected fibers, and the arithmetic number average of the measurements was calculated and rounded off to a whole number to give a value to represent the fiber diameter D (μm). Here, when the fiber's cross section perpendicular to the fiber axis was not a perfect circle, its area was measured, and the diameter calculated therefrom assuming a circle was adopted.

[0096] To determine the minimum thickness S_{min} of the sheath component referred to for the present invention, fibers are selected at random in each image of the photographed images, and a straight line is drawn from the center of gravity G1 of the core component 1, which exists in a fiber cross section, to an arbitrary fiber surface as described in, for example, Fig. 2(a) and Fig. 5(a). Then, the distance S1-F from the intersection S1 between the perimeter of the core component 1 and the straight line to the intersection F between the fiber surface and the straight line is measured to the first decimal place, and the smallest one of the measurements taken is determined. This procedure was repeated to take measurements from 10 randomly selected fibers, and the arithmetic number average of the results was calculated and rounded off to a whole number to give a value to represent the minimum thickness S_{min} (μm) of the sheath component. Here, as shown in Fig. 4(a) and Fig. 5(b) for example, when there existed another core component 2, in addition to the core component 1 which had the center of gravity G1, on the straight line drawn from the center of gravity G1 of the core component 1 to an arbitrary fiber surface, the distance S1-S2 measured from the intersection S1 between the perimeter of the core component 1 and the straight line to the intersection S2, which is the nearest to the intersection S1 among all intersections between the perimeter of the core component 2 and the straight line, was adopted.

[0097] Then, from the fiber diameter D and the minimum thickness S_{min} of the sheath component measured above, the arithmetic number average of the ratio of S_{min}/D was calculated and rounded off to the second decimal place to give a value to represent the ratio of S_{min}/D .

[0098] To determine the minimum thickness S_{max} of the sheath component referred to for the present invention, fibers are selected at random in each image of the photographed images, and a straight line is drawn from the center of gravity G1 of the core component 1, which exists in the fiber cross section, toward an arbitrary fiber surface as described in, for example, Fig. 2(a) and Fig. 5(a). Then, the distance S1-F from the intersection S1 between the perimeter of the core component 1 and the straight line to the intersection F between the fiber surface and the straight line is measured to the first decimal place, and the largest one of the measurements taken is determined. This procedure was repeated to take measurements from 10 randomly selected fibers, and the arithmetic number average of the results was calculated and rounded off to a whole number to give a value to represent the minimum thickness S_{max} (μm) of the sheath component. Here, as shown in Fig. 4(a) and Fig. 5(b) for example, when there existed another core component 2, in addition to the core component 1 which had the center of gravity G1, on the straight line drawn from the center of gravity G1 of the core component 1 to an arbitrary fiber surface, the distance S1-S2 measured from the intersection S1 between the perimeter of the core component 1 and the straight line to the intersection S2, which is the nearest to the intersection S1 among all intersections between the perimeter of the core component 2 and the straight line, was adopted.

[0099] From the maximum thickness S_{max} of the sheath component and the minimum thickness S_{min} of the sheath

component measured above, the arithmetic number average of the ratio of $S_{\max}/S_{\min}$ was calculated and rounded off to the first decimal place to give a value to represent the ratio of $S_{\max}/S_{\min}$.

F. Cross section parameter (GN/GM)

[0100] In the case where the core component of the core-sheath composite fiber observed in the above section E had a multilobar shape in which a groove extending toward the center of gravity of the core component existed at the apex of each convex portion, the ratio of GN/GM between the distance GM from the center of gravity G of the core component to the bottom M of the groove and the distance GN from the center of gravity G of the core component to the apex N of the convex portion was calculated. In this instance, if there was no groove at the apex of the convex portion of the core component, the relation of GN/GM = 1.0 was adopted.

[0101] As illustrated in Fig. 5(a) for example, the distance GM referred to for the present invention, which is measured from the center of gravity G of the core component to the bottom M of the groove, is determined by calculating the distance from the center of gravity G1 of the core component, which is the intersection between two arbitrary straight lines each dividing the area of the core component into halves, to the bottom M1 of the groove, which is the point on the groove surface located nearest to the center of gravity G1 of the core component. In this instance, if there were two or more core component regions, the largest value among these core component regions was adopted. This procedure was repeated to take measurements from 10 randomly selected fibers, and the arithmetic number average of the measurements was calculated and rounded off to a whole number to give a value to represent the distance GM (μm) from the center of gravity G of the core component to the bottom M of the groove.

[0102] As illustrated in Fig. 5(a) for example, furthermore, the distance GN referred to for the present invention, which is measured from the center of gravity G of the core component to the apex N of the convex portion, is determined by calculating the distance from the center of gravity G1 of the core component to the apex N1 of the convex portion, which is the point on the groove surface located farthest from the center of gravity G1 of the core component. In this instance, if there were two or more core component regions, the largest value among these core component regions was adopted. This procedure was repeated to take measurements from 10 randomly selected fibers, and the arithmetic number average of the measurements was calculated and rounded off to a whole number to give a value to represent the distance GN (μm) from the center of gravity G of the core component to the apex N of the convex portion.

[0103] From the distance GM from the center of gravity G of the core component to the bottom M of a groove and the distance GN from the center of gravity G of the core component to the apex N of the convex portion measured above, the arithmetic number average of the ratio of GN/GM was calculated and rounded off to the second decimal place to give a value to represent the ratio of GN/GM.

G. State of coexistence of fibers in multifilament

[0104] A multifilament cloth is examined by a HITACHI scanning electron microscope (SEM) to photograph the cloth's cross section perpendicular to the length direction of the cloth and also perpendicular to the fiber axis direction of the multifilament at a magnification where 10 or more fibers can be observed. The photographed image was analyzed using WinROOF (computer software supplied by Mitani Shoji Co., Ltd.). For an arbitrary fiber X in the multifilament as illustrated in Fig. 8(a), analysis was made to find all fibers Y each having no other fibers existing on the straight line drawn between the center of the gravity of the fiber X and the center of the gravity of that fiber Y, and the number of those fibers Y each being formed of a polymer different from the fiber X was counted and used for evaluation. This measuring procedure was repeated to take measurements from 10 randomly selected fibers in the multifilament, and the arithmetic number average of the results was calculated and rounded off to a whole number. The value obtained was used to evaluate the state of fiber coexistence according to the two stage criterion specified below.

[0105]

A: uniform coexistence (The number of fibers Y formed of a polymer different from the fiber X is one or more.)

C: uneven coexistence (The number of fibers Y formed of a polymer different from the fiber X is less than one.)

H. Crimp number (crimps/cm)

[0106] A multifilament cloth was prepared and a multifilament was pulled out of the cloth in such a manner that it did not suffer plastic deformation. One end of the multifilament was fixed and a weight of 1 mg/dtex was attached to the other end. After 30 seconds or more, marks were made on the multifilament in such a manner that the distance between them measured in the fiber axis direction was 1 cm. Subsequently, a fiber was separated from the multifilament in such a manner that it did not suffer plastic deformation and fixed on a slide glass in such a manner that the distance between the marks made above was adjusted to the original length of 1 cm. This sample was photographed using a digital

microscope (VHX-2000, manufactured by Keyence Corporation) at a magnification where the 1 cm spaced marks could be observed. In the photographed image, the number of crimps between the marks was counted. This procedure was repeated to take measurements from 10 fibers formed of the same polymer, and the arithmetic number average of the results was calculated and rounded off to a whole number to give a value to represent the crimp number (crimps/cm).
 When fibers formed of different polymers coexist, the crimp number was determined for the fibers formed of each polymer, and the crimp number of the fibers of the polymer giving the largest crimp number was adopted.

I. Difference in fiber length

[0107] A multifilament cloth was prepared and a multifilament was pulled out of the cloth in such a manner that it did not suffer plastic deformation. One end of the multifilament was fixed and a weight of 1 mg/dtex was attached to the other end. After 30 seconds or more, marks were made on the multifilament in such a manner that the distance between them measured in the fiber axis direction was 1 cm. Subsequently, a fiber was separated from the multifilament in such a manner that it did not suffer plastic deformation and fixed on a slide glass in such a manner that the distance between the marks made above was adjusted to the original length of 1 cm. This sample was photographed using a digital microscope (VHX-2000, manufactured by Keyence Corporation) at a magnification where the 1 cm spaced marks could be observed. The image obtained was analyzed using WinROOF (computer software supplied by Mitani Shoji Co., Ltd.) to determine the actual fiber length between the marks. For the fibers made of different polymers, this procedure was repeated to take measurements from 10 fibers formed of each polymer, and the arithmetic number average of the results was calculated. From the calculations obtained, the equation of (largest actual fiber length - shortest actual fiber length) / (shortest actual fiber length) $\times$ 100 was executed and rounded off to a whole number to give a value to represent the difference in fiber length (%).

J. Interfiber space distance

[0108] A multifilament cloth is examined by a HITACHI scanning electron microscope (SEM) to photograph the cloth's cross section perpendicular to the length direction of the cloth and also perpendicular to the fiber axis direction of the multifilament at a magnification where 10 or more fibers can be observed. The image obtained was analyzed using WinROOF (computer software supplied by Mitani Shoji Co., Ltd.). A perfect circle that contains 10 fibers was drawn as illustrated in Fig. 8(b), and a fiber was selected arbitrarily from the 10 fibers existing in the perfect circle. Then, a straight line extending between the center of gravity of the fiber and that of an adjacent fiber was drawn and the intersections between the straight line and the surfaces of the two fibers were identified, followed by measuring the distance between the intersections in μm to the first decimal place. Subsequently, the measured value was rounded off to a whole number to give a value to represent the interfiber space distance (μm). The term "adjacent" used herein implies that no other fiber exists on the straight line drawn between the centers of gravity of the two arbitrarily selected fibers. This procedure was performed to take measurements from all the 10 fibers existing in the perfect circle, and the arithmetic number average of the distances between all mutually-adjacent fibers was calculated as illustrated in Fig. 8(b) and rounded off to a whole number to give the average interfiber space distance (μm). The proportion of the spaces with interfiber space distances of less than 5 μm was also calculated.

K. Space proportion

[0109] A multifilament cloth is examined by a HITACHI scanning electron microscope (SEM) to photograph the cloth's cross section perpendicular to the length direction of the cloth and also perpendicular to the fiber axis direction of the multifilament at a magnification where 10 or more fibers can be observed. The image obtained was analyzed using WinROOF (computer software supplied by Mitani Shoji Co., Ltd.). A perfect circle that contains 10 fibers was drawn as illustrated in Fig. 8(b), and the total cross-sectional area of the 10 fibers existing in the perfect circle was subtracted from the cross-sectional area of the perfect circle. In this instance, a fiber was included in the calculation if 1/2 or more of its area existed inside the perfect circle, and the area of a cross section was measured in μm^2 to the first decimal place. Subsequently, the calculated value was divided by the cross section of the perfect circle, multiplied by 100, and rounded off to a whole number to give a value to represent the space proportion (%).

L. Diameter of fiber of irregular cross-sectional shape

[0110] Fibers were selected at random in each of the images photographed in the section K, and their diameters were measured in μm to the first decimal place. This procedure was repeated for 10 randomly selected fibers, and the largest one of the fiber diameter measurements was rounded off to a whole number to give a value to represent the fiber diameter D (μm). Here, when the fiber's cross section perpendicular to the fiber axis was not a perfect circle, its area was measured,

and the diameter calculated therefrom assuming a circle was adopted.

M. Cross section parameter (R_D/R_C)

[0111] The image photographed in the section K was analyzed using WinROOF (computer software supplied by Mitani Shoji Co., Ltd.) to determine the value of R_D/R_C , i.e., the ratio between the diameter R_D of the circumscribed circle of the fiber (for example, the diameter of C in Fig. 9(a)) and the diameter R_C of the inscribed circle of the fiber (for example, the diameter of C in Fig. 9(a)). For the present invention, three measurements were taken from each filament and the arithmetic number average of the measurements taken from 10 filaments were calculated and rounded off to the first decimal place to give a value to represent R_D/R_C .

N. Cross section parameter (MN/D)

[0112] If a fiber observed in the section K had a groove at the apex of a convex portion, the ratio MN/D between the distance MN from the bottom M of the groove to the apex N of the convex portion and the fiber diameter D was calculated. In this instance, if there was no groove at the apex of the convex portion in the fiber, the relation of $MN/D = 0$ was adopted.

[0113] To determine the ratio MN/D between the distance MN from the bottom M of the groove to the apex N of the convex portion and the fiber diameter D as referred to for the present invention, the multifilament is embedded in an embedding material such as epoxy resin, and its cross section perpendicular to the fiber axis is photographed using a HITACHI scanning electron microscope (SEM) at a magnification where 10 or more fibers can be observed. Fibers were randomly selected from each of the photographed images and analyzed using WinROOF (computer software supplied by Mitani Shoji Co., Ltd.). As illustrated in Fig. 9(b) for example, the distance MN measured from the bottom M of a groove, which is the point on the groove surface located nearest to the center of gravity G, i.e., the intersection between two arbitrary straight lines each dividing the cross-sectional area of the fiber into halves in the fiber cross section, to the apex N of the convex portion, which is the point located farthest therefrom, was calculated.

[0114] The diameter D of the fiber was also determined in μm to the first decimal place. In this instance, if the fiber cross section perpendicular to the fiber axis was not a perfect circle, its area was measured, and the diameter calculated therefrom assuming a circle was adopted to represent the fiber diameter D.

[0115] From these measurements of the distance MN from the bottom M of the groove to the apex N of the convex portion and the fiber diameter D, the ratio of MN/D was calculated to the fourth decimal place. This procedure was performed for 10 randomly selected fibers and the arithmetic number average of the results was calculated and rounded off to the second decimal place to give a value to represent the ratio of MN/D.

O. Texture evaluation (gloss, lightness, flexibility, resilience, and dry touch)

[0116] An eight-shaft satin fabric was woven with the numbers of fibers adjusted so that the warp-directional cover factor (CFA) was 800 and the weft-directional cover factor (CFB) was 1,200. The CFA and CFB referred to here are determined by measuring the warp density and weft density per 2.54 cm according to JIS L 1096 (2010) 8.6.1, and calculating the following equations: $CFA = \text{warp density} \times (\text{fineness of warp})^{1/2}$ and $CFB = \text{weft density} \times (\text{fineness of weft})^{1/2}$. Fabrics were woven and their textures were evaluated in terms of the five items of gloss, lightness, flexibility, resilience, and dry touch.

[0117] For gloss evaluation, an automatic goniophotometer (GP-200, manufactured by Murakami Color Research Laboratory Co., Ltd.) was used to apply a light beam to a sample at an incident angle 60° and perform two-dimensional reflected light distribution measurement to measure the light intensity over the light receiving angle range of 0° to 90° in 0.1° steps, and the maximum light intensity (specular reflection) at a light receiving angle of about 60° was divided by the minimum light intensity (diffuse reflection) at a light receiving angle of about 0° . This procedure was repeated to take measurements at 10 positions, three measurements at each position, and their arithmetic number average was calculated and rounded off to the first decimal place to give a value to represent the contrast gloss. Based on the contrast gloss values obtained above, a gloss evaluation was performed according to the three stage criterion specified below.

[0118]

S: Excellent gloss (contrast gloss < 1.6)

A: Good gloss ($1.6 \leq \text{contrast gloss} < 1.9$)

C: Inferior gloss ($1.9 \leq \text{contrast gloss}$)

[0119] For lightness evaluation, the thickness (cm) of a $20\text{ cm} \times 20\text{ cm}$ fabric sample was measured using a constant pressure thickness gauge (PG-14J, manufactured by TeloTech) and used to calculate the volume of the fabric sample, and then the weight of the fabric sample (g) was divided by the volume obtained above to calculate the apparent density

of the fabric (g/cm^3). Based on the apparent density measured above, a lightness evaluation was performed according to the three stage criterion specified below.

[0120]

- 5 S: Excellent lightness (apparent density ≤ 0.33)
 A: Good lightness ($0.34 < \text{apparent density} \leq 0.39$)
 C: Inferior lightness ($0.4 < \text{apparent density}$)

10 **[0121]** For flexibility evaluation, a $20 \text{ cm} \times 20 \text{ cm}$ fabric sample was fixed with an effective specimen length of $20 \text{ cm} \times 1 \text{ cm}$ on a pure bending test machine (KES-FB2, manufactured by Kato Tech Co., Ltd.) and bent in the weft direction up to maximum curvatures of $\pm 2.5 \text{ cm}^{-1}$. Then, the difference in bending moment per unit width ($\text{gf}\cdot\text{cm}/\text{cm}$) between the curvatures of 0.5 cm^{-1} and 1.5 cm^{-1} was divided by the difference in curvature of 1 cm^{-1} , and the difference in bending moment per unit width ($\text{gf}\cdot\text{cm}/\text{cm}$) between the curvatures of -0.5 cm^{-1} and -1.5 cm^{-1} was divided by the difference in curvature of 1 cm^{-1} , followed by calculating the average of the quotients. This procedure was repeated to take measurements at 10 positions, three measurements at each position, and their arithmetic number average was calculated, rounded off to the third decimal place, and divided by 100 to give a value to represent the flexural rigidity $B \times 10^{-2}$ ($\text{gf}\cdot\text{cm}^2/\text{cm}$). Based on the flexural rigidity $B \times 10^{-2}$ obtained above, a flexibility evaluation was performed according to the three stage criterion specified below.

[0122]

- 20 S: Excellent flexibility (flexural rigidity $B \times 10^{-2} \leq 1.0$)
 A: Good flexibility ($1.0 < \text{flexural rigidity } B \times 10^{-2} \leq 1.9$)
 C: Inferior flexibility ($1.9 < \text{flexural rigidity } B \times 10^{-2}$)

25 **[0123]** For resilience evaluation, a $20 \text{ cm} \times 20 \text{ cm}$ fabric sample was fixed with an effective specimen length of $20 \text{ cm} \times 1 \text{ cm}$ on a pure bending test machine (KES-FB2, manufactured by Kato Tech Co., Ltd.) and bent in the weft direction, and the hysteresis width ($\text{gf}\cdot\text{cm}/\text{cm}$) at the curvature of $\pm 1.0 \text{ cm}^{-1}$ was calculated. This procedure was repeated to take measurements at 10 positions, three measurements at each position, and their arithmetic number average was calculated, rounded off to the third decimal place, and divided by 100 to give a value to represent the bending recovery $2\text{HB} \times 10^{-2}$ ($\text{gf}\cdot\text{cm}/\text{cm}$). Based on the bending recovery $2\text{HB} \times 10^{-2}$ obtained above, a resilience evaluation was performed according to the three stage criterion specified below.

[0124]

- 35 S: Excellent resilience (bending recovery $2\text{HB} \times 10^{-2} \leq 1.0$)
 A: Good resilience ($1.0 < \text{bending recovery } 2\text{HB} \times 10^{-2} \leq 1.9$)
 C: Inferior resilience ($1.9 < \text{bending recovery } 2\text{HB} \times 10^{-2}$)

40 **[0125]** A dry touch evaluation was made by using an automated surface testing machine (KES-FB4 Kato Tech Co., Ltd.), in which a $1 \text{ cm} \times 1 \text{ cm}$ arm wound with piano wire was slid at a speed of $1.0 \text{ mm}/\text{sec}$ under a load of 50 g over a $10 \text{ cm} \times 10 \text{ cm}$ area of a $20 \text{ cm} \times 20 \text{ cm}$ fabric sample to determine the average friction coefficient MIU. This procedure was repeated to take measurements at 10 positions, three measurements at each position, and their arithmetic number average was calculated and rounded off to the first decimal place to give a value to represent the friction coefficient. Based on the friction coefficient obtained above, a dry touch evaluation was performed according to the three stage criterion specified below.

[0126]

- 45 S: Excellent dry touch ($0.7 \leq \text{friction coefficient}$)
 A: Good dry touch ($0.3 \leq \text{friction coefficient} < 0.7$)
 C: Inferior dry touch ($\text{friction coefficient} < 0.3$)

50 P. Color development property

55 **[0127]** An eight-shaft satin fabric was woven with the numbers of fibers adjusted so that the warp-directional cover factor (CFA) was 800 and the weft-directional cover factor (CFB) was 1,200. The resulting fabric was dyed in black using a disperse dye (Sumikaron Black S-3B, 10% owf). For the dyed fabric, reflection measurement was performed using CM-3700A, manufactured by Konica Minolta, Inc., to determine the L value. This procedure was repeated to take measurements at 10 positions, three measurements at each position, and their arithmetic number average was calculated and rounded off to a whole number to give a value to represent the L value of the black dyed fabric. Based on the L

value of the black dyed fabric obtained above, a color development property evaluation was performed according to the three stage criterion specified below.

[0128]

- S: Excellent color development property (L value of black dyed fabric < 15)
 A: Good color development property ($15 \leq$ L value of black dyed fabric < 18)
 C: Inferior color development property ($18 \leq$ L value of black dyed fabric)

Q. Wear resistance

[0129] A plain weave fabric was produced with the numbers of fibers adjusted so that the warp-directional cover factor (CFA) was 1,100 and the weft-directional cover factor (CFB) was 1,100. The resulting fabric was dyed in black using a disperse dye (Sumikaron Black S-3B, 10% owf). A circular sample with a diameter of 10 cm was cut out of the dyed fabric, wetted with distilled water, and fixed on a disk. In addition, a 30 cm $\times$ 30 cm portion was cut out of the fabric and, while kept in a dry state, fixed on a horizontal plate. The disk carrying a fabric sample wetted with distilled water was maintained horizontally as it was brought into contact with the fabric fixed on the horizontal plate, and then the disk was moved in a circular motion in such a manner that the center of the disk drew a circle with a diameter of 10 cm at a speed of 50 rpm for 10 minutes while applying a load of 420 g to cause the two pieces of fabric to rub each other. After the end of the rubbing step, they were left to stand for 4 hours and the degree of discoloration of the fabric sample fixed on the disk was determined according to a gray scale for discoloration test. It was rated in five grades, from 1 to 5 in 0.5 steps. Based on the rating made above, a wear resistance evaluation was performed according to the three stage criterion specified below.

[0130]

- S: Excellent wear resistance (grade: 4 or higher)
 A: Good wear resistance (grade: 3 or 3-4)
 C: Inferior wear resistance (grade: lower than 3)

[Example 1]

[0131] First, a polyethylene terephthalate copolymerized with 8 mol% of 5-sodium sulfoisophthalic acid and 9 wt% of polyethylene glycol (SSIA-PEG copolymerized PET, melt viscosity 100 Pa·s, melting point 233°C) was prepared as polymer 1 and a polyethylene terephthalate (PET, melt viscosity 130 Pa·s, 254°C) was prepared as polymer 2.

[0132] These polymers were melted separately at 290°C, weighed to adjust the weight ratio of polymer 1/polymer 2 to 30/70, and fed to a spinning pack containing a composite spinneret as illustrated in Fig. 12, and then the polymers fed were discharged through a discharge hole to form a perfect circular core-sheath composite fiber having a composite structure in which a core component having a trifoliate cross section with a groove at the apex of each convex portion was completely surrounded by a sheath component as illustrated in Fig. 5(a). Here, the polymer 1 and the polymer 2 were arranged in such a manner that they formed the sheath component and the core component, respectively.

[0133] The composite polymer flow discharged above was cooled for solidification, then supplied with a lubricant, wound up at a spinning speed of 1,500 m/min, and stretched between rollers heated at 90°C and 130°C to produce a 56 dtex - 36 filament core-sheath composite fiber.

[0134] The ratio of $S_{\min}/D$ between the minimum thickness of the resulting sheath component and the fiber diameter was 0.03 and the ratio of $S_{\max}/S_{\min}$ between the maximum thickness and the minimum thickness of the sheath component was 16. The ratio of GN/GM between the distance GM from the center of gravity G of the core component to the bottom M of a groove and the distance GN from the center of gravity G of the core component to the apex N of the convex portion was 1.42, proving that this core-sheath composite fiber was one according to the present invention.

[0135] Furthermore, the ratio between the diameter R_A of the inscribed circle and the diameter R_B of the circumscribed circle of the core-sheath composite fiber was 1.0, indicating that if it exists in the form of a multifilament, closest packing can be achieved easily and interfiber spaces can be formed uniformly without unevenness by the dissolution of the sheath component.

[0136] A fabric was produced by weaving the resulting core-sheath composite fiber and treated in a 1 wt% aqueous solution of sodium hydroxide (bath ratio 1:50) heated at 90°C to remove 99% or more of the sheath component to provide a fabric containing multifilaments (fiber diameter 10 μ m) formed of the core component of the core-sheath composite fiber.

[0137] As a result of the dissolution of the sheath component that completely surrounded the multilobar shaped core component, the fabric containing multifilaments had a space structure in which fine interfiber spaces with fiber-to-fiber distances of less than 5 μ m and coarse interfiber spaces with fiber-to-fiber distances of 10 μ m or more coexist uniformly as in natural silk to realize a natural silk-like texture having a good gloss independent on view angle (contrast gloss:

1.7), dry touch (friction coefficient: 0.7) with resilience (bending recovery 2HB: 0.6×10^{-2} gf·cm/cm), high lightness (apparent density: 0.40 g/cm^3), and high flexibility (flexural rigidity B: 0.7×10^{-2} gf·cm²/cm).

[0138] It was found that when dyed in black, the fabric had good color development property (L value of black dyed fabric: 14) due to diffused reflection of light by interfiber spaces existing uniformly between single fibers and by the groove at the apex of each convex portion of the fibers having irregular cross sections and also had a high wear resistance (grade 3-4) free of discoloration likely to be caused by fibrillation in the grooves. Results are shown in Tables 1-1.

[Examples 2 and 3]

[0139] Except that the weight ratio of polymer 1 to polymer 2 was 20/80 (Example 2) or 10/90 (Example 3), the same procedure as in Example 1 was carried out.

[0140] In Examples 2 and 3, the flexural rigidity increased with a decreasing content of the sheath component, and the fabric samples produced had characteristic elastic touch while maintaining a natural silk-like texture. In addition, the groove formed at the apex of each convex portion of the fibers in the multifilament was shallower, leading to a high wear resistance. Results are shown in Tables 1-1.

[Example 4]

[0141] Except that the core-sheath composite fiber had a composite structure as illustrated in Fig. 2(a), the same procedure as in Example 1 was carried out.

[0142] In Example 4, no groove existed at the apex of each convex portion of the fibers in the multifilament and consequently, diffused reflection of light decreased, leading to an increased reflection intensity and an increased gloss visibility. A higher wear resistance was also achieved. Results are shown in Tables 1-1.

[Comparative example 1]

[0143] First, a polyethylene terephthalate copolymerized with 8 mol% of 5-sodium sulfoisophthalic acid and 9 wt% of polyethylene glycol (SSIA-PEG copolymerized PET, melt viscosity 100 Pa·s, melting point 233°C) was prepared as polymer 1 and a polyethylene terephthalate (PET, melt viscosity 130 Pa·s, 254°C) was prepared as polymer 2.

[0144] These polymers were melted separately at 290°C, weighed to adjust the weight ratio of polymer 1/polymer 2 to 30/70, and fed to a spinning pack containing a composite spinneret as illustrated in Fig. 12, and then the polymers fed were discharged through a discharge hole to form a perfect circular core-sheath composite fiber having a simple composite structure in which a core component having a circular cross section was surrounded by a sheath component as illustrated in Fig. 3(a). Here, the polymer 1 and the polymer 2 were arranged in such a manner that they formed the sheath component and the core component, respectively.

[0145] The composite polymer flow discharged above was cooled for solidification, then supplied with a lubricant, wound up at a spinning speed of 1,500 m/min, and stretched between rollers heated at 90°C and 130°C to produce a 56 dtex - 36 filament core-sheath composite fiber.

[0146] A fabric was produced by weaving the resulting core-sheath composite fiber and treated in a 1 wt% aqueous solution of sodium hydroxide (bath ratio 1:50) heated at 90°C to remove 99% or more of the sheath component to provide a fabric containing multifilaments (fiber diameter 10 μm) formed of the core component of the core-sheath composite fiber.

[0147] Although having coarse interfiber spaces of 10 μm or more between individual fibers in multifilaments, the fabric sample produced above failed to have fine interfiber spaces of less than 5 μm and the spaces were destroyed when the fabric was touched, indicating poor lightness and resilience. In addition, the absence of convex portions and grooves in the core component led to poor dry touch. Results are shown in Tables 1-1.

[Comparative example 2]

[0148] Except that the core-sheath composite fiber had a composite structure as illustrated in Fig. 3(b), the same procedure as in Comparative example 1 was carried out.

[0149] In Comparative example 2, although the core component had a trifoliate cross section to achieve a slight improvement in dry touch, there were no fine interfiber spaces of less than 5 μm between individual fibers after dissolution of the sheath component, resulting in poor lightness and resilience. Results are shown in Tables 1-1.

[Comparative example 3]

[0150] First, a polyethylene terephthalate copolymerized with 8 mol% of 5-sodium sulfoisophthalic acid and 9 wt% of polyethylene glycol (SSIA-PEG copolymerized PET, melt viscosity 100 Pa·s, melting point 233°C) was prepared as

polymer 1 and a polyethylene terephthalate (PET, melt viscosity 130 Pa·s, 254°C) was prepared as polymer 2.

[0151] These polymers were melted separately at 290°C, weighed to adjust the weight ratio of polymer 1/polymer 2 to 5/95, and fed to a spinning pack containing a composite spinneret as illustrated in Fig. 12, and then the polymers fed were discharged through a discharge hole to form a composite structure that contained an hardly dissolvable component of a trifoliate shape in combination with an easily dissolvable component that was located at the apex of each convex portion and tapered toward the interior of the fiber as described in Japanese Unexamined Patent Publication (Kokai) No. SHO 57-5912 and illustrated in Fig. 6(a). Here, the polymer 1 and the polymer 2 were arranged so as to work as the easily dissolvable component and the hardly dissolvable component, respectively.

[0152] The composite polymer flow discharged above was cooled for solidification, then supplied with a lubricant, wound up at a spinning speed of 1,500 m/min, and stretched between rollers heated at 90°C and 130°C to produce a 56 dtex - 36 filament composite fiber.

[0153] A fabric was produced by weaving the composite fiber and treated in a 1 wt% aqueous solution of sodium hydroxide (bath ratio 1:50) heated at 90°C to remove 99% or more of the sheath component to provide a fabric containing multifilaments (fiber diameter 12 μm) formed of the hardly dissolvable component of the composite fiber.

[0154] In Comparative example 3, deep grooves tapered toward the interior of the fiber existed at the apex of each convex portion of the fiber having an irregular cross section of a trifoliate shape and accordingly, it had an increased friction coefficient and inferior wear resistance in spite of a good dry touch. In addition, coarse interfiber spaces of 10 μm or more did not exist between individual fibers after dissolution of the sheath component, and the fiber had a glaring gloss that lacked a sense of luxury and was poor in lightness, flexibility, and resilience. Results are shown in Tables 1-2.

[Examples 5 and 6]

[0155] Except for controlling the discharge rate in such a manner that the irregular cross-sectional fiber containing only the core component of the core-sheath composite fiber had a fiber diameter of 14 μm (Example 5) or 17 μm (Example 6), the same procedure as in Example 4 was carried out.

[0156] In Examples 5 and 6, as a result of the increase in fiber diameter, the fiber in the multifilament formed by the dissolution of the sheath component had a trifoliate cross section to enhance the degree of shape irregularity, leading to an increased reflection intensity to allow the resulting fabric to have a further increased gloss visibility. In addition, its flexural rigidity also increased to realize characteristic elastic touch while maintaining a natural silk-like texture. Results are shown in Tables 1-2.

[Example 7]

[0157] Except that the core-sheath composite fiber had a composite structure as illustrated in Fig. 2(b), the same procedure as in Example 4 was carried out.

[0158] In Example 7, the fiber in the multifilament had a tetrafoliate cross section, instead of a trifoliate cross section, to increase the diffused reflection of light in the convex portions. As a result, it was possible to produce a fabric that not only had a further improved luxurious gloss but also had a texture with an improved friction coefficient and improved dry touch. Results are shown in Tables 1-2.

[Comparative example 4]

[0159] First, a polyethylene terephthalate copolymerized with 8 mol% of 5-sodium sulfoisophthalic acid and 9 wt% of polyethylene glycol (SSIA-PEG copolymerized PET, melt viscosity 100 Pa·s, melting point 233°C) was prepared as polymer 1 and a polyethylene terephthalate (PET, melt viscosity 130 Pa·s, 254°C) was prepared as polymer 2.

[0160] These polymers were melted separately at 290°C, weighed to adjust the weight ratio of polymer 1/polymer 2 to 20/80, and fed to a spinning pack containing a composite spinneret as illustrated in Fig. 12, and then the polymers fed were discharged through a discharge hole to form a composite structure in which the hardly dissolvable component was divided by the easily dissolvable component into a plurality of parts as illustrated in Fig. 3(C) and as described in Japanese Unexamined Patent Publication (Kokai) No. 2010-222771. Here, the polymer 1 and the polymer 2 were arranged so as to work as the easily dissolvable component and the hardly dissolvable component, respectively.

[0161] The composite polymer flow discharged above was cooled for solidification, then supplied with a lubricant, wound up at a spinning speed of 1,500 m/min, and stretched between rollers heated at 90°C and 130°C to produce a 56 dtex - 18 filament composite fiber.

[0162] A fabric was produced by weaving the composite fiber and treated in a 1 wt% aqueous solution of sodium hydroxide (bath ratio 1:50) heated at 90°C to remove 99% or more of the sheath component to provide a fabric containing multifilaments (fiber diameter 6 μm) formed of the hardly dissolvable component of the composite fiber.

[0163] In Comparative example 4, the fibers in the multifilaments had small fiber diameters to give a good gloss and

high flexibility, but they failed to have fine interfiber spaces of less than 5 μm and coarse interfiber spaces of 10 μm or more failed to coexist uniformly between individual fibers, resulting in poor lightness and resilience. In addition, being small in fiber diameter, they were difficult to color with a dye and had poor color development property. Results are shown in Tables 1-2.

[Example 8]

[0164] First, a polyethylene terephthalate copolymerized with 8 mol% of 5-sodium sulfoisophthalic acid and 9 wt% of polyethylene glycol (SSIA-PEG copolymerized PET, melt viscosity 100 Pa·s, melting point 233°C) was prepared as polymer 1; a polyethylene terephthalate copolymerized with 7 mol% of isophthalic acid (IPA copolymerized PET, melt viscosity 140 Pa·s, melting point 232°C) was prepared as polymer 2; and a polyethylene terephthalate (PET, melt viscosity 130 Pa·s, melting point 254°C) was prepared as polymer 3.

[0165] These polymers were melted separately at 290°C, weighed to adjust the weight ratio of polymer 1/polymer 2/polymer 3 to 30/35/35, and fed to a spinning pack containing a composite spinneret as illustrated in Fig. 12, and then the polymers fed were discharged through a discharge hole to form an elliptic core-sheath composite fiber having a composite structure in which the core components were completely surrounded by the sheath component and divided by the sheath component in two regions, that is, the core component 1 and the core component 2, each having a trifoliate cross section with a groove at the apex of each convex portion, as illustrated in Fig. 5(b). Here, the polymer 1, the polymer 2, and the polymer 3 were arranged in such a manner that they formed the sheath component, the core component 1, and the core component 2, respectively.

[0166] The composite polymer flow discharged above was cooled for solidification, then supplied with a lubricant, wound up at a spinning speed of 1,500 m/min, and stretched between rollers heated at 90°C and 130°C to produce a 56 dtex - 18 filament core-sheath composite fiber.

[0167] The ratio of $S_{\min}/D$ between the minimum thickness of the resulting sheath component and the fiber diameter was 0.03 and the ratio of $S_{\max}/S_{\min}$ between the maximum thickness and the minimum thickness of the sheath component was 12. The ratio of GN/GM between the distance GM from the center of gravity G of the core component to the bottom M of a groove and the distance GN from the center of gravity G of the core component to the apex N of the convex portion was 1.38, proving that this core-sheath composite fiber was one according to the present invention.

[0168] Furthermore, the ratio between the diameter R_A of the inscribed circle and the diameter R_B of the circumscribed circle of the core-sheath composite fiber was 1.8, indicating that if it exists in the form of a multifilament, closest packing can be achieved easily and interfiber spaces can be formed uniformly without unevenness by the dissolution of the sheath component.

[0169] A fabric was produced by weaving the resulting core-sheath composite fiber, treated in a 1 wt% aqueous solution of sodium hydroxide (bath ratio 1:50) heated at 90°C to remove 99% or more of the sheath component, and heat-treated with moist heat at 130°C to provide a fabric containing multifilaments (fiber diameter 10 μm) formed of the core components of the core-sheath composite fiber.

[0170] As a result of the dissolution of the sheath component that completely surrounded the multilobar shaped core components, the fabric containing multifilaments had a space structure in which fine interfiber spaces of less than 5 μm and coarse interfiber spaces of 10 μm or more coexisted uniformly between individual fibers as in natural silk, and the core component 1 and the core component 2, which differed in shrinkage rate, developed a difference in fiber length as they were heat-treated after dissolving out the sheath component. Consequently, the interfiber spaces of 10 μm or more were coarser than those formed in Example 1, leading to a space structure more closely resembling that of interfiber spaces in natural silk. In addition, the texture had a luxurious gloss independent on view angle (contrast gloss: 1.4), dry touch (friction coefficient: 0.8) with high resilience (bending recovery 2HB: 0.8×10^{-2} gf·cm/cm), very high lightness (apparent density: 0.32 g/cm³), and high flexibility (flexural rigidity B: 0.9×10^{-2} gf·cm²/cm). Thus, the texture of the fabric was almost indistinguishable from natural silk.

[0171] It was also found that when dyed in black, the fabric had good color development property (L value of black dyed fabric: 13) due to enhanced diffused reflection of light and also had a high wear resistance (grade 3-4) free of discoloration likely to be caused by fibrillation in the grooves. Results are shown in Tables 2-1.

[Examples 9 and 10]

[0172] Except for using polypropylene terephthalate (PPT) (Example 9) and polyethylene terephthalate (PET) (Example 10) as the polymer 2, the same procedure as in Example 8 was carried out.

[0173] In Example 9, rubber elasticity of the PPT was added to allow the fabric to have not only a texture with a higher flexibility, but also a unique stretchable feature that cannot be realized in natural silk. Furthermore, PPT is lower in refractive index than PET and served to produce a fabric having good color development property.

[0174] In Example 10, although a difference in fiber length was not developed, a natural silk-like texture was formed

to a sufficiently high degree, and in addition, the two separated core components worked to allow the fine interfiber spaces of less than 5 μm and coarse interfiber spaces of 10 μm or more to exist more uniformly, resulting in a fabric having a texture with improved lightness, flexibility, and resilience. Results are shown in Tables 2-1.

5 [Example 11]

[0175] Except that the core-sheath composite fiber had a composite structure as illustrated in Fig. 4(a), the same procedure as in Example 8 was carried out.

10 [0176] In Example 11, no groove existed at the apex of each convex portion of the fibers having irregular cross-sectional shapes, and consequently, diffused reflection of light decreased, leading to an increased reflection intensity and an increased gloss visibility. A higher wear resistance was also achieved. Results are shown in Tables 2-1.

[Examples 12 and 13]

15 [0177] Except that the core-sheath composite fiber had a composite structure as illustrated in Fig. 4(a) and that the weight ratio of the polymer 2 to the polymer 3 was 50/20 (Example 12) and 20/50 (Example 13), respectively, the same procedure as in Example 8 was carried out.

20 [0178] In Examples 12 and 13, as the proportion of the polymer 2, that is, the higher shrinkage component, was increased, a larger difference in fiber length occurred and a lighter fabric was obtained, whereas as the proportion of the polymer 3, that is, the lower shrinkage component, was increased, not only diffused reflection of light decreased to cause increases in reflection intensity and gloss visibility, but also it served to decrease clogging that was likely to result from a large shrinkage of the higher shrinkage component during the moist heat treatment, leading to high flexibility and resilience. Results are given in Table 2-1 and Table 2-2.

25 [Example 14]

[0179] Except that the core-sheath composite fiber had a composite structure as illustrated in Fig. 4(a) and that the shape irregularity ratio R_B/R_A was 3.0, the same procedure as in Example 8 was carried out.

30 [0180] As the shape irregularity of the core-sheath composite fiber increases, the shape irregularity of the core component also increases, and accordingly, the fiber in the multifilament formed by the dissolution of the sheath component had a trifoliate cross section to enhance the degree of shape irregularity, leading to an increased reflection intensity to allow the resulting fabric to have a further increased gloss visibility. Results are shown in Tables 2-2.

[Example 15]

35 [0181] Except that the core-sheath composite fiber had a composite structure as illustrated in Fig. 4(b) and the shape irregularity ratio R_B/R_A was 1.0, the same procedure as in Example 8 was carried out.

40 [0182] It was found that in the case of a core-sheath composite fiber in the form of multifilaments, a decrease in shape irregularity allows closest packing to be achieved more easily and interfiber spaces can be formed more uniformly without unevenness by the dissolution of the sheath component, leading to a fabric with improved quality. Results are shown in Tables 2-2.

[Example 16]

45 [0183] Except that the core-sheath composite fiber had a composite structure as illustrated in Fig. 4(c) and the shape irregularity ratio R_B/R_A was 1.0, the same procedure as in Example 8 was carried out.

50 [0184] In Example 16, since six core component regions are divided by the sheath component, the fibers having irregular shaped cross sections formed by removing the sheath component had smaller fiber diameters, leading to a fabric not only having a milder and more luxurious gloss but also having a texture with higher flexibility. Results are shown in Tables 2-2.

[Comparative example 5]

55 [0185] First, a polyethylene terephthalate copolymerized with 8 mol% of 5-sodium sulfoisophthalic acid and 9 wt% of polyethylene glycol (SSIA-PEG copolymerized PET, melt viscosity 100 Pa·s, melting point 233°C) was prepared as polymer 1; a polyethylene terephthalate copolymerized with 7 mol% of isophthalic acid (IPA copolymerized PET, melt viscosity 140 Pa·s, melting point 232°C) was prepared as polymer 2; and a polyethylene terephthalate (PET, melt viscosity 130 Pa·s, melting point 254°C) was prepared as polymer 3.

[0186] These polymers were melted separately at 290°C, weighed to adjust the weight ratio of polymer 1/polymer 2/polymer 3 to 5/42.5/42.5, and fed to a spinning pack containing a composite spinneret as illustrated in Fig. 12, and then the polymers fed were discharged through a discharge hole to form a composite structure that contained hardly dissolvable components of trifoliate shapes in combination with an easily dissolvable component that was located at the apex of each convex portion and tapered toward the interior of the fiber as described in Japanese Unexamined Patent Publication (Kokai) No. HEI-2-145825, wherein the hardly dissolvable components were of two different polymer species, that is, a higher shrinkage component and a lower shrinkage component, as illustrated in Fig. 6(b). Here, the polymer 1, the polymer 2, and the polymer 3 were arranged so as to work as the easily dissolvable component, the higher shrinkage hardly dissolvable component, and the lower shrinkage hardly dissolvable component, respectively.

[0187] The composite polymer flow discharged above was cooled for solidification, then supplied with a lubricant, wound up at a spinning speed of 1,500 m/min, and stretched between rollers heated at 90°C and 130°C to produce a 56 dtex - 36 filament composite fiber (higher shrinkage: 28 dtex - 18 filament, lower shrinkage: 28 dtex - 18 filament).

[0188] A fabric was produced by weaving the resulting composite fiber, treated in a 1 wt% aqueous solution of sodium hydroxide (bath ratio 1:50) heated at 90°C to remove 99% or more of the sheath component, and heat-treated with moist heat at 130°C to provide a fabric containing multifilaments (fiber diameter 12 μm) formed of the hardly dissolvable components of the composite fiber.

[0189] In Comparative example 5, deep grooves tapered toward the interior of the fiber existed at the apex of each convex portion of the fiber having an irregular cross section of a trifoliate shape and accordingly, the fabric had an increased friction coefficient and inferior wear resistance in spite of a good dry touch. In addition, although good lightness was brought about from the development of crimps that was realized as a result of the difference in thermal shrinkage rate between the higher shrinkage component and the lower shrinkage component, it was poor in flexibility and resilience not only because fine interfiber spaces with of less than 5 μm and coarse interfiber spaces of 10 μm or more failed to coexist uniformly between individual fibers, but also because clogging occurred due to the high shrinkage rate of the higher shrinkage component. Results are shown in Tables 2-2.

[Example 17]

[0190] First, a polyethylene terephthalate copolymerized with 8 mol% of 5-sodium sulfoisophthalic acid and 9 wt% of polyethylene glycol (SSIA-PEG copolymerized PET, melt viscosity 100 Pa·s, melting point 233°C) was prepared as polymer 1; a polyethylene terephthalate copolymerized with 7 mol% of isophthalic acid (IPA copolymerized PET, melt viscosity 140 Pa·s, melting point 232°C) was prepared as polymer 2; and a polyethylene terephthalate (PET, melt viscosity 130 Pa·s, melting point 254°C) was prepared as polymer 3.

[0191] These polymers were melted separately at 290°C, weighed to adjust the weight ratio of polymer 1/polymer 2/polymer 3 to 30/35/35, and fed to a spinning pack containing a composite spinneret as illustrated in Fig. 12, and then the polymers fed were discharged through a discharge hole to form a core-sheath composite fiber having a composite structure in which the core components were completely surrounded by the sheath component and divided by the sheath component in two regions, that is, the core component 1 and the core component 2, each having a trifoliate cross section with a groove at the apex of each convex portion, as illustrated in Fig. 10(b). Here, the polymer 1, the polymer 2, and the polymer 3 were arranged in such a manner that they formed the sheath component, the core component 1, and the core component 2, respectively.

[0192] The composite polymer flow discharged above was cooled for solidification, then supplied with a lubricant, wound up at a spinning speed of 1,500 m/min, and stretched between rollers heated at 90°C and 130°C to produce a 56 dtex - 18 filament core-sheath composite fiber.

[0193] The ratio of $S_{\min}/D$ between the minimum thickness of the resulting sheath component and the fiber diameter was 0.03 and the ratio of $S_{\max}/S_{\min}$ between the maximum thickness and the minimum thickness of the sheath component was 12. The ratio of GN/GM between the distance GM from the center of gravity G of the core component to the bottom M of a groove and the distance GN from the center of gravity G of the core component to the apex N of the convex portion was 1.38, proving that this core-sheath composite fiber was one according to the present invention.

[0194] Furthermore, the ratio between the diameter R_A of the inscribed circle and the diameter R_B of the circumscribed circle of the core-sheath composite fiber was 1.8, indicating that if it exists in the form of a multifilament, closest packing can be achieved easily and interfiber spaces can be formed uniformly without unevenness by the dissolution of the sheath component.

[0195] A fabric was produced by weaving the core-sheath composite fiber, heat-treated with moist heat at 130°C, and treated in a 1 wt% aqueous solution of sodium hydroxide (bath ratio 1:50) heated at 90°C to remove 99% or more of the sheath component to provide a fabric containing multifilaments in which crimped fibers of different polymers coexisted uniformly. The resulting crimped fibers had a composite structure (shape irregularity ratio: 1.6) having a trifoliate cross section with a groove at the apex of each convex portion (MN/D : 0.13). The crimped fibers had a fiber diameter of 10 μm and the number of crimp peaks was 14 peaks/cm. They were formed of polymers with different melting points with

a fiber length difference of 7%.

[0196] In the multifilament fabric, crimps were formed during moist heat treatment due to a difference in thermal shrinkage rate between polymers with different melting points and excluded volume effect occurred between fibers. As a result, not only coarse interfiber spaces of 10 μm or more were formed between individual fibers, but also interfiber spaces of less than 5 μm were formed between mutually adjacent crimped fibers made of polymers with different melting points. In this way, the multifilament contained fine interfiber spaces of less than 5 μm and coarse interfiber spaces of 10 μm or more coexisting uniformly to form a space structure closely resembling that of interfiber spaces existing in natural silk. An examination of the space structure showed that the average interfiber space distance was 10.5 μm , and the proportion of spaces with an interfiber space distance of less than 5 μm was 25%. The space proportion was 65%.

[0197] In addition, the fabric had a luxurious gloss independent on view angle (contrast gloss: 1.4), very high lightness (apparent density: 0.32 g/cm³), and good dry touch (friction coefficient: 0.8), and at the same time, interfiber spaces of less than 5 μm were formed more stably than in Example 8, leading to a better resilience (bending recovery 2HB: 0.7×10^{-2} gf•cm/cm) and flexibility (flexural rigidity B: 0.8×10^{-2} gf•cm²/cm). Thus, the texture of the fabric was almost indistinguishable from natural silk.

[0198] It was also found that when dyed in black, the fabric had good color development property (L value of black dyed fabric: 13) due to enhanced diffused reflection of light that occurred in the coarse interfiber spaces of 10 μm or more existing uniformly between fibers and also had a high wear resistance (grade 3-4) free of discoloration likely to be caused by fibrillation in the grooves. Results are given in Table 3.

[Examples 18 and 19]

[0199] Except that the weight ratio of polymer 1/polymer 2/polymer 3 was 20/40/40 (Example 18) or 10/45/45 (Example 19), the same procedure as in Example 17 was carried out.

[0200] In Examples 18 and 19, as the content of the sheath component decreased, the proportion of spaces with interfiber space distances of less than 5 μm increased and accordingly, the flexural rigidity increased, making it possible to produce fabrics having characteristic elastic touch while maintaining a natural silk-like texture. In addition, the groove formed at the apex of each convex portion of the crimped fibers was shallower, leading to a high wear resistance. Results are given in Table 3.

[Example 20]

[0201] Except for using polypropylene terephthalate (PPT, melt viscosity: 150 Pa•s, melting point: 233°C) as the polymer 2, the same procedure as in Example 17 was carried out.

[0202] In Example 20, rubber elasticity of the PPT was added to allow the fabric to have not only a texture with a higher flexibility, but also a unique stretchable feature that cannot be realized in natural silk. Furthermore, PPT is lower in refractive index than PET and served to produce a fabric having good color development property. Results are given in Table 3.

[Example 21]

[0203] Except for using a polyethylene terephthalate with a high melt viscosity (high viscosity PET, melt viscosity 250 Pa•s, melting point 254°C) as the polymer 2, the same procedure as in Example 17 was carried out.

[0204] In Example 5, since crimps were formed by making use of a difference in viscosity, instead of a difference in melting point, between the polymer 3 and the polymer 2, the crimp number of the crimped fibers in the multifilament decreased and the diffused reflection of light by the space structure in the multifilament was suppressed, leading to an enhanced gloss visibility. Furthermore, the crimps formed by moist heat treatment were small and accordingly, the proportion of interfiber spaces with distances of less than 5 μm increased, leading to better resilience. Results are given in Table 3.

[Comparative example 6]

[0205] First, a polyethylene terephthalate copolymerized with 8 mol% of 5-sodium sulfoisophthalic acid and 9 wt% of polyethylene glycol (SSIA-PEG copolymerized PET, melt viscosity 100 Pa•s, melting point 233°C) was prepared as polymer 1; a polyethylene terephthalate copolymerized with 7 mol% of isophthalic acid (IPA copolymerized PET, melt viscosity 140 Pa•s, melting point 232°C) was prepared as polymer 2; and a polyethylene terephthalate (PET, melt viscosity 130 Pa•s, melting point 254°C) was prepared as polymer 3.

[0206] These polymers were melted separately at 290°C, weighed to adjust the weight ratio of polymer 1/polymer 2 and that of polymer 1/polymer 3 to 2.5/47.5 and 2.5/47.5, respectively, and fed to a spinning pack containing a composite

spinneret as illustrated in Fig. 12, and then the polymers fed were discharged through separate discharge holes to each form a composite structure that contained an hardly dissolvable component of a trifoliate shape in combination with an easily dissolvable component that was located at the apex of each convex portion and tapered toward the interior of the fiber as described in Japanese Unexamined Patent Publication (Kokai) No. HEI-2-145825, wherein one of the composite

fibers contained the two components of a higher shrinkage component and an easily dissolvable component and the other composite fiber contained the two components of a lower shrinkage component and an easily dissolvable component, as illustrated in Fig. 11. Here, the polymer 1, the polymer 2, and the polymer 3 were arranged so as to work as the easily dissolvable component, the higher shrinkage component, and the lower shrinkage component, respectively.

[0207] The composite polymer flows discharged above were cooled for solidification, then supplied with a lubricant, wound up at a spinning speed of 1,500 m/min, and stretched between rollers heated at 90°C and 130°C to produce a 56 dtex - 36 filament composite fiber (higher shrinkage: 28 dtex - 18 filament, lower shrinkage: 28 dtex - 18 filament).

[0208] A fabric was produced by weaving the composite fiber, heat-treated with moist heat at 130°C, and treated in a 1 wt% aqueous solution of sodium hydroxide (bath ratio 1:50) heated at 90°C to remove 99% or more of the sheath component to provide a fabric containing multifilaments (fiber diameter 12 μm) formed of the hardly dissolvable components of the composite fiber.

[0209] In Comparative example 6, deep grooves tapered toward the interior of the fiber existed at the apex of each convex portion of the fiber having an irregular cross section of a trifoliate shape and accordingly, the fabric had an increased friction coefficient and inferior wear resistance in spite of a good dry touch. In addition, although a difference in fiber length between the high shrinkage component and the low shrinkage component occurred to achieve lightness, the spinning-combining method was adopted to allow fibers containing different polymers coexisted unevenly, leading to poor resilience due to a small proportion interfiber spaces of less than 5 μm. Results are given in Table 3.

[Example 22]

[0210] Except that the core-sheath composite fiber had a composite structure as illustrated in Fig. 10(a), the same procedure as in Example 17 was carried out.

[0211] In Example 22, no groove existed at the apex of each convex portion of the crimped fibers in the multifilament and consequently, diffused reflection of light decreased, leading to an increased reflection intensity and an increased gloss visibility. A higher wear resistance was also achieved. Results are given in Table 4.

[Examples 23 and 24]

[0212] Except that the weight ratio of polymer 2/polymer 3 was 50/20 (Example 23) or 20/50 (Example 24), the same procedure as in Example 17 was carried out.

[0213] In examples 23 and 24, as the proportion of the polymer 2, that is, the higher shrinkage component, was increased, the crimp number and the difference in fiber length increased in the crimped fibers in the multifilament, and accordingly, the average interfiber space distance increased in the space structure of the multifilament, leading to a fabric with enhanced lightness. On the other hand, as the proportion of the polymer 3, that is, the lower shrinkage component, was increased, the crimp number decreased in the crimped fibers in the multifilament. Accordingly, the diffused reflection of light by the space structure in the multifilament was suppressed to enhance the gloss visibility, but also the crimps formed by moist heat treatment became smaller in size to increase the proportion of interfiber spaces of less than 5 μm, leading to better resilience. Results are given in Table 4.

[Examples 25 and 26]

[0214] Except for controlling the discharge rate in such a manner that the fiber diameter of the crimped fibers in the multifilament was 14 μm (Example 25) or 17 μm (Example 26), the same procedure as in Example 17 was carried out.

[0215] In Examples 25 and 26, as the fiber diameter was increased, the fibers in the multifilament having trifoliate cross sections had increased degrees of shape irregularity, leading to increased reflection intensities to allow the resulting fabric to have a further increased gloss visibility. In addition, its flexural rigidity also increased to realize characteristic elastic touch while maintaining a natural silk-like texture. Results are given in Table 4.

INDUSTRIAL APPLICABILITY

[0216] The multifilament according to the present invention contains two or more types of crimped fibers that are formed of different polymers and coexist uniformly in the multifilament, and accordingly, they can form a unique space structure in which fine interfiber spaces of less than 5 μm and coarse interfiber spaces of 10 μm or more coexist uniformly between the individual fibers in the multifilament as in natural silk. Therefore, fiber materials formed of the multifilament

according to the present invention can develop various natural silk-like textural features. Thus, with high handleability peculiar to synthetic fibers, they can be used suitably for the production of a wide range of textile products including jackets, skirts, pants, underwear, other general clothing, sportswear, clothing materials, carpets, sofas, curtains, other interior products, car seats, other vehicle interiors, cosmetics, cosmetic masks, wiping cloth, and health products, not to mention conventional Western and Japanese style clothing in which natural silk has been mainly used.

[Table 1-1]

[0217]

[Table 1-1]

	Example 1	Example 2	Example 3	Example 4	Comparative example 1	Comparative example 2
polymer	polymer 1	SSIA-PEG copolymerized PET	SSIA-PEG copolymerized PET	SSIA-PEG copolymerized PET	SSIA-PEG copolymerized PET	SSIA-PEG copolymerized PET
	polymer 2	PET	PET	PET	PET	PET
	weight ratio (polymer 1/2)	30/70	20/80	30/70	30/70	30/70
cross section of fiber	cross-sectional shape	perfect circle	perfect circle	perfect circle	perfect circle	trifoliate shape
	composite structure	Fig. 5(a)	Fig. 5(a)	Fig. 2(a)	Fig. 3(a)	Fig. 3(b)
	shape irregularity (R_B/R_A)	1.0	1.0	1.0	1.0	1.0
	$S_{\min}/D$	0.03	0.02	0.01	0.24	0.22
	$S_{\max}/S_{\min}$	16	11	7	1	2
diameter of irregular cross-sectional fiber (μm)	GN/GM	1.42	1.26	1.08	1.00	1.00
		10	11	11	10	10

(continued)

	Example 1	Example 2	Example 3	Example 4	Comparative example 1	Comparative example 2
gloss (contrast gloss)	A (1.7)	A (1.8)	A (1.9)	A (1.8)	A (1.6)	C (2.0)
lightness (apparent density (g/cm ³))	A (0.40)	A (0.44)	A (0.49)	A (0.40)	C (0.58)	C (0.52)
flexibility (flexural rigidity $B \times 10^{-2}$ (gf·cm ² /cm))	S (0.7)	A (1.1)	A (1.5)	S (0.7)	S (0.5)	S (0.6)
resilience (bending recovery 2HB $\times 10^{-2}$ (gf·cm/cm))	S (0.6)	S (0.8)	A (1.2)	S (0.6)	C (2.1)	C (2.4)
dry touch (friction coefficient)	S (0.7)	A (0.6)	A (0.5)	A (0.4)	C (0.1)	A (0.3)
color development property (L value of black dyed fabric)	S (14)	A (15)	A (16)	A (15)	A (15)	A (17)
wear resistance	A (grade 3-4)	A (grade 3-4)	S (grade 4)	S (grade 4)	S (grade 4)	S (grade 4)
PET: polyethylene terephthalate, PEG: polyethylene glycol, SSIA: 5-sodium sulfoisophthalic acid						

[Table 1-2]

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[0218]

[Table 1-2]

		Comparative example 3	Example 5	Example 6	Example 7	Comparative example 4
		SSIA-PEG copolymerized PET	SSIA-PEG copolymerized PET	SSIA-PEG copolymerized PET	SSIA-PEG copolymerized PET	SSIA-PEG copolymerized PET
polymer	polymer 1	PET	PET	PET	PET	PET
	weight ratio (polymer 1/2)	5/95	30/70	30/70	30/70	20/80
cross section of fiber	cross-sectional shape	trifoliate shape	perfect circle	perfect circle	perfect circle	perfect circle
	composite structure	Fig. 6 (a)	Fig. 2(a)	Fig. 2(a)	Fig. 2(b)	Fig. 3(c)
	shape irregularity (R_B/R_A)	1.8	1.0	1.0	1.0	1.0
	S_{min}/D	-	0.03	0.03	0.02	-
	S_{max}/S_{min}	-	17	17	12	-
diameter of irregular cross-sectional fiber (μm)	GN/GM	1.61	1.00	1.00	1.00	1.00
		12	14	17	10	6
texture evaluation	gloss (contrast gloss)	C (2.2)	A (1.8)	A (1.8)	A (1.6)	S (1.5)
	lightness (apparent density (g/cm^3))	C (0.58)	S (0.39)	S (0.38)	A (0.40)	C (0.55)
	flexibility (flexural rigidity $B \times 10^{-2}$ ($\text{gf} \cdot \text{cm}^2/\text{cm}$))	C (2.4)	A (1.3)	A (1.9)	S (0.7)	S (0.3)
	resilience (bending recovery $2\text{HB} \times 10^{-2}$ ($\text{gf} \cdot \text{cm}/\text{cm}$))	C (2.6)	S (0.5)	S (0.5)	S (0.6)	C (2.4)
	dry touch (friction coefficient)	S (0.8)	A (0.4)	A (0.5)	A (0.4)	A (0.5)
color development property (L value of black dyed fabric)		C (19)	A (16)	A (16)	A (15)	C (18)

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(continued)

	Comparative example 3	Example 5	Example 6	Example 7	Comparative example 4
wear resistance	C (grade 2-3)	S (grade 4)	S (grade 4)	S (grade 4)	A (grade 3-4)
PET: polyethylene terephthalate, PEG: polyethylene glycol, SSIA: 5-sodium sulfoisophthalic acid					

[Table 2-1]

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[0219]

[Table 2-1]

		Example 8	Example 9	Example 10	Example 11	Example 12
polymer	polymer 1	SSIA-PEG copolymerized PET	SSIA-PEG copolymerized PET	SSIA-PEG copolymerized PET	SSIA-PEG copolymerized PET	SSIA-PEG copolymerized PET
	polymer 2	IPA copolymerized PET	PPT	PET	IPA copolymerized PET	IPA copolymerized PET
	polymer 3	PET	PET	PET	PET	PET
	(melting point of polymer 3) - (melting point of polymer 2)	22°C	21°C	0°C	22°C	22°C
	weight ratio (polymer 1/2/3)	30/35/35	30/35/35	30/35/35	30/35/35	30/50/20
cross section of fiber	cross-sectional shape	elliptic	elliptic	elliptic	elliptic	elliptic
	composite structure	Fig. 5(b)	Fig. 5(b)	Fig. 5(b)	Fig. 4 (a)	Fig. 4 (a)
	shape irregularity (R_B/R_A)	1.8	1.7	1.8	1.8	1.8
	S_{min}/D	0.03	0.03	0.03	0.03	0.01
	S_{max}/S_{min}	12	12	12	11	20
diameter of irregular cross-sectional fiber (μm)	GN/GM	1.38	1.35	1.38	1.00	1.00
		10	10	10	10	12
texture evaluation	gloss (contrast gloss)	S (1.4)	S (1.3)	A (1.7)	S (1.5)	S (1.3)
	lightness (apparent density (g/cm^3))	S (0.32)	S (0.30)	A (0.37)	S (0.33)	S (0.30)
	flexibility (flexural rigidity $B \times 10^{-2}$ ($qf \cdot cm^2/cm$))	S (0.9)	S (0.8)	S (0.6)	S (0.8)	A (1.1)
	resilience (bending recovery $2HB \times 10^{-2}$ ($qf \cdot cm/cm$))	S (0.8)	S (1.0)	S (0.5)	S (0.8)	S (1.0)
	dry touch (friction coefficient)	S (0.8)	S (0.7)	S (0.7)	A (0.5)	A (0.6)

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(continued)

	Example 8	Example 9	Example 10	Example 11	Example 12
color development property (L value of black dyed fabric)	S (13)	S (13)	A (15)	S (14)	S (14)
wear resistance	A (grade 3-4)	A (grade 3-4)	A (grade 3-4)	S (grade 4)	S (grade 4)
PET: polyethylene terephthalate, PEG: polyethylene glycol, SSIA: 5-sodium sulfoisophthalic acid, IPA: isophthalic acid, PPT: polypropylene terephthalate					

[Table 2-2]

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[0220]

[Table 2-2]

	Example 13	Example 14	Example 15	Example 16	Comparative example 5
polymer	polymer 1	SSIA-PEG copolymerized PET	SSIA-PEG copolymerized PET	SSIA-PEG copolymerized PET	SSIA-PEG copolymerized PET
	polymer 2	IPA copolymerized PET	IPA copolymerized PET	IPA copolymerized PET	IPA copolymerized PET
	polymer 3	PET	PET	PET	PET
	(melting point of polymer 3) - (melting point of polymer 2)	22°C	22°C	22°C	22°C
	weight ratio (polymer 1/2/3)	30/20/50	30/35/35	30/35/35	5/42.5/42.5
cross section of fiber	cross-sectional shape	elliptic	perfect circle	perfect circle	elliptic
	composite structure	Fig. 4 (a)	Fig. 4 (a)	Fig. 4 (c)	Fig. 6 (b)
	shape irregularity (R_B/R_A)	1.8	3.0	1.0	1.8
	S_{min}/D	0.01	0.03	0.03	-
	S_{max}/S_{min}	20	12	10	—
diameter of irregular cross-sectional fiber (μm)	GN/GM	1.00	1.00	1.00	1.58
		12	10	10	12
	gloss (contrast gloss)	A (1.6)	S (1.5)	S (1.4)	A (1.8)
	lightness (apparent density (g/cm^3))	A (0.37)	S (0.31)	S (0.33)	A (0.40)
	flexibility (flexural rigidity $B \times 10^{-2}$ ($gf \cdot cm^2/cm$))	S (0.8)	S (0.9)	S (0.8)	C (2.4)
texture evaluation	resilience (bending recovery $2HB \times 10^{-2}$ ($gf \cdot cm/cm$))	S (0.7)	S (0.9)	S (0.7)	C (2.5)
	dry touch (friction coefficient)	A (0.4)	A (0.6)	A (0.5)	S (1.0)

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(continued)

	Example 13	Example 14	Example 15	Example 16	Comparative example 5
color development property (L value of black dyed fabric)	S (14)	S (14)	S (14)	A (15)	A (17)
wear resistance	S (grade 4)	S (grade 4)	S (grade 4)	A (grade 3-4)	C (grade 2-3)
PET: polyethylene terephthalate, PEG: polyethylene glycol, SSIA: 5-sodium sulfoisophthalic acid, IPA: isophthalic acid, PPT: polypropylene terephthalate					

[Table 3]

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[0221]

[Table 3]

	Example 17	Example 18	Example 19	Example 20	Example 21	Comparative example 6
polymer 1	SSIA-PEG copolymerized PET	SSIA-PEG copolymerized PET	SSIA-PEG copolymerized PET	SSIA-PEG copolymerized PET	SSIA-PEG copolymerized PET	SSIA-PEG copolymerized PET
polymer 2	IPA copolymerized PET	IPA copolymerized PET	IPA copolymerized PET	PPT	high-viscosity PET	IPA copolymerized PET
polymer 3	PET	PET	PET	PET	PET	PET
(melting point of polymer 3) - (melting point of polymer 2)	22°C	22°C	22°C	21°C	0°C	22°C
weight ratio (polymer 1/2/3)	30/35/35	20/40/40	10/45/45	30/35/35	30/35/35	5/47.5/47.5
composite cross-sectional structure	Fig. 10 (b)	Fig. 10 (b)	Fig. 10 (b)	Fig. 10 (b)	Fig. 10 (b)	Fig. 11
shape irregularity (R_B/R_A)	1.8	1.8	1.8	1.7	1.8	1.8
S_{min}/D	0.03	0.03	0.03	0.03	0.03	—
S_{max}/S_{min}	12	10	6	12	12	-
GN/GM	1.38	1.23	1.06	1.35	1.32	1.58
state of coexistence of fibers in multifilament	A	A	A	A	A	C
crimp number (crimps/cm)	14	15	15	24	6	0
difference in fiber length (%)	7	8	8	8	2	8
diameter of irregular cross-sectional fiber, D (μm)	10	11	11	10	10	12

(continued)

	Example 17	Example 18	Example 19	Example 20	Example 21	Comparative example 6
cross section of fiber	Fig. 9 (b)	Fig. 9 (b)	Fig. 9 (b)	Fig. 9 (b)	Fig. 9 (b)	Fig. 9 (b)
cross-sectional structure						
shape irregularity (R_D/R_C)	1.6	1.6	1.5	1.6	1.6	1.7
MN/D	0.13	0.08	0.03	0.13	0.12	0.32
average interfiber space distance (μm)	10.5	10.1	9.6	12.3	5.7	11.9
proportion of interfiber spaces of less than $5\mu\text{m}$ (%)	25	30	38	22	42	8
space structure						
space proportion (%)	65	61	56	71	33	58
gloss (contrast gloss)	S (1.4)	S (1.5)	S (1.5)	S (1.3)	A (1.7)	A (1.7)
lightness (apparent density (g/cm^3))	S (0.32)	S (0.33)	A (0.34)	S (0.30)	A (0.38)	S (0.33)
flexibility (flexural rigidity $B \times 10^{-2}$ ($\text{gf}\cdot\text{cm}^2/\text{cm}$))	S (0.8)	S (0.9)	S (0.9)	S (0.7)	S (0.9)	S (0.6)
resilience (bending recovery $2HB \times 10^{-2}$ ($\text{gf}\cdot\text{cm}/\text{cm}$))	S (0.7)	S (0.6)	S (0.5)	S (0.9)	S (0.5)	C (2.5)
dry touch (friction coefficient)	S (0.8)	A (0.6)	A (0.5)	S (0.7)	S (0.7)	S (1.0)
color development property (L value of black dyed fabric)	S (13)	S (14)	S (14)	S (13)	S (14)	A (17)
wear resistance	A (grade 3-4)	A (grade 3-4)	S (grade 4)	A (grade 3-4)	A (grade 3-4)	C (grade 2-3)
PET: polyethylene terephthalate, PEG: polyethylene glycol, SSIA: 5-sodium sulfoisophthalic acid, IPA: isophthalic acid, PPT: polypropylene terephthalate						

[Table 4]

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[0222]

[Table 4]

	Example 22	Example 23	Example 24	Example 25	Example 26
polymer 1	SSIA-PEG copolymerized PET	SSIA-PEG copolymerized PET	SSIA-PEG copolymerized PET	SSIA-PEG copolymerized PET	SSIA-PEG copolymerized PET
polymer 2	IPA copolymerized PET	IPA copolymerized PET	IPA copolymerized PET	IPA copolymerized PET	IPA copolymerized PET
polymer 3	PET	PET	PET	PET	PET
(melting point of polymer 3) - (melting point of polymer 2)	22°C	22°C	22°C	22°C	22°C
weight ratio (polymer 1/2/3)	30/35/35	30/50/20	30/20/50	30/35/35	30/35/35
composite cross-sectional structure	Fig. 10 (a)	Fig. 10 (a)	Fig. 10 (a)	Fig. 10 (a)	Fig. 10 (a)
shape irregularity (R_B/R_A)	1.8	1.8	1.8	1.8	1.8
S_{min}/D	0.03	0.01	0.01	0.01	0.01
S_{max}/S_{min}	11	20	20	20	20
GN/GM	1.00	1.00	1.00	1.00	1.00
state of coexistence of fibers in multifilament	A	A	A	A	A
crimp number (crimps/cm)	14	22	7	12	10
difference in fiber length (%)	7	9	5	8	8
diameter of irregular cross-sectional fiber, D (μm)	10	12	12	14	17
cross-sectional structure	Fig. 9 (a)	Fig. 9 (a)	Fig. 9 (a)	Fig. 9 (a)	Fig. 9 (a)
shape irregularity (R_D/R_C)	1.6	1.5	1.5	1.6	1.6
MN/D	0.00	0.00	0.00	0.00	0.00

(continued)

	Example 22	Example 23	Example 24	Example 25	Example 26
space structure	average interfiber space distance (μm)	10.4	12.3	7.4	10.2
	proportion of interfiber spaces of less than $5\mu\text{m}$ (%)	26	18	36	25
	space proportion (%)	63	71	46	61
textu re	gloss (contrast gloss)	S (1.5)	S (1.3)	A (1.6)	S (1.5)
	lightness (apparent density (g/cm^3))	S (0.33)	S (0.30)	A (0.37)	S (0.32)
	flexibility (flexural rigidity $B \times 10^{-2}$ ($\text{gf}\cdot\text{cm}^2/\text{cm}$))	S (0.8)	A (1.1)	S (0.7)	A (1.3)
	resilience (bending recovery $2\text{HB} \times 10^{-2}$ ($\text{gf}\cdot\text{cm}/\text{cm}$))	S (0.7)	S (0.9)	S (0.6)	S (0.6)
	dry touch (friction coefficient)	A (0.5)	A (0.6)	A (0.4)	A (0.5)
color development property (L value of black dyed fabric)	S (14)	S (14)	S (14)	S (14)	S (14)
wear resistance	S (grade 4)	S (grade 4)	S (grade 4)	S (grade 4)	S (grade 4)
PET: polyethylene terephthalate, PEG: polyethylene glycol, SSIA: 5-sodium sulfoisophthalic acid, IPA: isophthalic acid					

EXPLANATION OF SYMBOLS

[0223]

- 5 a: fibroin of hardly dissolvable component in raw silk yarn of natural silk
 b: sericin of easily dissolvable component in raw silk yarn of natural silk
 c: hardly dissolvable component
 d: easily dissolvable component
- 10 A: perfect circle inscribed in cross section of composite fiber at two or more points (inscribed circle)
 B: perfect circle circumscribed on cross section of composite fiber at two or more points (circumscribed circle)
 C: perfect circle inscribed in cross section of fiber at two or more points (inscribed circle)
 D: perfect circle circumscribed on cross section of fiber at two or more points (circumscribed circle)
 F: the intersection of a straight line drawn from the intersection of two arbitrary straight lines each dividing the cross-sectional area of the fiber into halves (center of gravity) toward an arbitrary fiber surface and the fiber surface
- 15 G: the intersection of two arbitrary straight lines each dividing the cross-sectional area of the fiber into halves (center of gravity)
 M: the point that exists on the groove surface at the apex of a convex portion and is located nearest to the intersection of two arbitrary straight lines each dividing the cross-sectional area of the fiber into halves (center of gravity)
 N: the point that exists on the groove surface at the apex of a convex portion and is located farthest from the intersection of two arbitrary straight lines each dividing the cross-sectional area of the fiber into halves (center of gravity)
- 20 S: the intersection of a straight line drawn from the intersection of two arbitrary straight lines each dividing the cross-sectional area of the fiber into halves toward an arbitrary fiber surface and the perimeter of the core component
 X: an arbitrary fiber in a multifilament
- 25 Y: a fiber formed of a polymer different from the fiber X in a multifilament and having no other fibers existing on the straight line drawn between its center of the gravity and the center of the gravity of the fiber X
 1: measuring plate
 2: distribution plate
 3: discharge plate
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Claims

- 35 1. A core-sheath composite fiber comprising two or more types of polymers and having a cross section containing a core component possessing a multilobar shape with three or more convex portions and a sheath component surrounding the core component completely, with the maximum thickness $S_{\max}$ and the minimum thickness $S_{\min}$ of the sheath component having a $S_{\max}/S_{\min}$ ratio of 5.0 or more.
- 40 2. The core-sheath composite fiber as set forth in claim 1, wherein the core component of a multilobar shape has a groove existing at the apex of each convex portion and extending toward the center of gravity of the core component and wherein the ratio of GN/GM between the distance GM from the center of gravity G of the core component to the bottom M of the groove and the distance GN from the center of gravity G of the core component to the apex N of the convex portion is 1.1 to 1.5.
- 45 3. The core-sheath composite fiber as set forth in either claim 1 or 2, wherein two or more core components are separated by the sheath component and wherein each of the separated core components has a multilobar shape.
- 50 4. The core-sheath composite fiber as set forth in claim 3, wherein core components are separated by the sheath component and wherein mutually adjacent core components are of polymers having different melting points.
- 55 5. A multifilament comprising the core component of the core-sheath composite fiber as set forth in any one of claims 1 to 4.
6. The multifilament as set forth in claim 5, wherein the average interfiber space distance is 5 to 30 μm and wherein there exists a space structure in which the interfiber spaces with distances of less than 5 μm account for 10% to 50%.
7. The multifilament as set forth in claim 6, wherein there exists a space structure in which the space proportion is 30% to 80%.

8. The multifilament as set forth in either claim 6 or 7, comprising two or more types of crimped fibers formed of polymers having different melting points, with the crimped fibers coexisting uniformly.
- 5 9. The multifilament as set forth in any one of claims 6 to 8, comprising a fiber of a multilobar shape having a three or more convex portions in the cross section of the fiber.
- 10 10. The multifilament as set forth in any one of claims 6 to 9, comprising a fiber wherein a groove exists at the apex of each convex portion in the cross section of the fiber and wherein the ratio of MN/D between the distance MN from the bottom M of the groove to the apex N of the convex portion and the fiber diameter D is 0.04 to 0.20.
- 15 11. A fiber product partially containing the core-sheath composite fiber or the multifilament as set forth in any one of claims 1 to 10.

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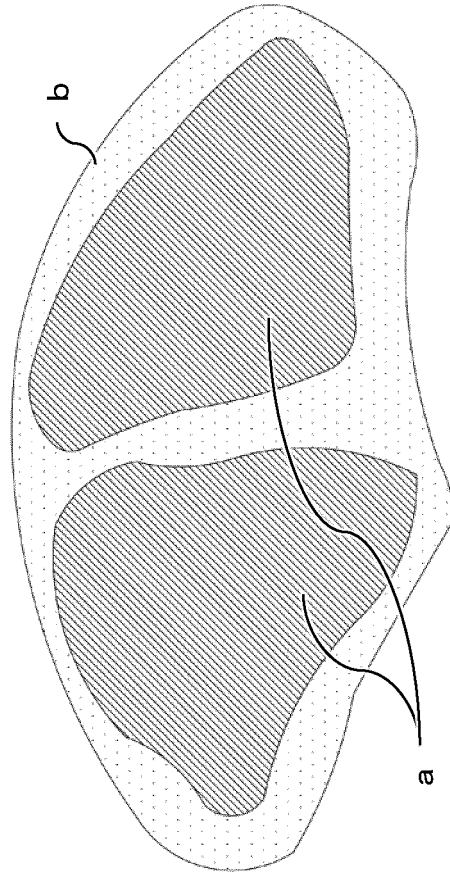
40

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Figure 1



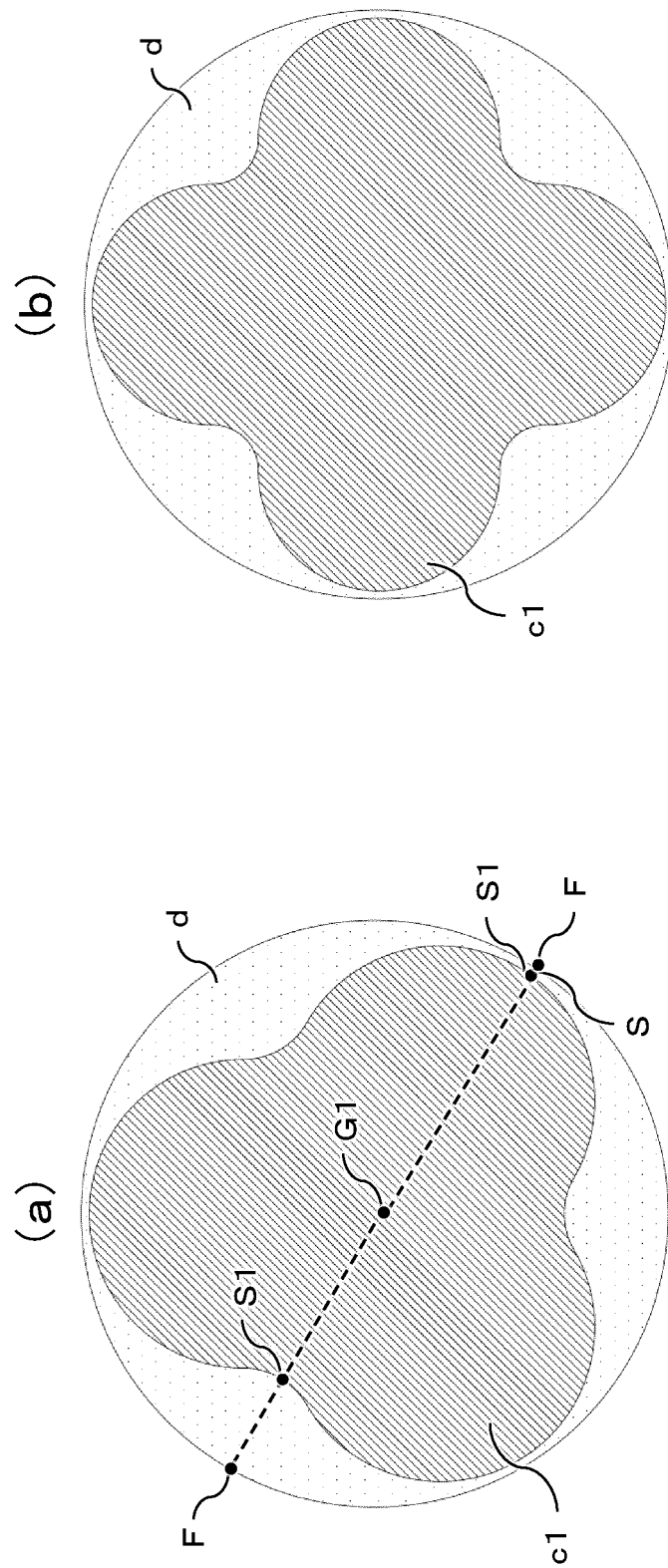


Figure 2

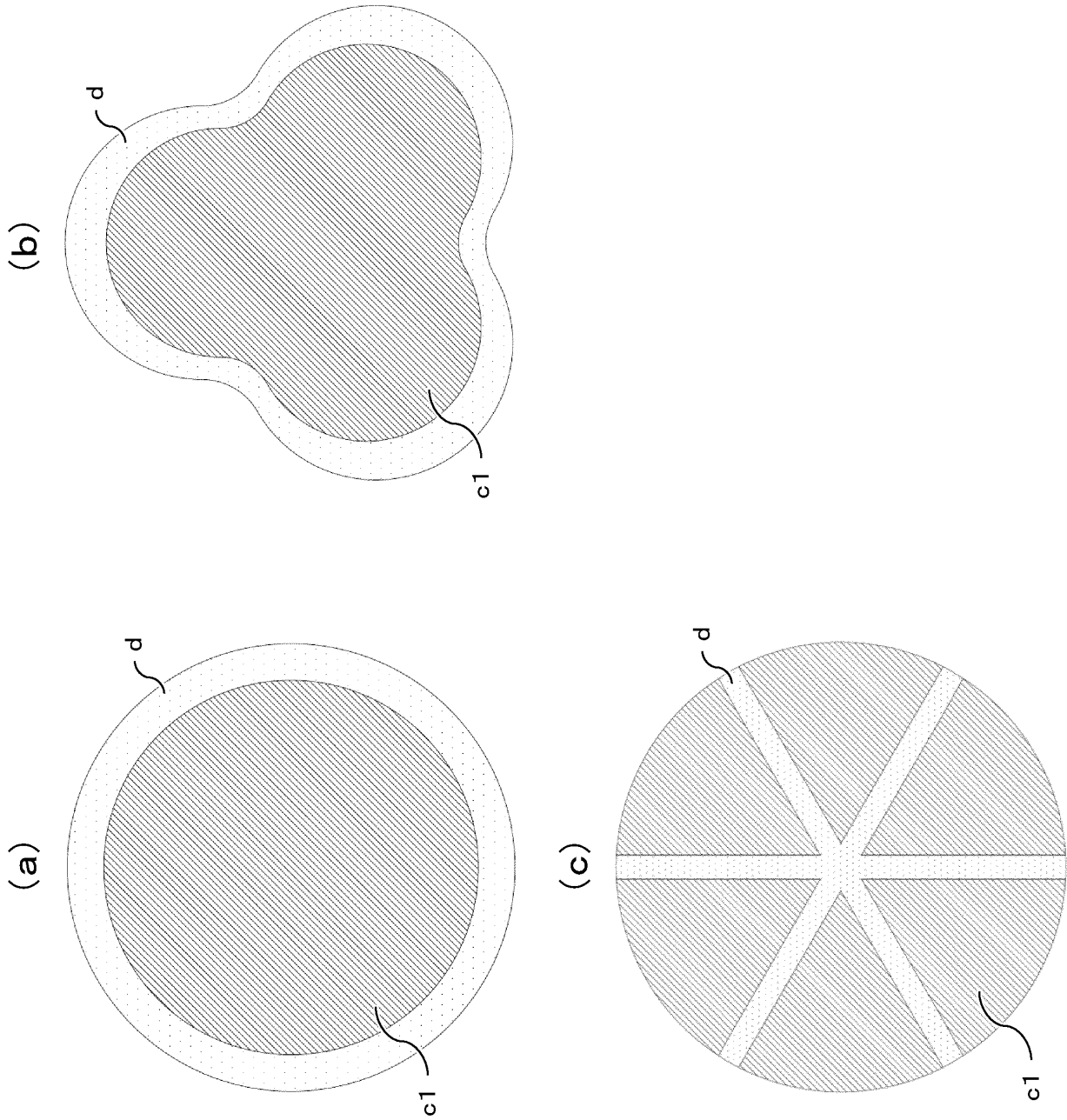


Figure 3

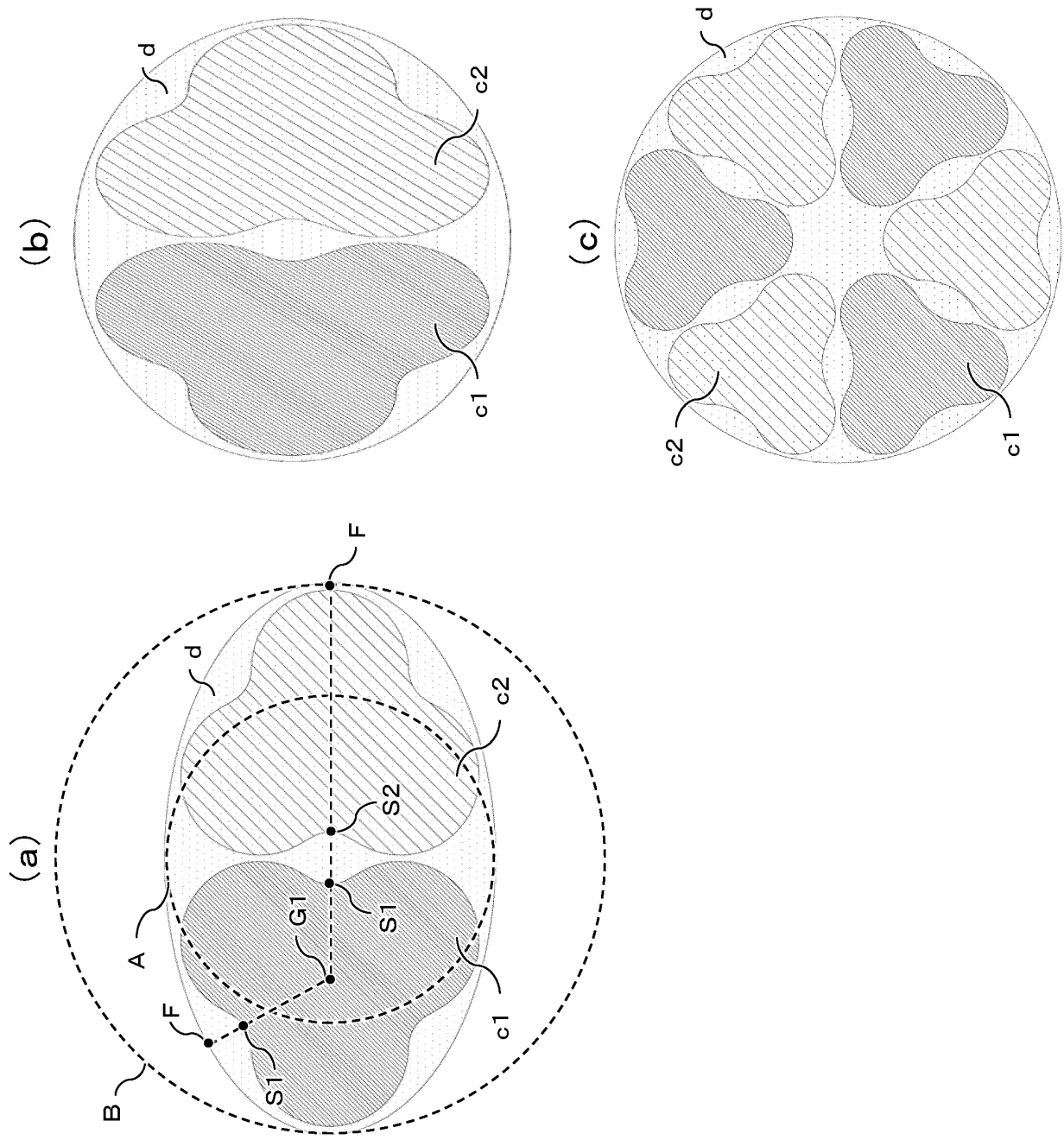


Figure 4

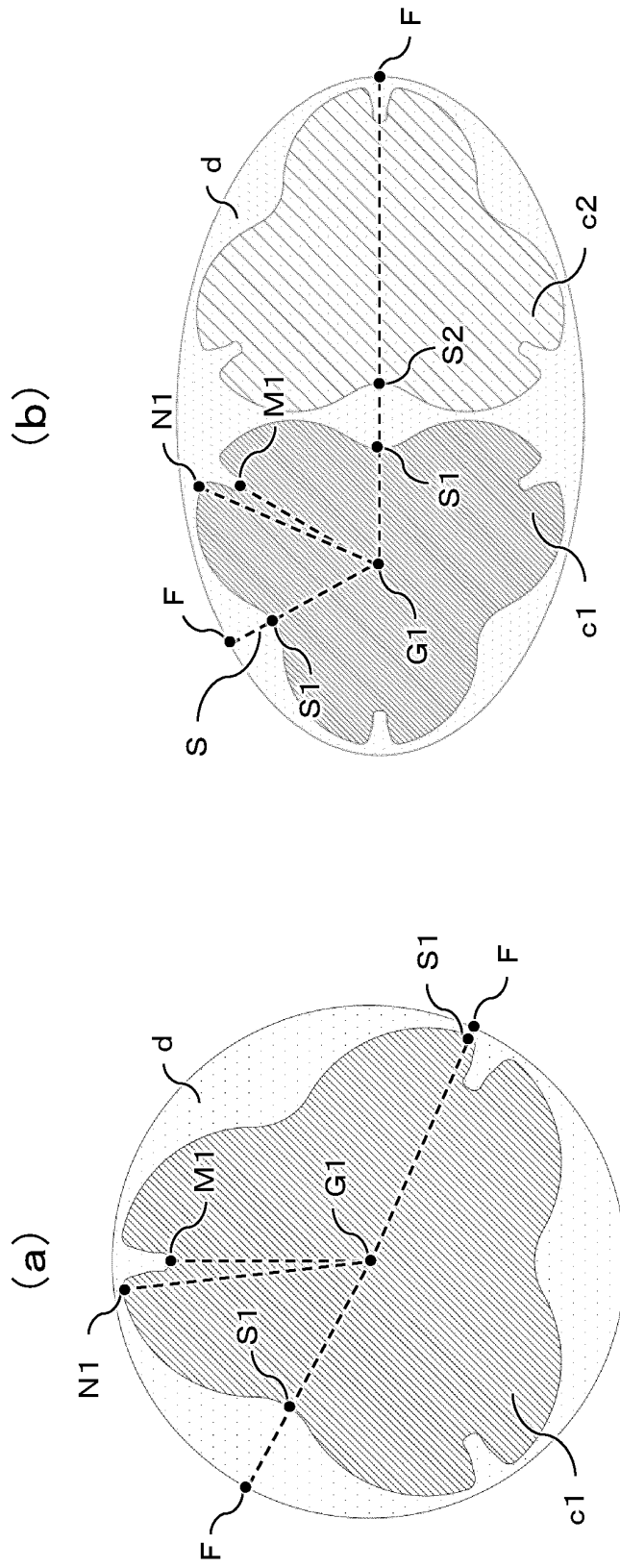


Figure 5

Figure 6

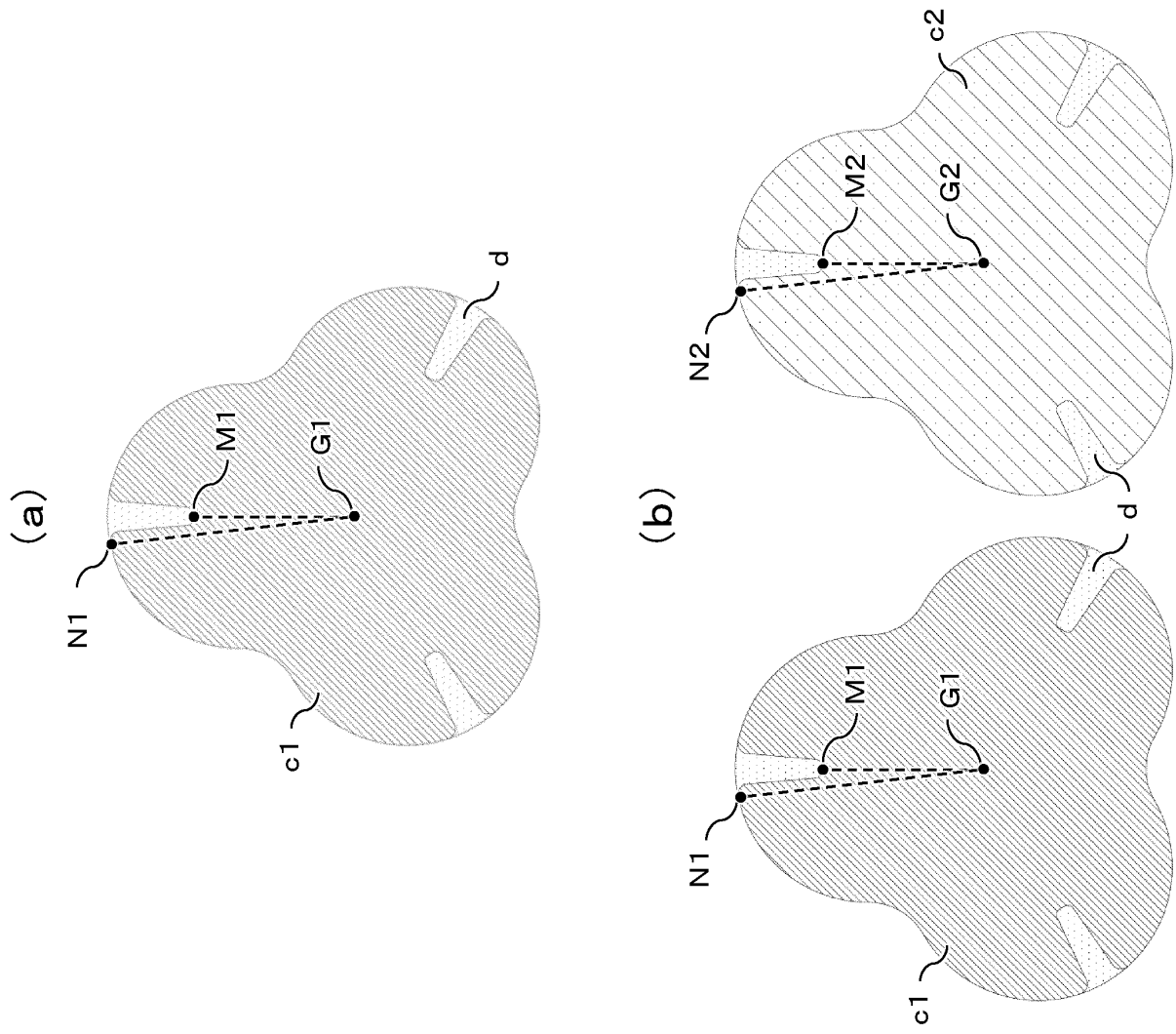


Figure 7

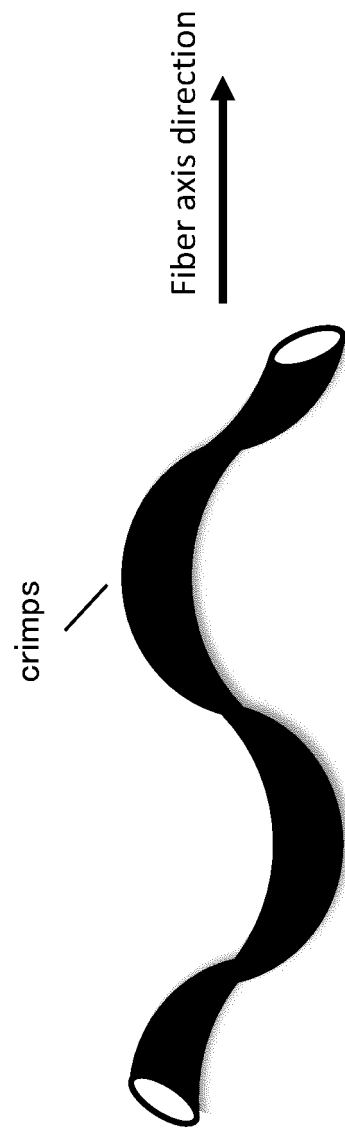
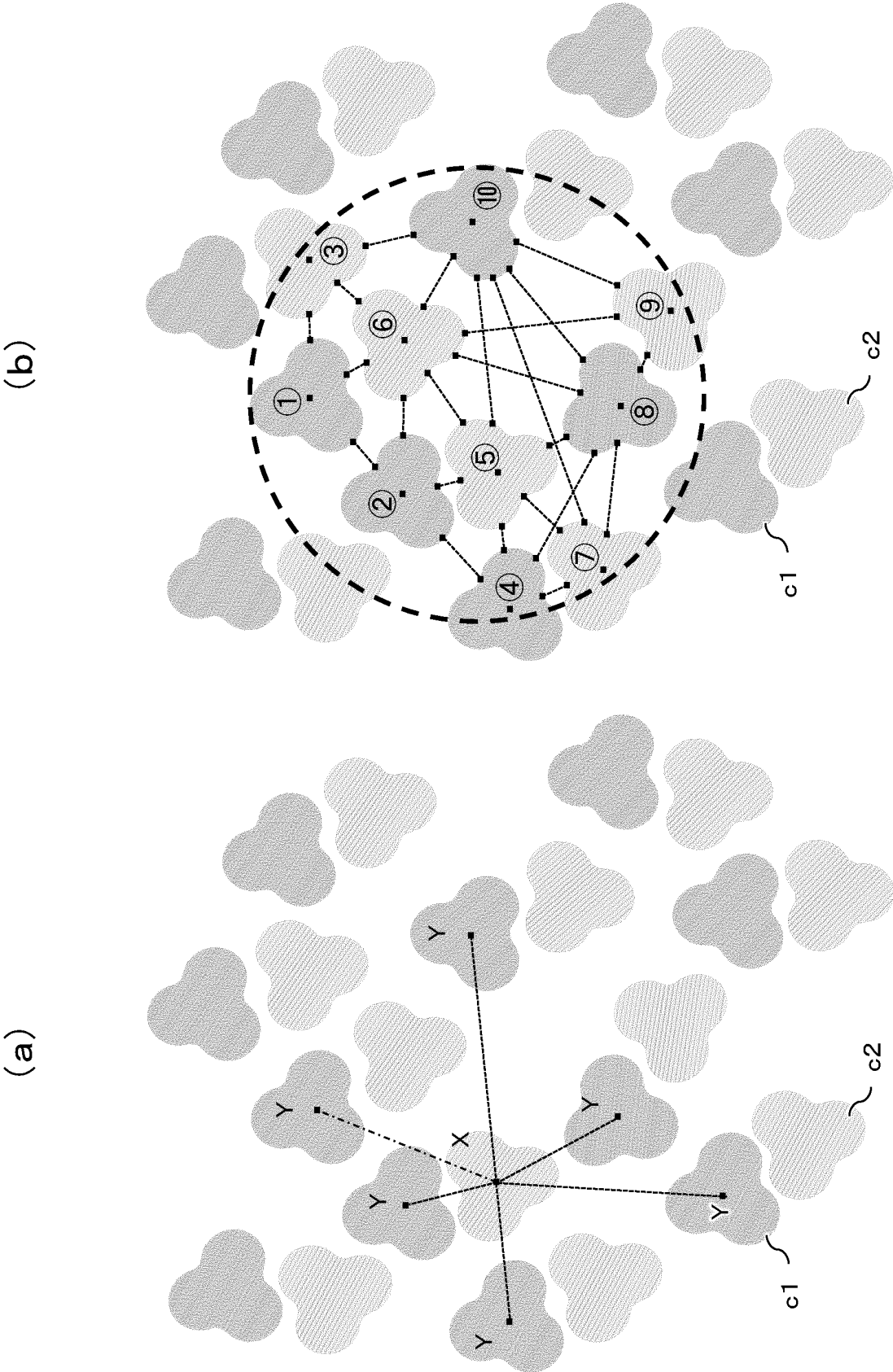


Figure 8



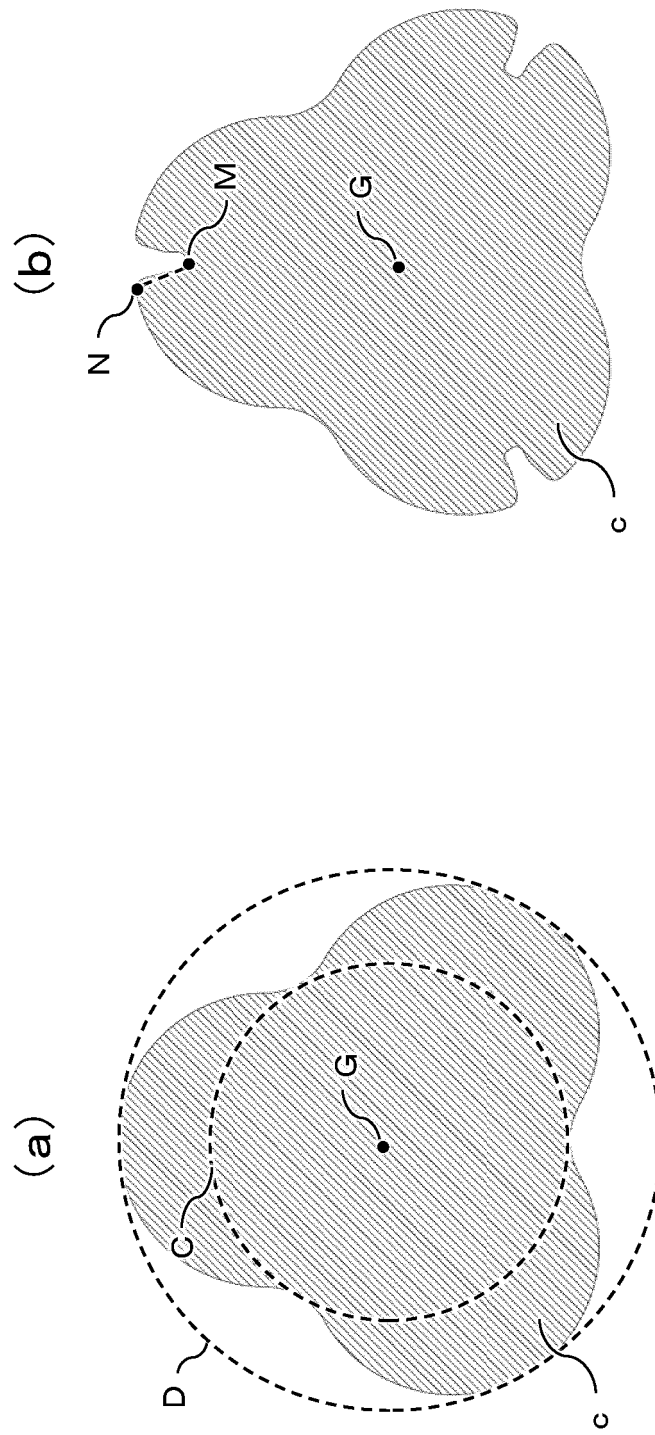
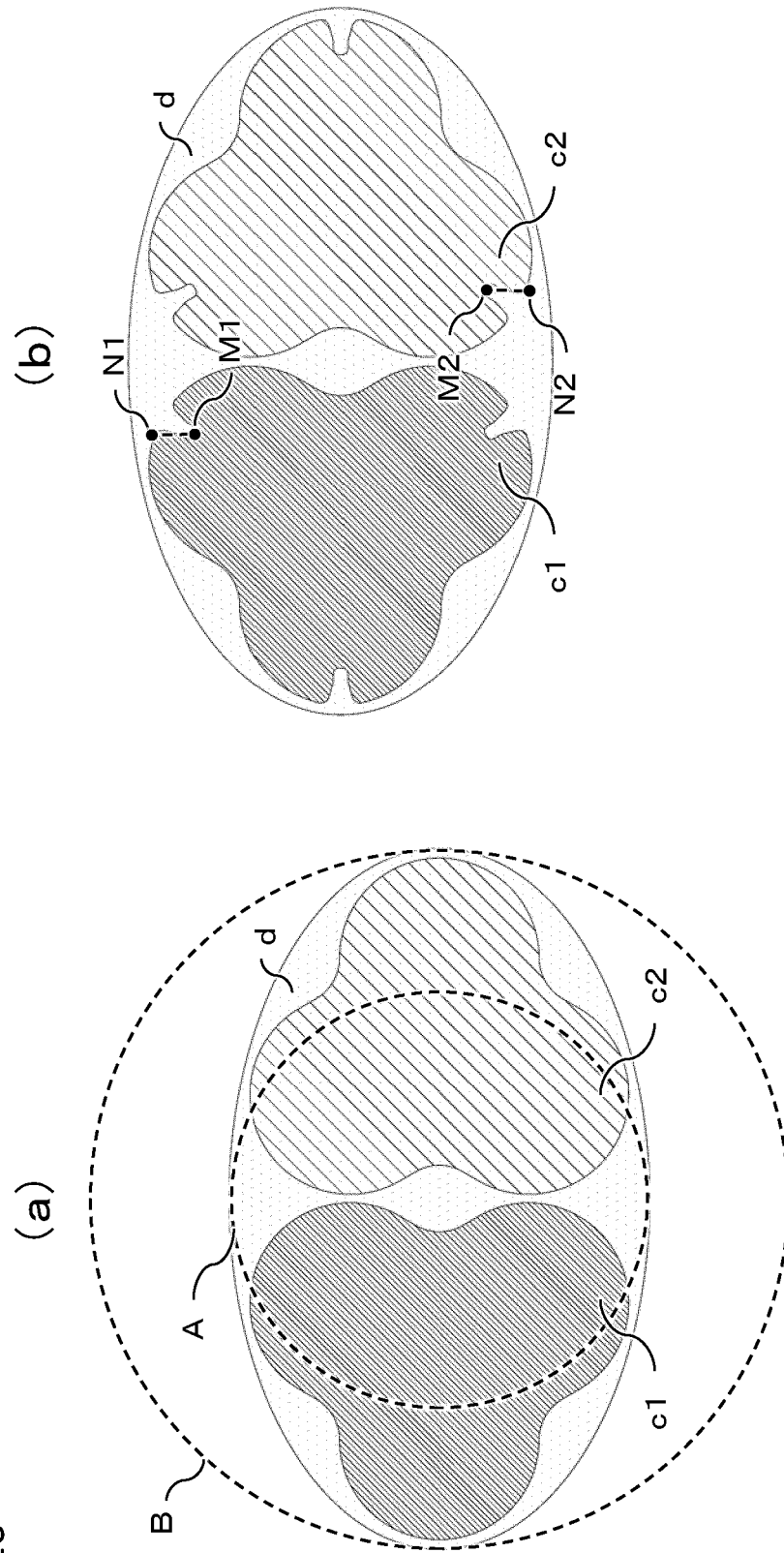


Figure 9

Figure 10



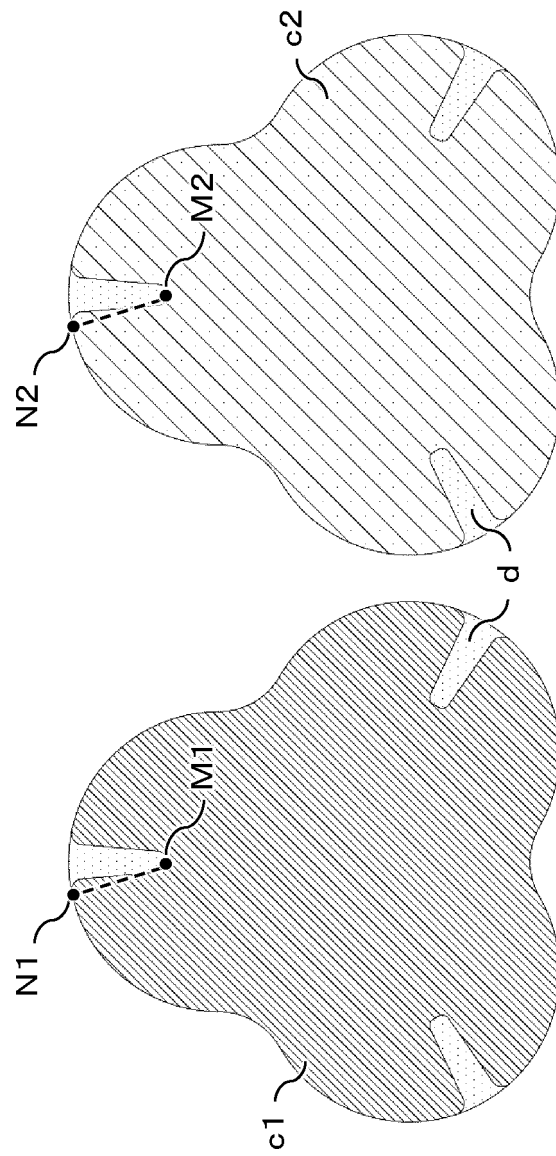


Figure 11

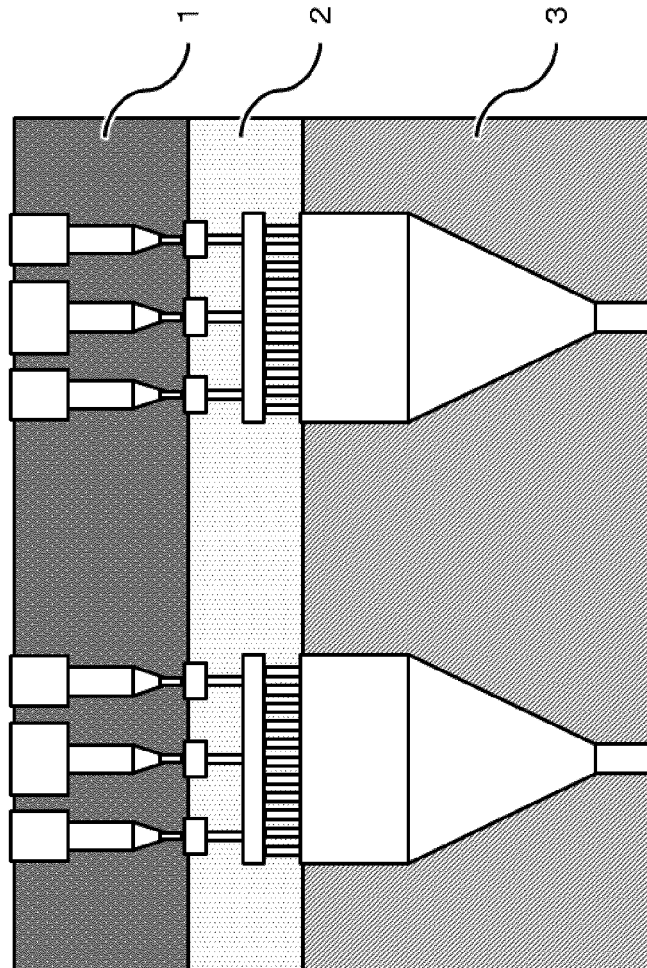


Figure 12

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2020/037537

A. CLASSIFICATION OF SUBJECT MATTER

D01F 8/14 (2006.01) i; D02C 3/04 (2006.01) i

FI: D01F8/14 B; D02C3/04

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; D02C1/00-3/48; D02J1/00-13/00; D01F1/00-6/96; D01F9/00-9/04; D03D1/00-27/18; D04B1/00-1/28; D04B21/00-21/20

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 1971-2020

Registered utility model specifications of Japan 1996-2020

Published registered utility model applications of Japan 1994-2020

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 59-33974 A (TORAY INDUSTRIES, INC.) 23 May 1984 (1984-05-23) claims, page 2, lower left column, page 3, lower right column, page 4, upper right column, fig. 5	1, 11
Y	claims, page 2, lower left column, page 3, lower right column, page 4, upper right column, fig. 5	2, 11
A		3-10
Y	JP 8-109513 A (NIPPON-ESTER CO., LTD.) 30 April 1996 (1996-04-30) claims, examples, fig. 2	2, 11
A		1, 3-10
X	JP 8-260278 A (UNITIKA LTD.) 08 October 1996 (1996-10-08) claims, paragraph [0035]	5, 11
Y	claims, examples, fig. 2	2, 11
A		1, 3-4, 6-10
X	JP 2016-186134 A (DAIWABO HOLDINGS CO., LTD.) 27 October 2016 (2016-10-27) claims, paragraphs [0033]-[0035], examples	1, 11
A		2-10



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
20 November 2020 (20.11.2020)Date of mailing of the international search report
08 December 2020 (08.12.2020)Name and mailing address of the ISA/
Japan Patent Office
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2020/037537

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