



(11)

**EP 3 150 751 A1**

(12)

**EUROPEAN PATENT APPLICATION**  
published in accordance with Art. 153(4) EPC

(43) Date of publication:

**05.04.2017 Bulletin 2017/14**

(21) Application number: **15798772.8**

(22) Date of filing: **21.05.2015**

(51) Int Cl.:

**D01F 6/60** (2006.01)

**D01F 8/12** (2006.01)

**D03D 15/00** (2006.01)

**D06M 11/05** (2006.01)

**A41B 17/00** (2006.01)

**D01F 8/14** (2006.01)

**D06M 11/00** (2006.01)

(86) International application number:

**PCT/JP2015/002575**

(87) International publication number:

**WO 2015/182088 (03.12.2015 Gazette 2015/48)**

(84) Designated Contracting States:

**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB  
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO  
PL PT RO RS SE SI SK SM TR**

Designated Extension States:

**BA ME**

Designated Validation States:

**MA**

(30) Priority: **26.05.2014 JP 2014108167**

**29.08.2014 JP 2014175654**

(71) Applicant: **Kuraray Co., Ltd.**

**Kurashiki-shi, Okayama 710-0801 (JP)**

(72) Inventors:

- **NAKATSUKA, Hitoshi**  
**Kurashiki-shi**  
**Okayama 713-8550 (JP)**

• **KAWAKADO, Shinya**

**Kurashiki-shi**

**Okayama 713-8550 (JP)**

• **IKEDA, Takayuki**

**Kurashiki-shi**

**Okayama 713-8550 (JP)**

• **OHGA, Daisuke**

**Saijo-shi**

**Ehime 793-8585 (JP)**

• **MURATE, Yasunori**

**Okayama-shi**

**Okayama 702-8601 (JP)**

(74) Representative: **Müller-Boré & Partner**

**Patentanwälte PartG mbB**

**Friedenheimer Brücke 21**

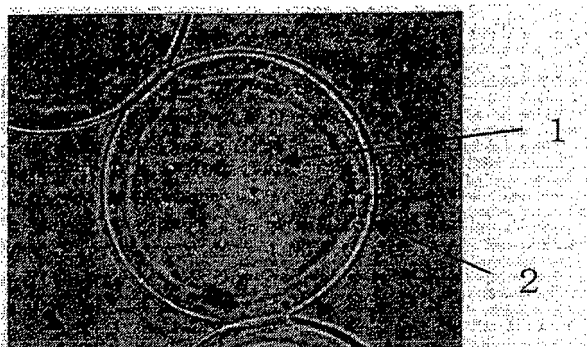
**80639 München (DE)**

(54) **POLYAMIDE FIBERS, FIBER STRUCTURE USING SAME, AND CLOTHING**

(57) Disclosed is a polyamide fiber having a degree of orientation equal to or higher than 0.7 and equal to or lower than 0.85. The polyamide fiber is suitably obtained

by forming a polyamide component having high moisture absorbency and a specific soluble component into a conjugated fiber under specific fiber formation conditions.

**FIG.1**



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## Description

### TECHNICAL FIELD

5 **[0001]** The present invention relates to a polyamide fiber for forming, for example, clothing for sports and underwear, and a fiber structure formed using the polyamide fiber.

### BACKGROUND ART

10 **[0002]** Known synthetic fibers, for example, polyester fibers, and polyamide fibers such as nylon-6 and nylon-6,6, are used not only for clothing, but also for a wide range of industrial purposes due to their good physical and chemical properties. These fibers are of high industrial value.

**[0003]** Unfortunately, these synthetic fibers are low in moisture absorbency and water absorbency, which actually limits their applications to clothing which are required to be absorbent of moisture and water, such as underwear, intermediate garment, bed sheets, and towels. In view of this, for polyester fibers, for example, some methods have been proposed for improving the low moisture absorbency and water absorbency, which can be referred to as the main shortcoming of the polyester fibers.

**[0004]** More specifically, the proposed methods include, for example, a method in which polyester fibers are post-treated using a hydrophilic post-processing agent, and a method in which polyester fibers are caused to have pores in their surfaces or interiors to obtain moisture absorbency and water absorbency. However, according to these methods, the moisture absorbency and water absorbency are insufficiently improved, and the properties provided to the fibers are deteriorated by washing.

**[0005]** Some methods have been proposed to solve the above problems. According to such methods, an ethylene-vinyl alcohol-based copolymer, which is obtained by saponifying an ethylene-vinyl acetate-based copolymer, is conjugated with another thermoplastic polymer such as polyester, polyamide, or polyolefin, and the resultant conjugated material is formed into fibers, thereby improving dimensional stability (see, for example, Patent Documents 1-3).

### CITATION LIST

#### 30 PATENT DOCUMENTS

##### **[0006]**

Patent Document 1: Japanese Examined Utility Model Publication No. S56-005846  
 35 Patent Document 2: Japanese Examined Utility Model Publication No. S55-001372  
 Patent Document 3: Japanese Examined Utility Model Publication No. H07-084681

### SUMMARY OF THE INVENTION

#### 40 TECHNICAL PROBLEM

**[0007]** However, the ethylene-vinyl alcohol-based copolymer according to the above-described known techniques has insufficient resistance to moist heat, which disadvantageously limits its applications.

**[0008]** Meanwhile, regarding nylon fibers used in underwear, socks, and other clothing, it is difficult to improve comfort of a fiber structure and clothing containing nylon fibers sufficiently by simply providing the nylon fibers themselves with moisture absorbency. Therefore, there is an increasing demand for moisture-absorbing, and water-absorbing extensible fibers capable of controlling humidity.

**[0009]** In view of the foregoing background, it is therefore an object of the present invention to provide a highly moisture-absorbent polyamide fiber which extends and contracts significantly in a reversible manner upon absorbing and releasing water, and from which a highly comfortable fiber structure can be produced. The present invention also aims to provide a fiber structure and clothing which are formed using the polyamide fiber.

### SOLUTION TO THE PROBLEM

55 **[0010]** To achieve the object, a polyamide fiber of the present invention has a degree of orientation equal to or higher than 0.7 and equal to or lower than 0.85.

## ADVANTAGES OF THE INVENTION

**[0011]** The present invention provides a fiber structure which controls humidity highly effectively and provides more comfort than ever.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0012]**

**[FIG. 1]** FIG. 1 is a photograph of an exemplary cross section of a conjugated fiber for obtaining a fiber of the present invention.

**[FIG. 2]** FIG. 2 is a photograph of an exemplary cross section of a conjugated fiber for obtaining a fiber of the present invention.

**[FIG. 3]** FIG. 3 is a photograph of an exemplary cross section of a conjugated fiber for obtaining a fiber of the present invention.

**[FIG. 4]** FIG. 4 is a photograph of an exemplary cross section of a conjugated fiber for obtaining a fiber of the present invention.

## DESCRIPTION OF EMBODIMENTS

**[0013]** A polyamide fiber of the present invention has a degree of orientation equal to or higher than 0.7 and equal to or lower than 0.85. If the degree of orientation were lower than 0.7, sufficient colorfast could not be obtained. If the degree of orientation were higher than 0.85, the fiber would reversibly extend and contract in an insufficient manner upon absorbing and releasing water. This would cause the stitches in woven or knitted fabric to open and close insufficiently and make it impossible to obtain a highly comfortable fiber structure.

**[0014]** Thus, a fiber structure such as woven or knitted fabric is produced using the polyamide fibers having a degree of orientation equal to or higher than 0.7 and equal to or lower than 0.85. When absorbing sweat, for example, the polyamide fibers extend to cause the stitches in the woven or knitted fabric to open, thereby releasing humidity inside the clothing. When dried, the polyamide fibers contract to restore the original length and cause the stitches to close, thereby preventing heat from being released outside the clothing. Thus, the use of the polyamide fibers of the present invention may provide woven or knitted fabric which is highly comfortable and has a so-called self-control function.

**[0015]** Note that the degree of orientation of the polyamide fiber is beneficially equal to or higher than 0.72, and more beneficially equal to or higher than 0.75. Further, the degree of orientation of the polyamide fiber is beneficially equal to or lower than 0.83, more beneficially equal to or lower than 0.8, and still more beneficially lower than 0.80. The degree of orientation of the polyamide resin is calculated by a measurement method which will be described later with reference to examples.

**[0016]** The polyamide fiber of the present invention beneficially has a moisture absorption rate equal to or higher than 5% at a temperature of 35°C and a humidity of 95%RH, and a water absorption extension rate equal to or higher than 5% at a temperature of 20°C and a humidity of 65%RH. A moisture absorption rate lower than 5% would cause a user to feel stickiness and sweatiness. A water absorption extension rate lower than 5% would cause the fiber to reversibly extend and contract in an insufficient manner upon absorbing and releasing, and would prevent stitches in woven or knitted fabric from opening and closing sufficiently. Such moisture absorption rate and water absorption extension rate make it impossible to obtain a highly comfortable fiber structure.

**[0017]** Thus, the use of the polyamide fiber having the above-specified moisture absorption rate and water absorption extension rate may enable the production of a fiber structure such as woven or knitted fabric, which has the self-control function described above and provides more comfort.

**[0018]** Excessive increases in the moisture absorption rate and the water absorption extension rate tend to reduce wash-fastness, weather resistance, light resistance, and chemical resistance, for example. In view of this, the moisture absorption rate is beneficially equal to or higher than 5% and equal to or lower than 30%, and more beneficially equal to or higher than 8% and equal to or lower than 25%. The water absorption extension rate is beneficially equal to or higher than 5%, more beneficially equal to or higher than 7%, still more beneficially equal to or higher than 8%, and particularly beneficially equal to or higher than 10%. Further, the water absorption extension rate is beneficially equal to or lower than 30%, more beneficially equal to or lower than 25%, and still more beneficially equal to or lower than 20%. The moisture absorption rate and the water absorption extension rate of the polyamide resin are measured according to a measurement method which will be described later with reference to the examples.

**[0019]** The polyamide fiber has a crimp extension rate which is beneficially equal to or higher than 1.5% and equal to or lower than 10%, more beneficially equal to or higher than 2% and equal to or lower than 8%, and still more beneficially equal to or higher than 2.5% and equal to or lower than 5.8%. A crimp extension rate equal to or higher than 1.5% and

equal to or lower than 10% provides silk-like feel and texture, and makes fabric soft and pleasant to the touch.

[0020] Examples of the polyamide to be used in the present invention include: polycaproatamide (nylon-6), poly- $\omega$ -aminoheptanoic acid (nylon-7), polyundecaneamide (nylon-11), polyethylene diamine adipamide (nylon-2,6), polytetramethylene adipamide (nylon-4,6), polyhexamethylene adipamide (nylon-6,6), polyhexamethylene sebacamide (nylon-2,10), polyhexamethylene dodecamide (nylon-6,12), polyoctamethylene adipamide (nylon-8,6), polydecanomethylene adipamide (nylon-10,6), and polydodecamethylene sebacamide (nylon-10,8). Examples of the polyamide- further include: caprolactam/lauric lactam copolymer (nylon-6/12), caprolactam/ $\omega$ -aminononanoic acid copolymer (nylon-6/9), caprolactam/hexamethylene adipate copolymer (nylon-6/6,6), lauric lactam/hexamethylene diamine adipate copolymer (nylon-12/6,6), hexamethylene diamine adipate/hexamethylene diamine sebacate copolymer (nylon-6,6/6,10), ethylenediamine adipate/hexamethylene diamine adipate copolymer (nylon-2,6/6,6), and caprolactam/hexamethylene diamine adipate/hexamethylene diamine sebacate copolymer (nylon-6,6/6,10).

[0021] Among these substances, nylon-6 and nylon-6,6 are most suitable as the polyamide of the present invention. Nylon-6 is still more beneficial because it is unexpansive and versatile, and has high moisture absorbency. Among the above copolymers, nylon-6/6,6 and nylon-6/12 are beneficial. Although the composition ratio between the component having a carbon number of 6 and the component having a carbon number of 12 that form the nylon-6/12 is not particularly limited, the component having a carbon number of 12 beneficially constitutes 50 mol% or less, and more beneficially 40 mol% or less.

[0022] The polyamide copolymers may be caused to contain an anti-static agent, a lubricant, an anti-blocking agent, a stabilizer, a dye, or a pigment, for example.

[0023] The polyamide fiber of the present invention may be produced by any method as long as the polyamide fiber has the above-described degree of orientation, moisture absorption rate, and water absorption extension rate. For example, a polyamide component (component A) and another soluble component (component B) are formed into a conjugated fiber, and thereafter, the component B is dissolved and removed, thereby suitably producing the polyamide fiber of the present invention. The use of such a conjugated fiber enables the control of the structure of the polyamide component, thereby enabling the production of a fiber which is exclusively made of polyamide, has a specific degree of orientation, high moisture absorbency and high water absorption extensibility, and is capable of reversibly extending and contracting upon absorbing and releasing water.

[0024] If the polyamide fiber of the present invention is produced from the conjugated fiber as described above, the other component, i.e., the soluble component (component B) plays an important role in the structure control. An exemplary polymer which can be used as the component B is a water-soluble thermoplastic polyvinyl alcohol-based polymer. This polyvinyl alcohol-based polymer beneficially has a viscosity average degree of polymerization of 200-500, a degree of saponification of 90-99.99 mol%, and a melting point of 160-230°C. Although the polyvinyl alcohol-based polymer may be a monopolymer or a copolymer, it is recommended to use a copolymerized polyvinyl alcohol which is 0.1-20 mol% modified by  $\alpha$ -olefin having a carbon number of 4 or less such as ethylene or propylene, in order to ensure ease of melt spinning, water solubility, and fiber physical properties. The polyamide fiber of the present invention can be suitably obtained by removing, by using hot water, the water-soluble thermoplastic polyvinyl alcohol-based polymer from the conjugated fiber including the component B.

[0025] A polyester-based polymer which is soluble in alkali at a high speed (easily alkali-soluble polyester-based polymer) is another example which can be used as the component B. Examples of such an easily alkali-soluble polyester-based polymer include a polylactic acid, and copolymerized polyester formed by copolymerizing 1-5 mol% of 5-sodium sulfoisophthalic acid, 5-30 wt. % of polyalkylene glycol, a conventionally used diol component, and a conventionally used dicarboxylic acid component. From a conjugated fiber containing this component B, the polyamide fiber of the present invention may be suitably obtained by the removal of the easily alkali-soluble polyester-based polymer by alkaline treatment.

[0026] It is beneficial that the conjugated fiber for producing the polyamide fiber of the present invention has a fiber cross section of which 50% or more is coated with the soluble component (component B). It is more beneficial that the entire cross section is coated with the soluble component (component B). That is to say, the conjugated fiber beneficially has a sheath-core cross section in which the polyamide component forms the core and the component B forms the sheath, or a sea-island cross section in which the polyamide component forms the islands and the component B forms the sea.

[0027] A conjugate ratio (A:B) of the conjugated fiber of the present invention between the polyamide component (A component) and the soluble component (B component) ranges beneficially from 90:10 to 40:60 (weight ratio), and more beneficially from 80:20 to 60:40 (weight ratio). The ratio may be adjusted according to fiber shapes. Note that if the component B is used in a small amount, it may become difficult to control the polyamide structure. This may makes it impossible to achieve desired moisture absorbency and water absorption extensibility, resulting in difficulty in humidity control.

[0028] The cross section of the conjugated fiber of the present invention is not particularly limited, provided that the component B is dissolved and removed by hot water treatment or alkali treatment, and cracks are not caused in the

component A. The cross section may be of a concentric, eccentric, or multi-centric type, for example. Further, the cross section may have, besides the circular shape shown in FIGS. 1 and 2, a multifoil shape shown in FIG. 3, or a modified shape such as a triangle or flat shape. Furthermore, as shown in FIG. 4, the component A may include therein a hollow portion. The cross section may have one or multiple hollow portions, without causing any problem.

**[0029]** The polyamide fiber of the present invention may beneficially have a monofilament size of 0.03-10 dtex, which is not limiting. The polyamide fiber of the present invention may be used not only as a long fiber, but also as a short fiber or a short-cut fiber.

**[0030]** Once a combination of a polyamide component (component A) and the other component, i.e., the soluble component (component B), is determined, the conjugated fiber of the present invention may be formed by using a known conjugated fiber-spinning machine.

**[0031]** Setting of fiber formation conditions is important to obtain the fiber of the present invention. It is most suitable to form the fiber by direct spinning and drawing method at a high speed. If the fiber is melt spun at a low or intermediate speed, and subjected to drawing thereafter, the temperature of heat treatment for the drawing is set to a temperature lower than 100°C, and beneficially to 80°C or lower, and the drawing rate is set to a rate lower than 2. If drawing and false twisting are performed at the same time or continuously after the spinning, the temperature of the heat treatment is also set to a temperature lower than 100°C, and beneficially to 80°C or lower, and the drawing rate is limited to a rate lower than 2. If the temperature were set to 100°C or higher, or if the drawing rate were set to 2 or higher, it would be difficult to control the polyamide structure, and desired degree of orientation, moisture absorbency, and water absorption extensibility could not be achieved.

**[0032]** The polyamide fiber of the present invention may be used to form various types of fiber structures (fiber aggregates). Here, the "fiber structure" may be configured as a multifilament thread, a spun yarn, woven or knitted fabric, non-woven fabric, paper, synthetic leather, and wadding which are exclusively made of the polyamide fiber of the present invention. Alternatively, the "fiber structure" may be configured as: woven or knitted fabric or non-woven fabric, part of which is made of the polyamide fiber of the present invention; combined woven or knitted fabric additionally containing fibers of a different type such as natural fibers, artificial fibers, synthetic fibers, or semi synthetic fibers; and woven or knitted fabric, cotton-containing non-woven fabric, or fiber layered product in which the polyamide fibers of the present invention are used as a finished yarn such as a blended yarn, a doubling-and-twisted yarn, a confound yarn, or a crimp yarn.

**[0033]** The weight ratio of the polyamide fiber of the present invention with respect to the entire woven or knitted fabric or non-woven fabric is beneficially 15 wt. % or more, more beneficially 18 wt.% or more, particularly beneficially 23 wt. % or more. After woven or knitted into fabric, or formed into a non-woven fabric, the fibers of the present invention may be subjected to napping treatment by means of wire raising or any other finishing.

**[0034]** If the polyamide fiber of the present invention is produced via the conjugated fiber described above, a fiber structure may be formed using the fiber which contains polyamide alone and from which the component B has been removed. Alternatively, the component B may be removed from a fiber structure which has been formed using the conjugated fiber.

## EXAMPLES

**[0035]** The present invention will be described more specifically below with reference to examples.

(Example 1)

(Production of Polyamide Fibers)

**[0036]** Nylon-6 having a reduced viscosity of 1.80 dL/g (at a concentration of 1g/dL in orthochlorophenol at 30°C) was used as a polyamide component (component A), and a thermoplastic modified polyvinyl alcohol (modified PVA) (product of Kuraray Co., Ltd. having a saponification degree of 98.5, an ethylene content of 8.0 mol%, and a degree of polymerization of 390) was used as a soluble component (component B). The components A and B were separately melted in different extruders, and a conjugated fiber having a cross section shown in FIG. 1 was injected through a multi-component fiber-spinning nozzle with a ratio of nylon-6:modified PVA set at 60:40 (weight ratio). Subsequently, a thread injected through a spinneret was cooled using a horizontal cooling air blower having a length of 1.0 m. Thereafter, water-free spinning oil including, as its components, an anti-static agent and a lubricating agent was applied to the thread. The thread was then wound using a roller at a take-off speed of 3500 m/min. In this manner, a conjugated fiber (111 dtex/24 filaments) was produced. Note that the process steps of fiber production were performed smoothly. The produced conjugated fiber was knitted into cylindrical fabric by a circular knitting machine (28 gauge). The resultant knitted fabric was subjected to a scouring step using hot water (90°C, 20 minutes) to dissolve and remove the modified PVA. In this manner, the polyamide fiber of the present invention was produced.

(Measurement of Degree of Orientation)

**[0037]** Next, the degree of orientation of the produced polyamide fiber was measured by using the following measurement device under the following measurement conditions.

**[0038]** Measurement device: a two dimensional detector-equipped X-ray diffractometer (product of Bruker AXS K.K., product name; "D8 Discover with GADDS")

Detector: Two-dimensional PSPC-Hi-STAR

Measurement conditions: a current of 110 mA; a voltage of 45 kV; a camera distance of 15 cm; a collimator diameter of 0.5 mm; an exposure time of 1200 sec.;  $2\theta$  axis at  $22^\circ$ ;  $\omega$  axis at  $0^\circ$ ; and  $\chi$  axis at  $90^\circ$  (equator line)- $0^\circ$  (meridian)

**[0039]** A single yarn was used as the sample. The angle of the  $\chi$  axis was adjusted such that the sample is positioned perpendicularly to the equator line and parallel to the meridian.

**[0040]** Thereafter, two-dimensional data in the meridian direction obtained in the foregoing manner was converted to an X-ray diffraction intensity curve in an azimuthal direction under the following conditions.

$2\theta = 9.7^\circ$ - $11.7^\circ$ ,  $\chi = -150^\circ = 30^\circ$ , step width =  $0.1^\circ$

**[0041]** Finally, the half-power bandwidth ( $Wi^\circ$ ) of an intensity map obtained in the above manner was found. The degree of orientation of the fiber was calculated by a simple method according to the following expression:

$$\text{Degree of orientation: } A = (360 - \sum Wi) / 360$$

(Measurement of Moisture Absorption Rate)

**[0042]** Next, the produced polyamide fiber was maintained in a thermo-hygrostat chamber regulated at  $35^\circ\text{C}$  and 90%RH for 24-hour humidity regulation. The moisture absorption rate of the fiber was then calculated based on an absolute dry sample weight and a humidity-regulated sample weight, according to the following expression. The results are shown in Table 1.

$$\text{Moisture absorption rate (\%)} = (\text{humidity-regulated sample weight} - \text{absolute dry sample weight}) \times 100 / \text{absolute dry sample weight}$$

(Measurement of Water Absorption Extension Rate)

**[0043]** The produced polyamide fiber was wound into a hank, and the hank was treated at no tension and in boiling water for 30 minutes. Thereafter, the hank was air-dried at a temperature of  $20^\circ\text{C}$  and a humidity of 65%RH, thereby regulating the humidity. The thread was then subjected to a dry heat treatment for two minutes in an atmosphere at  $160^\circ\text{C}$ , at no tension, and in a contactless fashion. Then, the thread was left in an atmosphere at a temperature of  $20^\circ\text{C}$  and a humidity of 65%RH for 24 hours. After the lapse of 24 hours, the length of the thread with a load of  $0.88 \times 10^{-3}$  cN/dtex applied thereto was measured. This length is referred to as "the thread length in dry state." Thereafter, the thread was immersed in softened water having a temperature adjusted to  $20^\circ\text{C}$  for one minute. The thread was then raised from the water, sandwiched between two sheets of filter paper which had been air-dried in an atmosphere at a temperature of  $20^\circ\text{C}$  and a humidity of 65%RH, and placed on a flat table. A weight of  $1.5 \text{ g/cm}^2$  was put and left over the thread for two seconds to remove excessive moisture on the fiber surface. After 10 seconds, the length of the thread was measured with a load of  $0.88 \times 10^{-3}$  cN/dtex applied thereto. This length is referred to as "the thread length in water absorption state." The water absorption extension rate of the polyamide resin was calculated according to the following expression. Note that all the measurements were performed in an atmosphere at a temperature of  $20^\circ\text{C}$  and a humidity of 65%RH.

$$\text{Water absorption extension rate (\%)} = (\text{"Thread length in water absorption state"} - \text{"Thread length in dry state"}) / \text{"Thread length in dry state"} \times 100$$

## (Evaluation Through Wear Test)

**[0044]** The produced polyamide fiber was knitted into some pieces of cylindrical knitted fabric by a circular knitting machine. Ten arbitrarily chosen testers passed one day with the resultant pieces put on their elbows and knees. The testers made sensory evaluation concerning feeling of stickiness and sweatiness. The results of the sensory evaluation were qualified in terms of points: "No feeling of stickiness or sweatiness and highly comfortable" was qualified as two points, "Comfortable" as one point, and "uncomfortable" as 0 point. The pieces of the knitted fabric were evaluated and classified into the following four levels according to the total sums of points. Table 1 shows the results.

- A: 15 points or more in total
- B: 8-14 points in total
- C: 5-7 points in total
- D: 4 points or less in total

## (Measurement of Crimp Extension Rate)

**[0045]** The polyamide fiber was wound into a small hank having 20 turns by using a sizing reel of which the frame perimeter was 1.125 m. The resultant small hank was heat-treated in boiling water at 98°C for five minutes with no load applied to the hank. The small hank was then left in a chamber at constant temperature and humidity (at a temperature of  $20 \pm 2^\circ\text{C}$  and a relative humidity of  $65 \pm 2\%$ ) for 24 hours. A load of 2 mg/d was applied to the humidity-regulated fiber, and the hank length  $L_1$  was measured after one minute. Next, a load of 0.1 g/d was applied to the small hank, and the hank length  $L_2$  was measured after one minute. The crimp extension rate is given by the following expression:

$$\text{Crimp extension rate (\%)} = (L_2 - L_1)/L_2 \times 100$$

**[0046]** Here, "g/d" represents a number of grams per denier.

**[0047]** Table 1 shows the results of these measurements and evaluation.

## (Example 2)

**[0048]** A polyamide fiber was produced in the same manner as in Example 1, except that polyethylene terephthalate (copolymerized PET) having a limiting viscosity number  $[\eta]$  of 0.52 dL/g and copolymerized with 8 wt.% of polyethylene glycol having a molecular weight of 2000 and 5 mol% of 5-sodium sulfoisophthalic acid was used as the component B. The degree of orientation, the moisture absorption rate, the water absorption extension rate, and the crimp extension rate of this polyamide fiber were measured, and the evaluation of knitted fabric of the fiber was performed through a wear test. The results of these measurements and evaluation are shown in Table 1.

## (Examples 3 and 4)

**[0049]** As shown in Table 1, a polyamide fiber of each of these examples was produced in the same manner as in Example 1, except that nylon-6,6 (Example 3) or nylon-6/12 (Example 4) was used as the component A. For each fiber, the degree of orientation, the moisture absorption rate, the water absorption extension rate, and the crimp extension rate were measured, and the evaluation of knitted fabric of each fiber was performed through a wear test. The results of these measurements and evaluation are shown in Table 1.

## (Examples 5 and 6)

**[0050]** As shown in Table 1, a polyamide fiber of each of these examples was produced in the same manner as in Example 1, except that the conjugated fiber was caused to have a cross section shown in FIG. 2 (Example 5) or a cross section shown in FIG. 4 (Example 6). For each fiber, the degree of orientation, the moisture absorption rate, the water absorption extension rate, and the crimp extension rate were measured, and the evaluation of knitted fabric of each fiber was performed through a wear test. The results of these measurements and evaluation are shown in Table 1.

## (Comparative Example 1)

**[0051]** A polyamide fiber was produced in the same manner as in Example 1, except that the soluble component

(component B) was omitted. The degree of orientation, the moisture absorption rate, the water absorption extension rate, and the crimp extension rate of this fiber were measured, and the evaluation of knitted fabric of the fiber was performed through a wear test. The results of these measurements and evaluation are shown in Table 1.

(Comparative Example 2)

**[0052]** A conjugated fiber (size: 275 dtex) having a cross section shown in FIG. 1 was injected through a multi-component fiber spinning nozzle, in the same manner as in Example 1. Subsequently, a thread injected from a spinneret was cooled using a horizontal cooling air blower having a length of 1.0 m. Thereafter, water-free spinning oil including, as its components, an anti-static agent and a lubricating agent was applied to the thread. The thread was then taken off using a roller at a speed of 1000 m/min., and drawn continuously without being wound. The thread was drawn until its length became 2.5 times as long as the original length, while being thermo-set at 150°C. In this manner, a conjugated fiber (110 dtex/24 filaments) was produced at a speed of 2500 m/min. The produced conjugated fiber was knitted into cylindrical fabric by a circular knitting machine (28 gauge). The resultant knitted fabric was subjected to a scouring step using hot water (90°C, 20 minutes) to dissolve and remove the modified PVA. In this manner, the polyamide fiber of this comparative example was produced.

**[0053]** Next, the degree of orientation and the water absorption extension rate of the polyamide fiber were measured, and the evaluation of knitted fabric of the fiber was performed through a wear test, in the same manner as in Example 1. Note that the moisture absorption rate and the crimp extension rate were not measured. The results of these measurements and evaluation are shown in Table 1.

(Comparative Example 3)

**[0054]** A polyamide fiber was produced in the same manner as in Example 1, except that nylon-12 was used as the component A. The degree of orientation and the water absorption extension rate of this polyamide fiber were measured, and the evaluation of knitted of the fiber was performed through a wear test. Note that the moisture absorption rate and the crimp extension rate were not measured. The results of these measurements and evaluation are shown in Table 1.

(Comparative Example 4)

**[0055]** A conjugated fiber (size: 275 dtex) having a cross section shown in FIG. 1 was injected through a multi-component fiber spinning nozzle, in the same manner as in Example 1. Subsequently, a thread injected through a spinneret was cooled using a horizontal cooling air blower having a length of 1.0 m. Thereafter, water-free spinning oil including, as its components, an anti-static agent and a lubricating agent was applied to the thread. The thread was then taken off using a roller at a speed of 2000 m/min., thereby obtaining undrawn thread. The obtained undrawn thread was knitted into cylindrical fabric by a circular knitting machine (28 gauge). The resultant knitted fabric was subjected to a scouring step using hot water (90°C, 20 minutes) to dissolve and remove the modified PVA. In this manner, the polyamide fiber of this comparative example was produced.

**[0056]** Next, the degree of orientation and the water absorption extension of this polyamide fiber were measured, and the evaluation of knitted fabric of the fiber was performed through a wear test in the same manner as in Example 1. Note that the moisture absorption rate and the crimp extension rate were not measured. The results of these measurements and evaluation are shown in Table 1.



[Table 1]

	Polyamide Component (Component A)	Soluble Component (Component B)	Conjugate Ratio A:B	Cross Section	Degree of Orientation	Moisture Absorption Rate (%)	Water Absorption Extension Rate (%)	Evaluation through Wear Test	Crimp Extension Rate (%)
Example 1	Nylon-6	Modified PVA	60:40	FIG. 1	0.78	9	11	A	4.8
Example 2	Nylon-6	Copolymerized PET	60:40	FIG. 1	0.84	7	5	B	3.6
Example 3	Nylon-6,6	Modified PVA	60:40	FIG. 1	0.75	9	11	A	5.3
Example 4	Nylon-6/12	Modified PVA	60:40	FIG. 1	0.74	8	8	B	4.5
Example 5	Nylon-6	Modified PVA	60:40	FIG. 2	0.7	10	13	A	5.8
Example 6	Nylon-6	Modified PVA	60:40	FIG. 4	0.8	6	9	A	2.8
Comparative Example 1	Nylon-6	-	-	Circular	0.95	3	0	D	1.3
Comparative Example 2	Nylon-6	Modified PVA	60:40	FIG. 1	0.88	-	2	C	-
(Comparative Example 3	Nylon-12	Modified PVA	60:40	FIG. 1	0.9	-	0	D	-
Comparative Example 4	Nylon-6	Modified PVA	60:40	FIG. 1	0.5	-	32	D	-

**[0057]** As shown in Table 1, the polyamide fibers of Examples 1-6 have a degree of orientation equal to or higher than 0.7 and equal to or lower than 0.85. Therefore, these fibers have a water absorption extension rate of 5% or more at a temperature of 20°C and a humidity of 65%RH. This means that these polyamide fibers effectively control humidity, and knitted fabric made of these fibers is highly comfortable when worn.

**[0058]** On the other hand, the polyamide fibers of Comparative Examples 1-3 have a degree of orientation equal to or higher than 0.85. Therefore, these fibers have a water absorption extension rate lower than 5% at a temperature of 20°C and a humidity of 65%RH. This means that these fibers control humidity less effectively and the knitted fabric made of the fibers of these comparative examples is notably uncomfortable when worn, as compared to the fibers of Examples 1-6. In particular, nylon-12 used in Comparative Example 3 is highly hydrophobic and has a high crystal orientation among polyamide resin. Consequently, the fiber of Comparative Example 3 has a high degree of orientation as shown in Table 1, which means that the obtained knitted fabric exhibits no water absorption extension rate and is remarkably uncomfortable when worn.

**[0059]** The polyamide fiber of Comparative Example 4 has a degree of orientation lower than 0.7. Therefore, the water absorption extension rate of this polyamide fiber is excessively high, resulting in that the fabric made of this fiber is remarkably uncomfortable when worn.

(Example 7)

**[0060]** Nylon-6 having a reduced viscosity of 1.80 dL/g (at a concentration of 1g/dL in orthochlorophenol at 30°C) was used as a polyamide component (component A), and a thermoplastic modified polyvinyl alcohol (modified PVA) (product of Kuraray Co., Ltd. having a saponification degree of 98.5, an ethylene content of 8.0 mol%, and a degree of polymerization of 380) was used as the other component, i.e., the soluble component (component B). The components A and B were separately melted in different extruders, and a conjugated fiber having a cross section shown in FIG. 1 was injected through a multi-component fiber-spinning nozzle with a ratio of nylon-6: modified PVA set to 70:30 (weight ratio). Subsequently, a thread injected through a spinneret was cooled using a horizontal cooling air blower having a length of 1.0 m. Thereafter, water-free spinning oil including, as its components, an anti-static agent and a lubricating agent was applied to the thread. The thread was then wound using a roller at a take-off speed of 3500 m/min. In this manner, a conjugated fiber (111 dtex/24 filaments) was produced. Note that the process steps of fiber production were performed smoothly. The produced conjugated fiber was knitted into cylindrical fabric by a circular knitting machine (28 gauge). The resultant knitted fabric was subjected to a scouring step using hot water (90°C, 20 minutes) to dissolve and remove the modified PVA.

**[0061]** In the same manner as in Example 1, the degree of orientation, the moisture absorption rate, the water absorption extension rate, and the crimp extension rate of this polyamide fiber were measured, and the evaluation of knitted fabric of the fiber was performed through a wear test. The results of these measurements and evaluation are shown in Table 2.

(Examples 8 and 9)

**[0062]** A polyamide fiber of Example 8 was produced in the same manner as in Example 7, except that polyethylene terephthalate (copolymerized PET) having a limiting viscosity number  $[\eta]$  of 0.52 dL/g and copolymerized with 8 wt.% of polyethylene glycol having a molecular weight of 2000 and 5 mol% of 5-sodium sulfoisophthalic acid was used as the component B. A polyamide fiber of Example 9 was produced in the same manner as in Example 7, except that polylactic acid was used as the soluble component (component B), and a ratio of nylon-6:component B was set to 67:33. The degree of orientation, the moisture absorption rate, the water absorption extension rate, and the crimp extension rate of each polyamide fiber were measured, and the evaluation of knitted fabric of each fiber was performed through a wear test. The results of these measurements and evaluation are shown in Table 2.

(Examples 10 and 11)

**[0063]** As shown in Table 2, a polyamide fiber of each of these examples was produced in the same manner as in Example 7, except that nylon-6,6 (Example 10) or nylon-6/12 (Example 11) was used as the component A. For each fiber, the degree of orientation, the moisture absorption rate, the water absorption extension rate, and the crimp extension rate were measured, and the evaluation of knitted fabric of each fiber was performed through a wear test. The results of these measurements and evaluation are shown in Table 2.

(Examples 12 and 13)

**[0064]** As shown in Table 2, a polyamide fiber of each of these examples was produced in the same manner as in Example 7, except that the conjugated fiber was caused to have a cross section shown in FIG. 2 (Example 12) or a

cross section shown in FIG. 3 (Example 13). For each fiber, the degree of orientation, the moisture absorption rate, the water absorption extension rate, and the crimp extension rate were measured, and the evaluation of knitted fabric of each fiber was performed through a wear test. The results of these measurements and evaluation are shown in Table 2.

(Comparative Example 5)

**[0065]** A conjugated fiber (size: 220 dtex) having a cross section shown in FIG. 1 was injected through a multi-component fiber spinning nozzle, in the same or similar manner to Example 7. Subsequently, a thread injected through a spinneret was cooled using a horizontal cooling air blower having a length of 1.0 m. Thereafter, water-free spinning oil including, as its components, an anti-static agent and a lubricating agent was applied to the thread. The thread was then taken off using a roller at a speed of 1000 m/min., and drawn continuously without being wound. The thread was drawn until its length became 2.5 times as long as the original length, while being thermo-set at 150°C. In this manner, a conjugated fiber (110 dtex/24 filaments) was produced at a speed of 2500 m/min. The produced conjugated fiber was knitted into cylindrical fabric by a circular knitting machine (28 gauge). The resultant knitted fabric was subjected to a scouring step using hot water (90°C, 20 minutes) to dissolve and remove the modified PVA. In this manner, the polyamide fiber of this comparative example was produced.

**[0066]** Next, the degree of orientation and the water absorption extension rate of this polyamide fiber were measured, and the evaluation of knitted fabric of the fiber was performed through a wear test, in the same or similar manner to Example 7. Note that the moisture absorption rate and the crimp extension rate were not measured. The results of these measurements and evaluation are shown in Table 2.

(Comparative Example 6)

**[0067]** A polyamide fiber was produced in the same manner as in Example 7, except that nylon-12 was used as the component A. The degree of orientation and the water absorption extension rate of this polyamide fiber were measured, and the evaluation of knitted fabric of the fiber was performed through a wear test. Note that the moisture absorption rate and the crimp extension rate were not measured. The results of these measurements and evaluation are shown in Table 2.

[Table 2]

	Polyamide Component (Component A)	Soluble Component (Component B)	Conjugate Ratio A:B	Cross Section	Degree of Orientation	Moisture Absorption Rate (%)	Water Absorption Extension Rate (%)	Evaluation through Wear Test	Crimp Extension Rate (%)
Example 7	Nylon-6	Modified PVA	70:30	FIG. 1	0.78	8	10	A	4.3
Example 8	Nylon-6	Copolymerized PET	67:33	FIG. 1	0.84	6	5	B	3.4
Example 9	Nylon-6	Poly(lactic Acid	67:33	FIG. 1	0.82	6	5	B	3
Example 10	Nylon-6,6	Modified PVA	70:30	FIG. 1	0.77	7	10	A	5.5
Example 11	Nylon-6/12	Modified PVA	70:30	FIG. 1	0.75	5	7	B	4.7
Example 12	Nylon-6	Modified PVA	70:30	FIG. 2	0.71	9	12	A	5.6
Example 13	Nylon-6	Modified PVA	70:30	FIG. 3	0.8	6	8	A	2.5
Comparative Example 5	Nylon-6	Modified PVA	70:30	FIG. 1	-	4	1	C	-
Comparative Example 6	Nylon-12	Modified PVA	70:30	FIG. 1	-	2	0	D	-

**[0068]** As shown in Table 2, the polyamide fibers of Examples 7-13 have a moisture absorption rate equal to or higher than 5% at a temperature 35°C and a humidity 95%RH, and a water absorption extension rate equal to or higher than 5% at a temperature 20°C and a humidity of 65%RH. This means that these polyamide fibers effectively control humidity, and knitted fabric made of these fibers is highly comfortable when worn.

**[0069]** On the other hand, the polyamide fibers of Comparative Examples 5 and 6 have a moisture absorption rate lower than 5% at a temperature of 35°C and a humidity of 95%RH, and a water absorption extension rate lower than 5% at a temperature of 20°C and a humidity of 65%RH. This means that the fibers of these comparative examples control humidity less effectively and knitted fabric made of the fibers of these comparative examples is notably uncomfortable when worn, as compared to the fibers of Examples 7-13. In particular, nylon-12 used in Comparative Example 6 is highly hydrophobic and has high crystal orientation among polyamide resin. Consequently, the fiber of Comparative Example 6 has a notably reduced moisture absorption rate, as shown in Table 2, which means that the obtained knitted fabric exhibits no water absorption extension rate and is remarkably uncomfortable when worn.

#### INDUSTRIAL APPLICABILITY

**[0070]** The polyamide fiber of the present invention suitably absorbs and releases moisture, and extends and contracts reversibly upon absorbing and releasing water. Therefore, a fiber structure containing the polyamide fiber of the present invention exhibits a self-control function by which the opening degree of stitches in the fiber structure is varied depending on absorption and release of water. Thus, the polyamide fiber of the present invention may enable the production of a highly comfortable fiber structure. The polyamide fiber of the present invention is highly suitable for the field of clothing, and exhibits good performance when used in sportswear, underwear, lining, pantyhose, socks, and other types of clothing.

#### DESCRIPTION OF REFERENCE CHARACTERS

##### **[0071]**

- 1 Polyamide Component (Component A) in Conjugated fiber
- 2 Soluble Component (Component B) in Conjugated fiber
- 3 Hollow Portion in Conjugated fiber

#### Claims

1. A polyamide fiber having a degree of orientation equal to or higher than 0.7 and equal to or lower than 0.85.
2. The polyamide resin of claim 1, having a moisture absorption rate equal to or higher than 5% at a temperature of 35°C and a humidity of 95%RH, and a water absorption extension rate equal to or higher than 5% at a temperature of 20°C and a humidity of 65%RH.
3. The polyamide fiber of claim 1 or 2, obtained by removing, from a conjugated fiber containing a water-soluble thermoplastic polyvinyl alcohol-based polymer and polyamide, the water-soluble thermoplastic polyvinyl alcohol-based polymer by using hot water.
4. The polyamide fiber of claim 1 or 2, obtained by removing, from a conjugated fiber containing an easily alkali-soluble polyester-based polymer and polyamide, the easily alkali-soluble polyester-based polymer by alkali treatment.
5. The polyamide fiber of claim 3 or 4, wherein the polyamide is nylon-6.
6. The polyamide fiber of any one of claims 1-5, wherein the polyamide fiber extends and contracts reversibly upon absorbing and releasing water.
7. A fiber structure, at least part of which is made of the polyamide fiber of any one of claims 1-6.
8. Clothing made of the fiber structure of claim 7.
9. The clothing of claim 8, wherein the closing is configured as one selected from the group consisting of underwear, sportswear, lining, pantyhose, and socks.

FIG.1

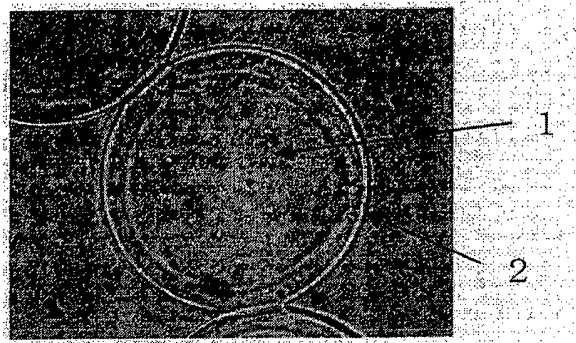


FIG.2

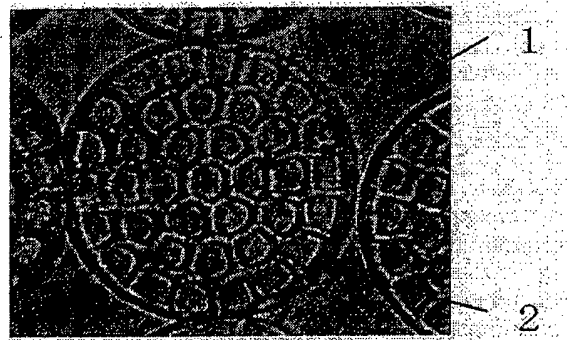
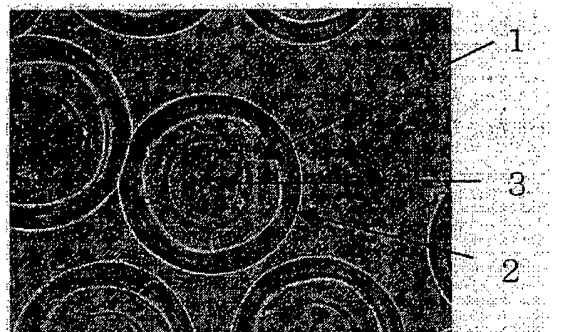


FIG.3



FIG.4



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2015/002575

## A. CLASSIFICATION OF SUBJECT MATTER

D01F6/60(2006.01)i, A41B17/00(2006.01)i, D01F8/12(2006.01)i, D01F8/14(2006.01)i, D03D15/00(2006.01)i, D06M11/00(2006.01)i, D06M11/05(2006.01)i

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

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

D01F1/00-6/96, D01F9/00-9/04, D01F8/00-8/18, D03D1/00-27/18, A41B17/00, D06M11/00, D06M11/05

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

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2015  
Kokai Jitsuyo Shinan Koho 1971-2015 Toroku Jitsuyo Shinan Koho 1994-2015

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 57-66116 A (Asahi Chemical Industry Co., Ltd.), 22 April 1982 (22.04.1982), claims; page 2, upper left column, lines 5 to 6; table 3 (Family: none)	1-8
X	JP 2010-229582 A (Teijin Techno Products Ltd.), 14 October 2010 (14.10.2010), claims; paragraph [0002]; table 1 (Family: none)	1-9

☒ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

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Date of the actual completion of the international search  
12 August 2015 (12.08.15)

Date of mailing of the international search report  
25 August 2015 (25.08.15)

Name and mailing address of the ISA/  
Japan Patent Office  
3-4-3, Kasumigaseki, Chiyoda-ku,  
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2015/002575

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2006-124905 A (Toray Industries, Inc.), 18 May 2006 (18.05.2006), claims; paragraphs [0011], [0016], [0023], [0024], [0030], [0059]; tables 1, 2 & JP 2004-332186 A & US 2005/0260911 A1 & US 2006/0255499 A1 & US 2006/0257656 A1 & WO 2004/013388 A1 & EP 1550746 A1 & KR 10-2005-0032592 A & CN 1312335 C & CN 101003681 A & KR 10-1029515 B1 & TW 200420765 A	1-9
A	JP 2007-303019 A (Toray Industries, Inc.), 22 November 2007 (22.11.2007), claims; paragraphs [0016], [0041], [0043] to [0045] (Family: none)	1-9
A	JP 2003-293224 A (Kuraray Co., Ltd.), 15 October 2003 (15.10.2003), claims; paragraphs [0001], [0002] (Family: none)	1-9

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**REFERENCES CITED IN THE DESCRIPTION**

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- JP 55001372 A [0006]
- JP H07084681 A [0006]