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(54) **MONOFILAMENT AND METHOD FOR PRODUCING SAME**

(57) To provide a monofilament of PA4, which has a low density. The monofilament of polyamide 4 in an embodiment of the present invention has a density of 1.230 g/cm³ or less. A method for producing a monofilament of polyamide 4 according to an embodiment of the present

invention includes: melt-extruding polyamide 4; and cooling a melted and extruded matter of the polyamide 4 obtained by the melt-extruding process, at -10°C or lower by using a nonpolar solvent.

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Description

TECHNICAL FIELD

5 [0001] The present invention relates to a monofilament of polyamide 4 and a method for producing the same.

BACKGROUND ART

10 [0002] Practical use of polyamide 4 (hereinafter, also referred to as "PA4") in a filament used for a fishing line, a fishing net, or the like as a bioplastic has been expected. In such a filament, linear strength, knot strength, and transparency are important required properties.

[0003] As a method for producing a monofilament of PA4, for example, a method by melt spinning is known (e.g., see Patent Document 1).

15 Citation List

Patent Literature

20 [0004] Patent Document 1: WO 2012/157576

SUMMARY OF INVENTION

TECHNICAL PROBLEM

25 [0005] To obtain the monofilament that satisfies the requirements described above, an undrawn monofilament formed in an extrusion process in melt spinning is required to be in an amorphous state, that is, to have a low density. Note that, since PA4 may undergo thermolysis during melt spinning, a spinning temperature needs to be set around a melting temperature. When spinning is carried out at around the melting temperature, the amount of residual crystal nuclei tends to be large, and a crystallization rate in a cooling process after the extrusion becomes faster. Therefore, it is difficult to produce a monofilament in an amorphous state.

30 [0006] To complete cooling in a short time period, rapid cooling using cold water at approximately 5°C is performed for other polyamide resins such as nylon 6 and nylon 66. However, the cooling method by cold water causes dissolution and hydrolysis of PA4 on the surface thereof because PA4 has a high hydrophilicity. As a result, there is a problem of deterioration in desired physical properties due to occurrence of surface roughness and white powder.

35 [0007] An object of an aspect of the present invention is to provide a monofilament of PA4, which has a low density.

SOLUTION TO PROBLEM

40 [0008] To solve the problems described above, a monofilament according to an aspect of the present invention is a monofilament of polyamide 4, and the density thereof is 1.230 g/cm³ or less.

[0009] To solve the problems described above, a method for producing a monofilament according to an aspect of the present invention includes: melt-extruding polyamide 4; and cooling a melted and extruded fibrous matter of the polyamide 4 obtained by the melt-extruding process, at -10°C or lower by using a nonpolar solvent.

45 ADVANTAGEOUS EFFECTS OF INVENTION

[0010] According to an aspect of the present invention, a PA4 monofilament having a low density can be provided.

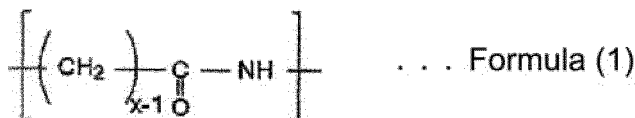
DESCRIPTION OF EMBODIMENTS

50 Monofilament

Polyamide 4

55 [0011] The monofilament of an embodiment of the present invention is substantially made of polyamide 4 (PA4). The PA4 is a polymer compound containing a structural unit represented by Formula (1) below. In the formula, x is 4.

[Chemical Formula 1]



[0012] In an embodiment of the present invention, a polymer compound constituting a structure of a monofilament may be PA4 alone. In an embodiment of the present invention, an additional component besides the PA4 may be further contained in a range where the effects of the present embodiment can be provided. The additional component may be one or more kinds, examples of which include a reinforcing agent, a plasticizer, a lubricant, and a stabilizer. The additional component may contain a polymer compound other than the PA4. The additional component is appropriately used in an amount that further exhibits the effects of the additional component. Thus, the monofilament of an embodiment of the present invention is a monofilament of the PA4.

Density

[0013] The monofilament of an embodiment of the present invention has a density of 1.230 g/cm³ or less. The density of the monofilament correlates with the degree of crystallization of the monofilament, and a lower density tends to result in a lower degree of crystallization. For example, the density of the monofilament of 1.230 g/cm³ corresponds to a degree of crystallization of the monofilament of approximately 10%. When the density of the monofilament is high, the tensile strength and elongation when the monofilament is knotted may be insufficient. From the viewpoint of further enhancing tensile characteristics when the monofilament is knotted, the density of the monofilament is preferably 1.225 g/cm³ or less, and more preferably 1.223 g/cm³ or less. The density of the monofilament is only required to be in a range that can be achieved for the monofilament of the PA4 and, for example, may be 1.215 g/cm³ or greater.

[0014] The density of the monofilament can be determined by a method that is also called "density gradient method". Furthermore, the density of the monofilament can be adjusted by the cooling conditions in the production of an undrawn monofilament and, for example, the density can be reduced by cooling in the cooling process in the production method described below.

Other Physical Properties

[0015] The monofilament of an embodiment of the present invention is only required to have the physical properties described above and may further have other physical properties besides those described above as long as the effect of the present embodiment described above is achieved.

Filament Diameter

[0016] The filament diameter of the monofilament of an embodiment of the present invention may be appropriately selected based on the use of the monofilament; however, from the viewpoint of adequately reducing the density of the monofilament, the filament diameter is preferably 1 mm or less. Note that, herein, the filament diameter of the monofilament is a filament diameter of an undrawn monofilament.

[0017] When the filament diameter is greater than 1 mm, cooling in the cooling process of the production method described below may be insufficient, and the density of the monofilament may be increased. From the viewpoint of adequately reducing the density of the monofilament, the filament diameter of the monofilament is preferably 0.8 mm or less, and more preferably 0.5 mm or less. Meanwhile, the filament diameter of the monofilament is only required to be in a range that can be achieved for the monofilament of the PA4 based on the use of the monofilament; however, from the viewpoint of adequately performing cooling described above, the filament diameter may be 0.1 mm or greater. The filament diameter of the monofilament can be adjusted by a pore diameter of the die.

[0018] The filament diameter of the monofilament can be measured by a known technique for measuring a filament diameter, and for example, the measurement can be performed by a known method for measuring the filament diameter of a monofilament by sandwiching the monofilament. The filament diameter of the monofilament tends to be smaller when the drawing ratio in the production method described below is higher.

[0019] In a case where the monofilament of an embodiment of the present invention is a drawn monofilament, the filament diameter of the monofilament is more preferably 0.4 mm or less, and even more preferably 0.25 mm or less, from the viewpoint of adequately reducing the density of the monofilament before drawn. The filament diameter of the

monofilament as a drawn monofilament may be, for example, 0.05 mm or greater from the viewpoint of practical usability as a monofilament based on the use. The filament diameter of the monofilament as a drawn monofilament can be adjusted by the drawing ratio.

5 Tensile Characteristics of Monofilament When Knotted

[0020] The tensile strength when the drawn monofilament of an embodiment of the present invention is knotted is preferably 460 MPa or greater from the viewpoint of achieving adequate tensile strength for use where the monofilament may be used in a knotted state. An example of use where the monofilament may be used in a knotted state is a fishing line. The tensile strength of the monofilament when knotted can be appropriately selected depending on the use of the monofilament. From the viewpoint of preventing cutting of the monofilament at a knotted position when the monofilament is pulled, the tensile strength of the monofilament when knotted is preferably high and, for example, more preferably 470 MPa or greater, and even more preferably 480 MPa or greater. On the other hand, the tensile strength of the monofilament when knotted is only required to be in a range that can be achieved for the monofilament of the PA4, and from such a viewpoint, the tensile strength of the monofilament when knotted may be 800 MPa or less.

[0021] The tensile strength of the monofilament when knotted can be measured by using a known instrument that can perform a tensile test for a monofilament. The tensile strength of the monofilament when knotted can be adequately increased by setting the density of the monofilament to the range described above. Furthermore, the tensile strength of the monofilament when knotted can be enhanced by drawing in the production of the monofilament.

[0022] The elongation at break when the drawn monofilament of an embodiment of the present invention is knotted is preferably 10% or greater from the viewpoint of suppressing breakage when the monofilament is used in a knotted state. The elongation at break of the monofilament when knotted can be appropriately selected depending on the use of the monofilament. From the viewpoints described above, the elongation at break is more preferably 12% or greater, and even more preferably 14% or greater. On the other hand, the elongation at break of the monofilament when knotted is only required to be in a range that can be achieved for the monofilament of the PA4, and from such a viewpoint, the elongation at break of the monofilament when knotted may be 30% or less.

[0023] The elongation at break of the monofilament when knotted can be measured by using a known instrument that can perform a tensile test for a monofilament. The elongation at break of the monofilament when knotted can be adequately increased by setting the density of the monofilament to the range described above. Furthermore, the elongation at break of the monofilament when knotted can be enhanced by drawing in the production of the monofilament.

Birefringence

[0024] In the drawn monofilament of an embodiment of the present invention, the PA4 having a specific orientation is preferred from the viewpoint of enhancing tensile characteristics of the monofilament. From such a viewpoint, the monofilament has a birefringence of preferably 50×10^{-3} or greater. The birefringence of the monofilament material is a scale of degree of orientation with respect to a filament axial direction of a polymer chain of a polymer compound constituting the monofilament. A larger absolute value of the birefringence indicates a larger degree of orientation in the monofilament of the polymer compound. From the viewpoints described above, the birefringence of the monofilament is more preferably 55×10^{-3} or greater, and even more preferably 60×10^{-3} or greater. The birefringence of the monofilament in an embodiment of the present invention is only required to be in a range that can be achieved for the monofilament of the PA4 and, from such a viewpoint, the birefringence may be 90×10^{-3} or less.

[0025] The birefringence of the monofilament can be determined by retardation measurement using a polarizing microscope equipped with a Berek compensator and a sodium lamp as a light source. Furthermore, the birefringence of the monofilament can be adjusted by the degree of orientation of the PA4 in the monofilament, and can be further increased when a drawing ratio in the production method described below is increased.

Method for Producing Monofilament

[0026] The method for producing a monofilament according to an embodiment of the present invention includes melt-extruding polyamide 4, and cooling a melted and extruded fibrous matter of the polyamide 4 obtained by the melt-extruding process, at -10°C or lower by using a nonpolar solvent. These processes can be performed by a known melt spinning technique for producing an undrawn monofilament by liquid cooling in a range that satisfies the conditions described below.

Melt-Extruding Process

[0027] In the melt-extruding process, a melted and extruded fibrous matter of the PA4 is produced by extruding a

melted and kneaded matter of the PA4 through extrusion molding. The spinning temperature in the melt-extruding process described above is preferably high from the viewpoint of reducing the amount of crystal nuclei of the PA4 in the melted and extruded matter. From such viewpoints, the spinning temperature is preferably 255°C or higher, more preferably 260°C or higher, and even more preferably 262°C or higher, in terms of the resin temperature. Meanwhile, the spinning temperature is preferably low from the viewpoint of suppressing thermolysis of the PA4. From such viewpoints, the spinning temperature is preferably 275°C or lower, more preferably 270°C or lower, and even more preferably 267°C or lower, in terms of the resin temperature.

Cooling Process

[0028] The cooling temperature of the melted and extruded matter in the cooling process by the nonpolar solvent is -10°C or lower. When the cooling temperature is too high, the density of the undrawn monofilament may become excessively high. From the viewpoint of achieving an adequately low density of the undrawn monofilament, the cooling temperature is preferably -15°C or lower, and more preferably -20°C or lower. The cooling temperature can be appropriately selected based on the type of the coolant and production cost in a range in which the effects of the present embodiment can be achieved, and in the present embodiment in which the coolant is a nonpolar solvent, for example, from the viewpoint of cost, the cooling temperature may be -60°C or higher.

[0029] In the cooling process, from the viewpoint of reducing the density of the undrawn monofilament, the cooling time is preferably long and, more specifically, preferably 0.1 seconds or longer, more preferably 0.2 seconds or longer, and even more preferably 0.3 seconds or longer. From the viewpoint of productivity, the cooling time is preferably short. From such a viewpoint, the cooling time is preferably 5 seconds or less, more preferably 3 seconds or less, and even more preferably 2 seconds or less.

Nonpolar Solvent

[0030] From the viewpoints of preventing surface roughness of the undrawn monofilament or preventing occurrence of whitening, the nonpolar solvent is substantially inert to the melted and extruded matter of the PA4. "Substantially inert" means that substantially no action is applied to the melted and extruded matter, and more specifically indicates being dissolved sparingly or insoluble in PA4 and having no permeability into the melted and extruded matter of the PA4.

[0031] From the viewpoint of stability of a coolant in the cooling process, the melting point (T_m) of the nonpolar solvent is preferably -20°C or lower, and the boiling point (T_b) of the nonpolar solvent is preferably 100°C or higher. One or more nonpolar solvents may be used. Examples of the nonpolar solvent include silicone oil, hexane, nonane, decane, ethylcyclohexane, isopropylcyclohexane, toluene, and p-cymene. Examples of the nonpolar solvent and their melting points and boiling points are listed in Table 1.

[Table 1]

[0032]

Table 1

Nonpolar solvent	T _m [°C]	T _b [°C]
Silicone oil	-40	210
Hexane	-120	69
Nonane	-51	151
Decane	-30	174
Ethylcyclohexane	-111	131
Isopropylcyclohexane	-89	155
Toluene	-95	110
p-Cymene	-68	176

Other process

[0033] The method for producing the monofilament of an embodiment of the present invention may further include

another process besides the melt-extruding and cooling processes described above as long as the effects of an embodiment of the present invention can be achieved. For example, the production method may further include drawing the monofilament cooled in the cooling process (drawing process). The drawing process is more effective from the viewpoint of enhancing tensile characteristics of the monofilament.

[0034] The drawing process may be dry heat drawing or wet heat drawing. Furthermore, the drawing process may be performed once or for multiple times. The drawing temperature in the drawing process can be appropriately set to a range of 40 to 240°C based on an aspect of the drawing process. Furthermore, the final drawing ratio in the drawing process can be appropriately set to a range of 3.5 to 6 times based on an aspect of the drawing process. Note that, in the present specification, the wording "from A to B" represents a range including numerical values on both ends, which is a range of A or greater and B or less.

[0035] For example, when an aspect of the drawing process has one round of dry heat drawing, the drawing temperature may be from 150 to 240°C (e.g., 200°C), and the drawing ratio may be from 3.5 to 5 times (e.g., 4 times). Furthermore, for example, when an aspect of the drawing process has two rounds of dry heat drawing, the drawing temperature in the first round of dry heat drawing may be from 40 to 80°C (e.g., 60°C), and the drawing ratio may be from 2.5 to 3.5 times (e.g., 3 times). The drawing temperature in the second round of dry heat drawing may be from 150 to 240°C (e.g., 200°C), and the drawing ratio may be from 1.05 to 2.0 times (e.g., 1.33 times).

[0036] Note that, in the spinning, typically, the melted and extruded fibrous matter is cooled while being pulled at a rate greater than a discharging rate of the melted and extruded matter and then supplied to a drawing device. In an embodiment of the present invention, from the melt-extruding process to the cooling process and the pulling of the melted and extruded matter to supply the melted and extruded matter to the following drawing process are not included in the drawing process and may be set appropriately in a range in which the effects of the present embodiment can be achieved.

Effect

[0037] The monofilament in an embodiment of the present invention is substantially made of the PA4 described above, and is a monofilament having a density of 1.230 g/cm³ or less. The monofilament having a low density has higher tensile characteristics when the monofilament is knotted as compared to a monofilament having a high density. Thus, according to an embodiment of the present invention, a monofilament having improved tensile characteristics when the monofilament is knotted can be provided and, more specifically, a monofilament having high tensile strength and high elongation at break when the monofilament is knotted can be provided.

[0038] The method for producing a monofilament according to an embodiment of the present invention includes melt-extruding a monofilament, and cooling a melted and extruded monofilament, at -10°C or lower by using a nonpolar solvent. According to this configuration, a monofilament having a density of 1.230 g/cm³ or less can be produced.

[0039] By setting an adequately small diameter of the undrawn monofilament, a cooling effect in the cooling process can be adequately exhibited. From such a viewpoint, for example, the diameter of the monofilament is advantageously 1 mm or less.

[0040] The nonpolar solvent of an embodiment of the present invention can be selected from the group consisting of silicone oil, hexane, nonane, decane, ethylcyclohexane, isopropylcyclohexane, toluene, and p-. These nonpolar solvents are preferred from the viewpoint of stability as a coolant in the cooling process described above.

[0041] Furthermore, when the method for producing a monofilament of an embodiment of the present invention further includes drawing the monofilament cooled in the cooling process, adequate tensile characteristics that are applicable to use in a fishing line, a fishing net, or the like can be exhibited.

[0042] Note that, in the production of a monofilament of polyamide 6, a method of using hexane at -10°C to +20°C as a coolant is reported (JP 03-27118 A). In a case where the temperature of the coolant is lower than -10°C, the cooling rate is too rapid, and drawing in the following process cannot be smoothly performed. Polyamide 4 has problems in that a crystallization rate of the monofilament during the production process is higher than that of the polyamide 6 and that the strength is not increased due to progression of crystallization of the monofilament if the temperature is not adequately low in the cooling process. Therefore, an embodiment of the present invention prioritizes prevention of crystallization.

[0043] Furthermore, in WO 2018/150835, air cooling and air cooling are used in the production process of polyamide particles. In these methods, adequate and uniform cooling cannot be performed in production of a monofilament, and these methods are less likely to prevent crystallization or less likely to achieve adequate drawing. Therefore, liquid cooling is employed in an embodiment of the present invention.

[Summary]

[0044] As is clear from the description above, a monofilament according to an embodiment of the present invention is a monofilament of polyamide 4, and the density thereof is 1.230 g/cm³ or less.

[0045] Furthermore, a method for producing a monofilament according to an embodiment of the present invention

includes melt-extruding polyamide 4, and cooling a melted and extruded fibrous matter of the polyamide 4 obtained by the melt-extruding process, at -10°C or lower by using a nonpolar solvent.

[0046] In an embodiment of the present invention, the monofilament may have a diameter of 1 mm or less. This configuration is even more effective from the viewpoint of enhancing tensile characteristics of the monofilament.

[0047] In an embodiment of the present invention, the nonpolar solvent may be at least one solvent selected from the group consisting of silicone oil, hexane, nonane, decane, ethylcyclohexane, isopropylcyclohexane, toluene, and p-cymene.

[0048] The method for producing a monofilament of an embodiment of the present invention may further include drawing the monofilament cooled in the cooling process. This configuration is even more effective from the viewpoint of producing a monofilament having excellent tensile characteristics.

[0049] The present invention is not limited to the embodiments described above, and may be variously modified within the scope indicated in the claims. Embodiments obtained by appropriately combining technical means disclosed in different embodiments are also included in the technical scope of the present invention.

EXAMPLES

Example 1

[0050] At room temperature, in a polymerization vessel, 2 mol% potassium tert-butoxide was added to α -pyrrolidone and stirred. After potassium tert-butoxide was dissolved, 2 mol% tetramethylammonium chloride as a polymerization auxiliary agent and 0.1 mol% N,N'-adipyl-dipyrrolidone as an initiator were added. After the addition, the system became cloudy and became difficult to be stirred soon. At 72 hours after the stirring was stopped, the aggregate produced in the flask was removed and pulverized. Then, the unreacted product and lowmolecular weight substance were washed with acetone. The pulverized product after the washing was then dried, and a powdery PA4 was obtained. The weight average molecular weight (Mw) of the obtained PA4 was 140000.

[0051] The Mw of the PA4 was measured using the following procedure, analysis device and conditions.

Measurement Procedure

[0052] In hexafluoroisopropanol (HFIP) in which sodium trifluoroacetate was dissolved at a concentration of 5 mM, 10 mg of the PA4 sample obtained as described above was dissolved to prepare a solution of 10 cm³, and then the solution was filtered using a membrane filter to obtain a sample solution. An amount of 10 μ L of the sample solution was injected into the analysis device described below, and the weight average molecular weight of the PA4 was measured under the measurement conditions described below.

[Analyzer]

GPC apparatus: HLC-8420 GPC, available from TOSOH CORPORATION

[Measurement conditions]

A) Column: GPC HFIP806M $\times$ 2 (connected in series), available from Shoko Science Co., Ltd.

B) Eluent: 5 mM CF₃COONa/HFIP

C) MALS: DAWN HELEOS 2, available from Wyatt Technology Co.

D) 10 to 11 mg of sample/5 mM CF₃COONa/10 mL of HFIP

E) Flow rate: 1.0 mL/min

F) dn/dc: 0.240

[0053] The PA4 was molded in a fibrous form by melt-extrusion at a temperature of 265°C, and immediately after the molding, the resulting melted and extruded fibrous matter was passed through a volatile silicone oil ("KF-995", available from Shin-Etsu Chemical Co., Ltd.) bath at -20°C for 0.3 seconds, and cooled and solidified. Thus, an undrawn monofilament of the PA4 having a filament diameter of 340 μ m was produced. The density of the undrawn monofilament was measured by the measurement method described below. The density of the undrawn monofilament was 1.220 g/cm³.

Measurement Method of Density

[0054] The density of the undrawn monofilament was determined by a density gradient method. As the solvent, 6 mixed solvents, in which the densities were adjusted to a range of 1.20 to 1.30 g/cm³ and varied in 0.02 increments by changing the mixing ratio of heptane and carbon tetrachloride, were used.

[0055] Then, the produced undrawn monofilament was drawn by dry heat drawing at a drawing temperature of 60°C and a drawing ratio of 3.0 times. As a second round of drawing, drawing was performed by dry heat drawing at a drawing temperature of 200°C and a drawing ratio of 1.33 times (4.0 times in terms of total drawing ratio). A humidity of an atmosphere during dry heat drawing was 10%RH or less. Thus, the drawn monofilament of the PA4 was produced.

Example 2

[0056] A monofilament was produced in the same manner as in Example 1 except for changing the filament diameter of the undrawn monofilament to 480 μm. The density of the undrawn monofilament was 1.220 g/cm³.

Example 3

[0057] A monofilament was produced in the same manner as in Example 1 except for changing the coolant to hexane and changing the temperature of the coolant to -55°C. The density of the undrawn monofilament was 1.219 g/cm³.

Example 4

[0058] A monofilament was produced in the same manner as in Example 1 except for changing the coolant to toluene and changing the temperature of the coolant to -50°C. The density of the undrawn monofilament was 1.219 g/cm³.

Comparative Example 1

[0059] A monofilament was produced in the same manner as in Example 1 except for changing the coolant to water and changing the temperature of the coolant to 4°C. Due to surface roughness of the undrawn monofilament, measurement of the density of the undrawn monofilament was not possible. Furthermore, due to surface roughness of the undrawn monofilament, drawing breakage occurred in the following drawing, and thus a drawn monofilament was not obtained.

Comparative Example 2

[0060] A monofilament was produced in the same manner as in Example 1 except for changing the coolant to tetradecane and changing the temperature of the coolant to 40°C. The density of the undrawn monofilament was 1.240 g/cm³.

Comparative Example 3

[0061] A monofilament was produced in the same manner as in Example 1 except for changing the temperature of the coolant to 40°C. The density of the undrawn monofilament was 1.240 g/cm³.

[0062] The filament diameter of the drawn monofilament of each of Examples 1 to 4 and Comparative Examples 1 to 3 was determined in the same manner as for the filament diameter of the undrawn monofilament, and the filament diameter was from 170 to 240 μm. The density of the drawn monofilament of each of Examples 1 to 4 and Comparative Examples 1 to 3 was determined in the same manner as for the density of the undrawn monofilament, and the density was from 1.246 to 1.250 g/cm³. Furthermore, the birefringence of the drawn monofilament of each of Examples 1 to 4 and Comparative Examples 1 to 3 was determined, and the birefringence was from 58×10^{-3} to 67×10^{-3} .

Measurement Method of Birefringence

[0063] The birefringence of the PA4 in the drawn monofilament was determined by retardation measurement using a polarizing microscope equipped with a Berek compensator and a sodium lamp as a light source.

Evaluation

Tensile Characteristics of Monofilament When Knotted

[0064] For each of the monofilaments in Examples and Comparative Examples above, a tensile strength and an elongation at break of the monofilament when knotted were measured by the measurement methods described below.

Measurement Method of Tensile Strength and Elongation at Break

[0065] By using Tensilon RTF-1210 as a tester, tensile measurement was performed by setting a distance between

chucks to 150 mm and a tensile test speed to 150 mm/min at 23°C and a humidity of 50%RH. When the monofilament was knotted, the knotted part was placed at a center of the chucks.

[0066] The production conditions and density of the undrawn monofilament, and the tensile strength and the elongation at break of the drawn monofilament when knotted in Examples and Comparative Examples described above are listed in Table 2.

[Table 2]

[0067]

Table 2

	Cooling process		Undrawn monofilament		Tensile characteristics of drawn monofilament when knotted	
	Coolant	Cooling temperature [°C]	Filament diameter [μm]	Density [g/cm ³]	Tensile strength (MPa)	Elongation at break (MPa)
Example 1	Silicone oil	-20	340	1.220	471	15
Example 2	Silicone oil	-20	480	1.220	482	17
Example 3	Hexane	-55	340	1.219	480	18
Example 4	Toluene	-50	340	1.219	472	18
Comparative Example 1	Water	4	340	Unmeasurable	-	-
Comparative Example 2	Tetradecane	40	340	1.240	439	9
Comparative Example 3	Silicone oil	40	340	1.240	456	10

Discussion of Examples 1 to 4 and Comparative Examples 1 to 3

[0068] As is clear from Table 1, the densities of the monofilaments of Examples were all 1.230 g/cm³ or less. As a result, the tensile strength and knot elongation of the drawn monofilament obtained by drawing the undrawn monofilament when knotted were higher than those of the drawn monofilaments of Comparative Examples.

[0069] On the other hand, in Comparative Example 1, surface roughness occurred in the undrawn monofilament. It is conceived that this is because water was used as the coolant, the PA4 of the undrawn monofilament was dissolved in water or moistened during the cooling. Furthermore, in Comparative Example 1, drawing of the undrawn monofilament could not be performed. It is conceived that this is because the strength of the undrawn monofilament deteriorated due to the surface roughness and dissolution or moisture absorption of the undrawn monofilament described above.

[0070] In each of Comparative Examples 2 and 3, the density of the undrawn monofilament was low. Furthermore, in each of Comparative Examples 2 and 3, the tensile strength and the elongation at break of the drawn monofilament when knotted were lower than those of Example 1. It is conceived that this is because the cooling temperature during the production of the undrawn monofilament was too high, and crystallization of the PA4 was promoted in the undrawn monofilament.

INDUSTRIAL APPLICABILITY

[0071] The monofilament of the PA4 of an embodiment of the present invention can be used as a synthetic monofilament having excellent tensile characteristics. According to an embodiment of the present invention, environmental damage upon use of the synthetic monofilament is expected to be further reduced.

Claims

1. A monofilament of polyamide 4, the monofilament having a density of 1.230 g/cm³ or less.

2. The monofilament according to claim 1, wherein the monofilament has a diameter of 1 mm or less.

3. A method for producing a monofilament, the method comprising:

5 melt-extruding polyamide 4, and
cooling a melted and extruded fibrous matter of the polyamide 4 obtained by the melt-extruding process, at
-10°C or lower by using a nonpolar solvent.

10 4. The method for producing a monofilament according to claim 3, wherein the nonpolar solvent contains at least one
solvent selected from the group consisting of silicone oil, hexane, nonane, decane, ethylcyclohexane, isopropylcyclohexane, toluene, and p-cymene.

15 5. The method for producing a monofilament according to claim 3 or 4, further comprising drawing the monofilament
cooled in the cooling process.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2022/020957

A. CLASSIFICATION OF SUBJECT MATTER

D01F 6/60(2006.01)i

FI: D01F6/60 341B; D01F6/60 301A; D01F6/60 311K

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)

D01F6/60; C08G69/00-69/50

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

Published examined utility model applications of Japan 1922-1996

Published unexamined utility model applications of Japan 1971-2022

Registered utility model specifications of Japan 1996-2022

Published registered utility model applications of Japan 1994-2022

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2019-137934 A (BRIDGESTONE CORP) 22 August 2019 (2019-08-22) example 1	1-5
A	JP 2021-31790 A (BRIDGESTONE CORP) 01 March 2021 (2021-03-01) example 1	1-5
A	JP 55-6726 B2 (MITSUBISHI CHEM IND LTD.) 19 February 1980 (1980-02-19) examples	1-5
A	JP 4-136215 A (KURARAY CO LTD) 11 May 1992 (1992-05-11) examples 1-3	1-5

☐ 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

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“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

08 June 2022

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Name and mailing address of the ISA/JP

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2022/020957

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Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP	2019-137934	A	22 August 2019	(Family: none)	
JP	2021-31790	A	01 March 2021	(Family: none)	
JP	55-6726	B2	19 February 1980	JP	49-61419 A
JP	4-136215	A	11 May 1992	EP	434029 A2
				KR	10-1991-0012392 A

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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- JP 3027118 A [0042]
- WO 2018150835 A [0043]